

# Лабораторная работа №6

## Настройка пропускной способности глобальной сети с помощью Token Bucket Filter

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# Цели и задачи

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## Цель лабораторной 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.

1. Задайте топологию (рис. 6.3), 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.

# Процесс выполнения лабораторной работы

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## Запуск лабораторной топологии

```

root@mininet:~# ood@mininet:~#
root@mininet:~# ood@mininet:~# ifconfig
eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.56.100 netmask 255.255.255.0 broadcast 192.168.56.255
    ether 08:00:27:fd:bd:ca txqueuelen 1000 (Ethernet)
    RX packets 2661 bytes 536581 (536.6 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 2426 bytes 96443 (964.4 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 10.8.0.215 netmask 255.255.255.0 broadcast 10.8.0.255
    ether 08:00:27:86:0d:24 txqueuelen 1000 (Ethernet)
    RX packets 242 bytes 33759 (33.7 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 259 bytes 24275 (24.2 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 Loop)
    RX packets 5183 bytes 1222238 (1.2 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 5183 bytes 1222238 (1.2 MB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

s1-eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    ether 9a:0d:9a:04:4d:25 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

s1-eth2: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    ether 2a:1d:3d:54:4b:21 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 ce:04:3b:03:4b:75 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 02:01:54:0a:0b:7e 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

```

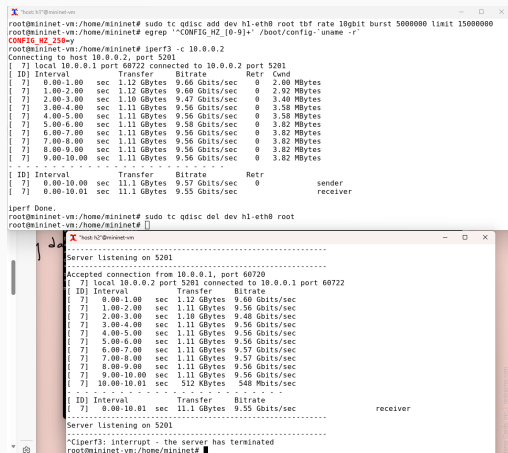
Рис. 1: Информация о сетевом интерфейсе и IP-адресе s1

```
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=2.47 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.221 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.058 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.127 ms

--- 10.0.0.2 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3045ms
rtt min/avg/max/mdev = 0.058/0.718/2.467/1.011 ms
root@mininet-vm:/home/mininet#
```

Рис. 2: Проверка подключение от h2 к h1

# Ограничение скорости на конечных хостах



The image shows two terminal windows. The top window is titled 'host h1T@mininet-vn' and shows the configuration of a traffic control (tc) rule on the h1-eth0 interface to limit the rate to 10 Gbit/sec with a burst of 5000000 and a limit of 15000000. It then starts an iperf3 client on port 5201. The bottom window is titled 'host h2@mininet-vn' and shows the server listening on port 5201. It receives a connection from 10.0.0.2 and runs iperf3, showing a transfer rate of approximately 9.55 Gb/sec. The iperf3 client in the top window shows a transfer rate of approximately 9.56 Gb/sec, matching the server's rate.

```
root@mininet-vn:/home/mininet# sudo tc qdisc add dev h1-eth0 root tbf rate 10gbit burst 5000000 limit 15000000
root@mininet-vn:/home/mininet# egrep '^CONFIG_HZ_[0-9]+' /boot/config-`uname -r`
CONFIG_HZ_250=y
root@mininet-vn:/home/mininet# iperf3 -c 10.0.0.2
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 60722 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer     Bitrate      Retr  Cwnd
[ 7] 0.00-1.00 sec  1.12 GBytes  9.66 Gbits/sec  0    2.00 MBytes
[ 7] 1.00-2.00 sec  1.12 GBytes  9.60 Gbits/sec  0    2.92 MBytes
[ 7] 2.00-3.00 sec  1.10 GBytes  9.47 Gbits/sec  0    3.40 MBytes
[ 7] 3.00-4.00 sec  1.11 GBytes  9.56 Gbits/sec  0    3.58 MBytes
[ 7] 4.00-5.00 sec  1.11 GBytes  9.56 Gbits/sec  0    3.58 MBytes
[ 7] 5.00-6.00 sec  1.11 GBytes  9.58 Gbits/sec  0    3.82 MBytes
[ 7] 6.00-7.00 sec  1.11 GBytes  9.56 Gbits/sec  0    3.82 MBytes
[ 7] 7.00-8.00 sec  1.11 GBytes  9.56 Gbits/sec  0    3.82 MBytes
[ 7] 8.00-9.00 sec  1.11 GBytes  9.56 Gbits/sec  0    3.82 MBytes
[ 7] 9.00-10.00 sec 1.11 GBytes  9.56 Gbits/sec  0    3.82 MBytes
- - - - -
[ ID] Interval      Transfer     Bitrate      Retr
[ 7] 0.00-10.01 sec 11.1 GBytes  9.57 Gbits/sec  0          sender
[ 7] 0.00-10.01 sec 11.1 GBytes  9.55 Gbits/sec                                receiver

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

```
Server listening on 5201
Accepted connection from 10.0.0.2 port 5201 connected to 10.0.0.1 port 60722
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 60722
[ ID] Interval      Transfer     Bitrate
[ 7] 0.00-1.00 sec  1.12 GBytes  9.60 Gbits/sec
[ 7] 1.00-2.00 sec  1.11 GBytes  9.56 Gbits/sec
[ 7] 2.00-3.00 sec  1.10 GBytes  9.48 Gbits/sec
[ 7] 3.00-4.00 sec  1.11 GBytes  9.56 Gbits/sec
[ 7] 4.00-5.00 sec  1.11 GBytes  9.56 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  9.57 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] 10.00-10.01 sec 512 KBytes  548 Mbits/sec
- - - - -
[ ID] Interval      Transfer     Bitrate
[ 7] 0.00-10.01 sec 11.1 GBytes  9.55 Gbits/sec                                receiver

Server listening on 5201
^Ciperf3: Interrupt - the server has terminated
root@mininet-vn:/home/mininet#
```

Рис. 3: Настройка tbf на конечных хостах и проверки



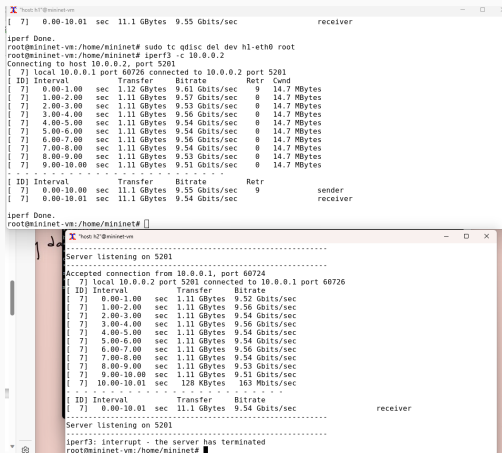
# Ограничение скорости на коммутаторах

```
ether 02:a1:54:a1:ab:76 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 qdisc add dev s1-eth2 root tbf rate 10gbit burst 5000000 limit 15000000
root@mininet-vm:/home/mininet#
```

Рис. 4: Настройка tbf на коммутаторах

# Ограничение скорости на коммутаторах



```
root@h2~# iperf -t 10 -c 10.0.0.2 -P 5201
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 60726 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer     Bitrate      Retr  Cwnd
[ 7] 0.00-1.00 sec  1.12 GBytes  9.61 Gbits/sec  0   14.7 MBytes
[ 7] 1.00-2.00 sec  1.11 GBytes  9.57 Gbits/sec  0   14.7 MBytes
[ 7] 2.00-3.00 sec  1.11 GBytes  9.53 Gbits/sec  0   14.7 MBytes
[ 7] 3.00-4.00 sec  1.11 GBytes  9.56 Gbits/sec  0   14.7 MBytes
[ 7] 4.00-5.00 sec  1.11 GBytes  9.54 Gbits/sec  0   14.7 MBytes
[ 7] 5.00-6.00 sec  1.11 GBytes  9.54 Gbits/sec  0   14.7 MBytes
[ 7] 6.00-7.00 sec  1.11 GBytes  9.56 Gbits/sec  0   14.7 MBytes
[ 7] 7.00-8.00 sec  1.11 GBytes  9.54 Gbits/sec  0   14.7 MBytes
[ 7] 8.00-9.00 sec  1.11 GBytes  9.53 Gbits/sec  0   14.7 MBytes
[ 7] 9.00-10.00 sec 1.11 GBytes  9.51 Gbits/sec  0   14.7 MBytes
-----
[ ID] Interval      Transfer     Bitrate      Retr      sender
[ 7] 0.00-10.00 sec 11.1 GBytes  9.55 Gbits/sec  9          receiver
iperf Done.
root@mininet-vm:/home/mininet#
```

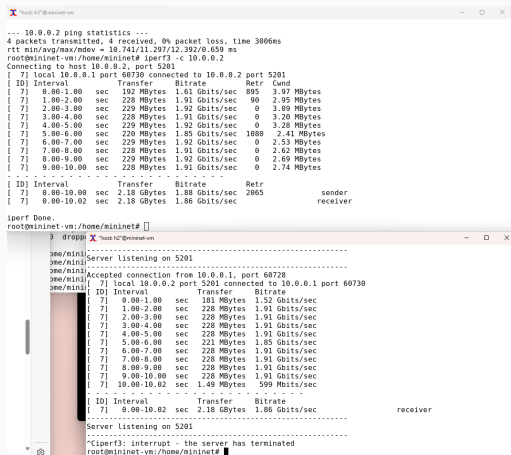
```
root@h2~# iperf3 -s
Server listening on 5201
Accepted connection from 10.0.0.1, port 60724
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 60726
[ ID] Interval      Transfer     Bitrate
[ 7] 0.00-1.00 sec  1.11 GBytes  9.52 Gbits/sec
[ 7] 1.00-2.00 sec  1.11 GBytes  9.56 Gbits/sec
[ 7] 2.00-3.00 sec  1.11 GBytes  9.54 Gbits/sec
[ 7] 3.00-4.00 sec  1.11 GBytes  9.56 Gbits/sec
[ 7] 4.00-5.00 sec  1.11 GBytes  9.54 Gbits/sec
[ 7] 5.00-6.00 sec  1.11 GBytes  9.54 Gbits/sec
[ 7] 6.00-7.00 sec  1.11 GBytes  9.56 Gbits/sec
[ 7] 7.00-8.00 sec  1.11 GBytes  9.54 Gbits/sec
[ 7] 8.00-9.00 sec  1.11 GBytes  9.53 Gbits/sec
[ 7] 9.00-10.00 sec 1.11 GBytes  9.51 Gbits/sec
[ 7] 10.00-10.01 sec 128 MBytes  163 Mbits/sec
[ ID] Interval      Transfer     Bitrate
[ 7] 0.00-10.01 sec 11.1 GBytes  9.54 Gbits/sec
-----
Server listening on 5201
iperf3: Interrupt - the server has terminated
root@mininet-vm:/home/mininet#
```

Рис. 5: Запуск iperf3 для проверки

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

Рис. 6: Добавление второе правило на коммутаторе s1

# Объединение NETEM и TBF



```
root@mininet-vn: /home/mininet# iperf3 -c 10.0.0.2
--- 10.0.0.2 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3006ms
rtt min/avg/max/ndev = 10.741/11.297/12.392/0.659 ms
root@mininet-vn: /home/mininet# iperf3 -c 10.0.0.2
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 60730 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer      Bitrate      Retr      Cwnd
[ 7] 0.00-1.00 sec    192 MBytes    1.61 Gbits/sec  895      3.97 MBytes
[ 7] 1.00-2.00 sec    228 MBytes    1.91 Gbits/sec   90      2.95 MBytes
[ 7] 2.00-3.00 sec    229 MBytes    1.92 Gbits/sec    0      3.89 MBytes
[ 7] 3.00-4.00 sec    228 MBytes    1.91 Gbits/sec    0      3.20 MBytes
[ 7] 4.00-5.00 sec    229 MBytes    1.92 Gbits/sec    0      3.28 MBytes
[ 7] 5.00-6.00 sec    220 MBytes    1.85 Gbits/sec 1080      2.41 MBytes
[ 7] 6.00-7.00 sec    229 MBytes    1.92 Gbits/sec    0      2.53 MBytes
[ 7] 7.00-8.00 sec    228 MBytes    1.91 Gbits/sec    0      2.62 MBytes
[ 7] 8.00-9.00 sec    229 MBytes    1.92 Gbits/sec    0      2.69 MBytes
[ 7] 9.00-10.00 sec   228 MBytes    1.91 Gbits/sec    0      2.74 MBytes
-----
[ ID] Interval      Transfer      Bitrate      Retr      sender
[ 7] 0.00-10.00 sec  2.18 GBytes    1.88 Gbits/sec 2065
[ 7] 0.00-10.02 sec  2.18 GBytes    1.86 Gbits/sec
iperf Done.
root@mininet-vn: /home/mininet#
```

```
root@mininet-vn: /home/mininet#
dropp
Server Listening on 5201
Accepted connection from 10.0.0.1, port 60728
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 60730
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-1.00 sec    181 MBytes    1.52 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    221 MBytes    1.85 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] 10.00-10.02 sec   1.49 MBytes    599 Mbits/sec
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-10.02 sec  2.18 GBytes    1.86 Gbits/sec
receiver
Server listening on 5201
^Ciperf3: interrupt - the server has terminated
root@mininet-vn: /home/mininet#
```

Рис. 7: Запуск iperf3 для проверки

# Воспроизводимые эксперименты

```
GNU nano 4.8 /home/mininet/work/lab_tbf/lab_tbf.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.link import TCLink
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' )
    s2 = net.addSwitch( 's2' )

    info( '*** Creating links\n' )
    net.addLink( h1, s1 )
    net.addLink( h2, s2 )
    net.addLink( s1, s2 )

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

    info( '*** Set delay\n' )
    s1.cmdPrint( 'tc qdisc add dev s1-eth2 root handle 1: netem delay 10ms' )
    s1.cmdPrint( 'tc qdisc add dev s1-eth2 parent 1: handle 2: tbf rate 2gbit burst 1000000 limit 2000000' )

    info( '*** Traffic generation\n' )
    h2.cmdPrint( 'iperf3 -s -D -l' )
    time.sleep(10) # Wait 10 seconds for servers to start
    h1.cmdPrint( 'iperf3 -c', h2.IP(), '-J > iperf_result.json' )
    h1.cmdPrint( 'ping -c 100', h2.IP(), '| grep "time" | awk \'{print $5, $7}\'} | sed -e "/s/time//g" -e "/s/icmp_seq//g" > ping.dat' )

    info( '*** Stopping network' )
    net.stop()

if __name__ == '__main__':
    setLogLevel( 'info' )
    emptyNet()
```

Рис. 8: Скрипт lab\_tbf.py

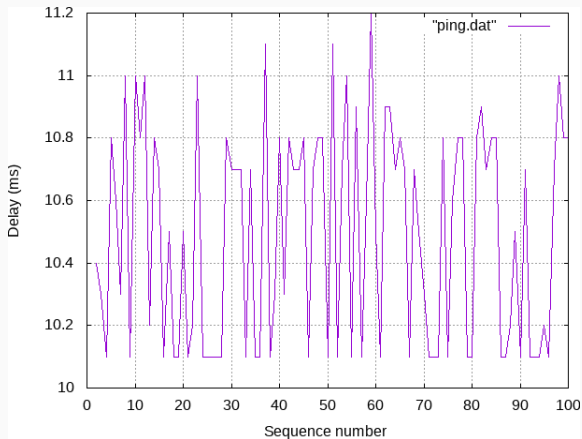


Рис. 9: График

## Выводы по проделанной работе

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Я познакомилась 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.