

# Лабораторная работа № 6. Настройка пропускной способности глобальной сети с помощью Token Bucket Filter

Моделирование сетей передачи данных

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## Информация

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## Введение

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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.

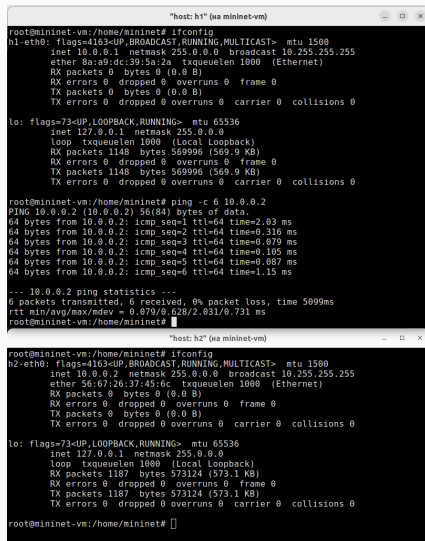
## Задачи

1. Задайте простейшую топологию.
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

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# Запуск лабораторной топологии



```
"host: h1" (на 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 10.255.255.255
    ether 8a:a9:dc:39:5a:2a 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 1148 bytes 569996 (569.9 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 1148 bytes 569996 (569.9 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

root@mininet-vm:/home/mininet# ping -c 6 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=2.03 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.316 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.079 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.105 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.087 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=1.15 ms

--- 10.0.0.2 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5099ms
rtt min/avg/max/mdev = 0.079/0.628/2.031/0.731 ms
root@mininet-vm:/home/mininet#

"host: h2" (на 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 56:67:26:37:45:6c 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 1187 bytes 573124 (573.1 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 1187 bytes 573124 (573.1 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

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

# Запуск лабораторной топологии

```
"host: h1" (na mininet-vn)
%~C
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root
Error: Cannot delete qdisc with handle of zero.
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 41298 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer    Bitrate      Retr  Cwnd
[ 7] 0.00-1.00 sec  3.76 GBytes 32.3 Gbits/sec  11   16.0 MBytes
[ 7] 1.00-2.00 sec  3.52 GBytes 30.3 Gbits/sec   4   16.0 MBytes
[ 7] 2.00-3.00 sec  3.54 GBytes 30.4 Gbits/sec   1   16.0 MBytes
[ 7] 3.00-4.00 sec  3.59 GBytes 30.8 Gbits/sec   3   16.0 MBytes
[ 7] 4.00-5.00 sec  3.21 GBytes 27.6 Gbits/sec   0   16.0 MBytes
[ 7] 5.00-6.00 sec  3.45 GBytes 29.6 Gbits/sec   1   16.0 MBytes
[ 7] 6.00-7.00 sec  3.42 GBytes 29.4 Gbits/sec   0   16.0 MBytes
[ 7] 7.00-8.00 sec  3.71 GBytes 31.8 Gbits/sec   2   16.0 MBytes
[ 7] 8.00-9.00 sec  3.70 GBytes 31.8 Gbits/sec   3   16.0 MBytes
[ 7] 9.00-10.00 sec 3.76 GBytes 32.3 Gbits/sec   3   16.0 MBytes
-----
[ ID] Interval      Transfer    Bitrate      Retr  sender receiver
[ 7] 0.00-10.00 sec 35.7 GBytes 30.6 Gbits/sec  28
[ 7] 0.00-10.00 sec 35.7 GBytes 30.6 Gbits/sec

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

"host: h2" (na mininet-vm)
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 41296
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 41298
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-1.00 sec  3.76 GBytes 32.3 Gbits/sec
[ 7] 1.00-2.00 sec  3.52 GBytes 30.3 Gbits/sec
[ 7] 2.00-3.00 sec  3.53 GBytes 30.3 Gbits/sec
[ 7] 3.00-4.00 sec  3.59 GBytes 30.8 Gbits/sec
[ 7] 4.00-5.00 sec  3.21 GBytes 27.5 Gbits/sec
[ 7] 5.00-6.00 sec  3.45 GBytes 29.7 Gbits/sec
[ 7] 6.00-7.00 sec  3.42 GBytes 29.4 Gbits/sec
[ 7] 7.00-8.00 sec  3.71 GBytes 31.8 Gbits/sec
[ 7] 8.00-9.00 sec  3.69 GBytes 31.7 Gbits/sec
[ 7] 9.00-10.00 sec 3.76 GBytes 32.3 Gbits/sec
-----
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-10.00 sec 35.7 GBytes 30.6 Gbits/sec
-----
Server listening on 5201
-----
```

Рис. 2: Результат отработки iPerf3



# Ограничение скорости на конечных хостах

```
"host: h1" (на mininet-vm)
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 41302 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer    Bitrate      Retr  Cwnd
[ 7] 0.00-1.00 sec  1.13 GBytes  9.60 Gbits/sec  0    2.03 MBytes
[ 7] 1.00-2.00 sec  1.11 GBytes  9.57 Gbits/sec  0    3.26 MBytes
[ 7] 2.00-3.00 sec  1.11 GBytes  9.56 Gbits/sec  0    3.26 MBytes
[ 7] 3.00-4.00 sec  1.11 GBytes  9.56 Gbits/sec  0    3.26 MBytes
[ 7] 4.00-5.00 sec  1.11 GBytes  9.57 Gbits/sec  0    3.42 MBytes
[ 7] 5.00-6.00 sec  1.11 GBytes  9.53 Gbits/sec  0    3.77 MBytes
[ 7] 6.00-7.00 sec  1.11 GBytes  9.51 Gbits/sec  0    4.00 MBytes
[ 7] 7.00-8.00 sec  1.11 GBytes  9.56 Gbits/sec  0    4.00 MBytes
[ 7] 8.00-9.00 sec  1.11 GBytes  9.56 Gbits/sec  0    4.00 MBytes
[ 7] 9.00-10.00 sec 1.11 GBytes  9.57 Gbits/sec  0    4.00 MBytes
[ ID] Interval      Transfer    Bitrate      Retr  sender receiver
[ 7] 0.00-10.01 sec 11.1 GBytes  9.57 Gbits/sec  0
[ 7] 0.00-10.01 sec 11.1 GBytes  9.55 Gbits/sec  0

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

"host: h2" (на mininet-vm)
warning: this system does not seem to support IPv6 - trying IPv4
Server listening on 5201
Accepted connection from 10.0.0.1, port 41300
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 41302
[ ID] Interval      Transfer    Bitrate      Retr  Cwnd
[ 7] 0.00-1.00 sec  1.12 GBytes  9.59 Gbits/sec  0    2.03 MBytes
[ 7] 1.00-2.00 sec  1.11 GBytes  9.57 Gbits/sec  0    3.26 MBytes
[ 7] 2.00-3.00 sec  1.11 GBytes  9.57 Gbits/sec  0    3.26 MBytes
[ 7] 3.00-4.00 sec  1.11 GBytes  9.55 Gbits/sec  0    3.26 MBytes
[ 7] 4.00-5.00 sec  1.11 GBytes  9.57 Gbits/sec  0    3.42 MBytes
[ 7] 5.00-6.00 sec  1.11 GBytes  9.53 Gbits/sec  0    3.77 MBytes
[ 7] 6.00-7.00 sec  1.11 GBytes  9.50 Gbits/sec  0    4.00 MBytes
[ 7] 7.00-8.00 sec  1.11 GBytes  9.56 Gbits/sec  0    4.00 MBytes
[ 7] 8.00-9.00 sec  1.11 GBytes  9.56 Gbits/sec  0    4.00 MBytes
[ 7] 9.00-10.00 sec 1.11 GBytes  9.57 Gbits/sec  0    4.00 MBytes
[ 7] 10.00-10.01 sec 764 KBytes  792 Mbits/sec  0    4.00 MBytes
[ ID] Interval      Transfer    Bitrate      Retr  sender receiver
[ 7] 0.00-10.01 sec 11.1 GBytes  9.55 Gbits/sec  0

Server listening on 5201
[
```

Рис. 3: Ограничение скорости на конечных хостах

# Ограничение скорости на коммутаторах

```
"host: h1" (na mininet-vm)
iperf Done.
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root
root@mininet-vm:/home/mininet#
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 41306 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer    Bitrate      Retr  Cwnd
[ 7] 0.00-1.00 sec  1.13 GBytes  9.69 Gbits/sec  0    2.04 MBytes
[ 7] 1.00-2.00 sec  1.11 GBytes  9.56 Gbits/sec  0    3.36 MBytes
[ 7] 2.00-3.00 sec  1.11 GBytes  9.56 Gbits/sec  0    3.58 MBytes
[ 7] 3.00-4.00 sec  1.11 GBytes  9.58 Gbits/sec  0    3.78 MBytes
[ 7] 4.00-5.00 sec  1.11 GBytes  9.56 Gbits/sec  0    3.78 MBytes
[ 7] 5.00-6.00 sec  1.11 GBytes  9.56 Gbits/sec  0    3.96 MBytes
[ 7] 6.00-7.00 sec  1.11 GBytes  9.57 Gbits/sec  0    3.96 MBytes
[ 7] 7.00-8.00 sec  1.11 GBytes  9.56 Gbits/sec  0    3.96 MBytes
[ 7] 8.00-9.00 sec  1.11 GBytes  9.56 Gbits/sec  0    3.96 MBytes
[ 7] 9.00-10.00 sec 1.11 GBytes  9.57 Gbits/sec  0    3.96 MBytes
-----
[ ID] Interval      Transfer    Bitrate      Retr
[ 7] 0.00-10.00 sec 11.1 GBytes  9.58 Gbits/sec  0
[ 7] 0.00-10.02 sec 11.1 GBytes  9.55 Gbits/sec
sender
receiver

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

"host: h2" (na mininet-vm)
warning: this system does not seem to support IPv6 - trying IPv4
-----
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 41304
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 41306
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-1.00 sec  1.12 GBytes  9.58 Gbits/sec
[ 7] 1.00-2.00 sec  1.11 GBytes  9.57 Gbits/sec
[ 7] 2.00-3.00 sec  1.12 GBytes  9.58 Gbits/sec
[ 7] 3.00-4.00 sec  1.11 GBytes  9.56 Gbits/sec
[ 7] 4.00-5.00 sec  1.11 GBytes  9.57 Gbits/sec
[ 7] 5.00-6.00 sec  1.11 GBytes  9.56 Gbits/sec
[ 7] 6.00-7.00 sec  1.11 GBytes  9.57 Gbits/sec
[ 7] 7.00-8.00 sec  1.11 GBytes  9.56 Gbits/sec
[ 7] 8.00-9.00 sec  1.11 GBytes  9.56 Gbits/sec
[ 7] 9.00-10.00 sec  1.11 GBytes  9.56 Gbits/sec
[ 7] 10.00-10.02 sec 128 KBytes  59.7 Mbits/sec
-----
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-10.02 sec 11.1 GBytes  9.55 Gbits/sec
receiver

Server listening on 5201
[
```

Рис. 4: Ограничение скорости на коммутаторах

```
ipertt done.  
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=13.6 ms  
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=11.9 ms  
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=10.9 ms  
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=10.4 ms  
  
--- 10.0.0.2 ping statistics ---  
4 packets transmitted, 4 received, 0% packet loss, time 3005ms  
rtt min/avg/max/mdev = 10.353/11.662/13.553/1.215 ms  
root@mininet-vm:/home/mininet#
```

Рис. 5: Изменение задержки

```
"host: h1" (ns mininet-vm)
--- 10.0.0.2 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3006ms
rtt min/avg/max/mdev = 10.321/11.395/12.718/0.975 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 41310 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer    Bitrate      Retr  Cwnd
[ 7] 0.00-1.00 sec   216 MBytes  1.81 Gbits/sec  1125  2.78 MBytes
[ 7] 1.00-2.00 sec   228 MBytes  1.91 Gbits/sec    0   2.92 MBytes
[ 7] 2.00-3.00 sec   229 MBytes  1.92 Gbits/sec    0   3.03 MBytes
[ 7] 3.00-4.00 sec   214 MBytes  1.79 Gbits/sec  585   2.22 MBytes
[ 7] 4.00-5.00 sec   221 MBytes  1.86 Gbits/sec    0   2.34 MBytes
[ 7] 5.00-6.00 sec   228 MBytes  1.91 Gbits/sec    0   2.43 MBytes
[ 7] 6.00-7.00 sec   229 MBytes  1.92 Gbits/sec    0   2.49 MBytes
[ 7] 7.00-8.00 sec   228 MBytes  1.91 Gbits/sec    0   2.54 MBytes
[ 7] 8.00-9.00 sec   229 MBytes  1.92 Gbits/sec    0   2.57 MBytes
[ 7] 9.00-10.00 sec  228 MBytes  1.91 Gbits/sec    0   2.59 MBytes
-----
[ ID] Interval      Transfer    Bitrate      Retr
[ 7] 0.00-10.01 sec  2.19 GBytes  1.89 Gbits/sec  1710
[ 7] 0.00-10.01 sec  2.19 GBytes  1.87 Gbits/sec
iperf Done.
root@mininet-vm:/home/mininet#

"host: h2" (ns mininet-vm)
warning: this system does not seem to support IPv6 - trying IPv4
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 41308
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 41310
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-1.00 sec   204 MBytes  1.71 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   214 MBytes  1.80 Gbits/sec
[ 7] 4.00-5.00 sec   222 MBytes  1.86 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   228 MBytes  1.91 Gbits/sec
[ 7] 8.00-9.00 sec   228 MBytes  1.91 Gbits/sec
[ 7] 9.00-10.00 sec   228 MBytes  1.91 Gbits/sec
[ 7] 10.00-10.01 sec  2.05 MBytes  1.17 Gbits/sec
-----
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-10.01 sec  2.19 GBytes  1.87 Gbits/sec
-----
Server listening on 5201
[ 7] 0.00-10.01 sec  2.19 GBytes  1.87 Gbits/sec
-----
[ 7] 0.00-10.01 sec  2.19 GBytes  1.87 Gbits/sec
-----
[ 7] 0.00-10.01 sec  2.19 GBytes  1.87 Gbits/sec
-----
```

Рис. 6: Добавление правила на коммутатор

```
mininet@mininet-vn:~/work/lab_neten_ll/simple-tbf$ sudo python lab_neten_ll.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 10gbt burst 5000000 limit 15000000',)
*** 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 $7}' > ping.dat',)
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 2 links
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
mininet@mininet-vn:~/work/lab_neten_ll/simple-tbf$ cat ping.dat
9.65
9.57
9.56
9.56
9.56
9.56
9.56
9.56
9.56
9.57
9.56
mininet@mininet-vn:~/work/lab_neten_ll/simple-tbf$
```

Рис. 7: Запуск эксперимента

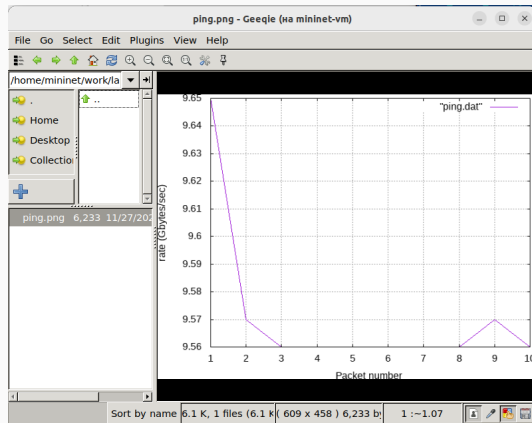


Рис. 8: График изменения скорости передачи

## Выводы

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В результате выполнения работы познакомились с принципами работы дисциплины очереди Token Bucket Filter, которая формирует входящий/исходящий трафик для ограничения пропускной способности, а также получили 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: 11.12.2024).