

Лабораторная работы №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.

Выполнение лабораторной работы

The image shows four terminal windows from a Mininet VM. Each window displays the output of the 'ifconfig' command.

- Host h1:** Shows two interfaces: h1-eth0 (Ethernet) and lo (loopback). h1-eth0 has an IP of 10.0.0.1 and MAC 00:0c:29:e1:6a:72. lo has an IP of 127.0.0.1 and MAC 00:00:00:00:00:00.
- Host h2:** Shows two interfaces: h2-eth0 (Ethernet) and lo (loopback). h2-eth0 has an IP of 10.0.0.2 and MAC 12:43:fd:29:e2:79. lo has an IP of 127.0.0.1 and MAC 00:00:00:00:00:00.
- Switch s1:** Shows two interfaces: s1-eth1 (Ethernet) and s1-eth2 (Ethernet). Both have an IP of 192.168.11.128 and MAC 00:0c:29:be:cc:10. They are connected to hosts h1 and h2 respectively.
- Switch s2:** Shows two interfaces: s2-eth1 (Ethernet) and s2-eth2 (Ethernet). Both have an IP of 192.168.11.129 and MAC 62:65:34:9c:4b:1a. They are connected to hosts h1 and h2 respectively.

Each interface's configuration includes MTU, broadcast address, and various statistics like RX/TX bytes and errors.

Рис. 1: Задание топологии

Выполнение лабораторной работы

The image shows two terminal windows side-by-side. Both windows have a title bar with the host name and the command used to open the window.

Terminal 1 (host: h1@mininet-vm):

```
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=0.056 ms

--- 10.0.0.2 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3055ms
rtt min/avg/max/mdev = 0.056/4.139/15.637/6.642 ms
root@mininet-vm:/home/mininet#
```

Terminal 2 (host: h2@mininet-vm):

```
root@mininet-vm:/home/mininet# ifconfig
1: 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

10: eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 10.0.0.1 brd 10.0.0.255 netmask 255.255.255.0
        broadcast 10.0.0.255
        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=23.3 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=0.295 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

The image shows two terminal windows side-by-side. Both windows have a red icon in the top-left corner and are titled with the host name and session ID.

Host h1 Terminal:

```
rtt min/avg/max/mdev = 0.096/4.139/15.637/6.642 ms
root@mininet-vm:/home/mininet# iperf3 -c 10.0.0.2
Connected 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
[ 7]  0.00-1.00   sec  1.29 Gbytes  11.0 Gbits/sec  0      sender
[ 7]  1.00-2.00   sec  1.11 Gbytes  9.55 Gbits/sec  0      sender
[ 7]  2.00-3.01   sec  966 MBytes  8.05 Gbits/sec  0      sender
[ 7]  3.01-4.00   sec  1.12 Gbytes  9.73 Gbits/sec  0      sender
[ 7]  4.00-5.00   sec  998 MBytes  8.36 Gbits/sec  0      sender
[ 7]  5.00-6.00   sec  788 MBytes  6.59 Gbits/sec  0      sender
[ 7]  6.00-7.00   sec  878 MBytes  7.36 Gbits/sec  0      sender
[ 7]  7.00-8.00   sec  1.24 Gbytes  10.7 Gbits/sec  0      sender
[ 7]  8.00-9.00   sec  1.20 Gbytes  10.3 Gbits/sec  0      sender
[ 7]  9.00-10.00  sec  1.11 Gbytes  9.53 Gbits/sec  0      sender
[ 7]                                -.- sender
[ 7]  0.00-10.00  sec  10.6 Gbytes  9.12 Gbits/sec  0      sender
[ 7]                                -.- receiver
iperf Done.
root@mininet-vm:/home/mininet#
```

Host h2 Terminal:

```
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      Retr
[ 7]  0.00-1.00   sec  1.29 Gbytes  11.0 Gbits/sec  0      sender
[ 7]  1.00-2.00   sec  1.11 Gbytes  9.55 Gbits/sec  0      sender
[ 7]  2.00-3.00   sec  966 MBytes  8.05 Gbits/sec  0      sender
[ 7]  3.00-4.00   sec  1.12 Gbytes  9.73 Gbits/sec  0      sender
[ 7]  4.00-5.00   sec  998 MBytes  8.36 Gbits/sec  0      sender
[ 7]  5.00-6.00   sec  788 MBytes  6.59 Gbits/sec  0      sender
[ 7]  6.00-7.00   sec  878 MBytes  7.36 Gbits/sec  0      sender
[ 7]  7.00-8.00   sec  1.24 Gbytes  10.7 Gbits/sec  0      sender
[ 7]  8.00-9.00   sec  1.20 Gbytes  10.3 Gbits/sec  0      sender
[ 7]  9.00-10.00  sec  1.11 Gbytes  9.53 Gbits/sec  0      sender
[ 7]                                -.- sender
[ 7]  0.00-10.00  sec  10.6 Gbytes  9.12 Gbits/sec  0      sender
[ 7]                                -.- receiver
Server listening on 5201
[Clean-UP interrupt - the server has terminated]
```

Рис. 3: Запуск iperf3 на хостах

Выполнение лабораторной работы

The image shows two terminal windows side-by-side. Both windows are titled "host h1" and "host h2" respectively, and are running on a "mininet-vm" host.

Host h1 Terminal:

```
iperf Done.  
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root tbft rate 10gbit 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# iperf3 -c 10.0.0.2  
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 995 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 992 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 sender  
[ 7] 0.00-10.00 sec 9.63 GBytes 8.27 Gbits/sec receiver  
iperf Done.  
root@mininet-vm:/home/mininet#
```

Host h2 Terminal:

```
[ 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

The image shows three terminal windows from a Mininet VM. The top-left window is on the switch (s1) and shows the command to add a TBF queue discipline to interface s1-eth2 with a rate of 10Gb/s. The top-right window is on host h2 and shows iperf3 listening on port 5201. The bottom-left window is on host h1 and shows iperf3 connecting to host h2. The output of the connection shows a transfer rate of approximately 8.86 Gbit/sec over a 10-second interval.

```
tbf: illegal value for "burst": "sudo"
root@mininet-vm:/home/mininet# sudo tc qdisc add dev s1-eth2 root tbf rate 10gbit burst 10
root@mininet-vm:/home/mininet#
```

```
"switch: s1" (root)@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 sender
[ 7] 0,00-10,00 sec 10.0 GBytes 8.63 Gbits/sec 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 2.92 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 995 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 sender
[ 7] 0,00-10,00 sec 10.3 GBytes 8.84 Gbits/sec receiver
```

```
"host: h2" (root)@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
,BROADCAST,RUNNING,MULTICAST> mtu 1500
```

Рис. 5: Ограничение скорости на коммутаторах

Выполнение лабораторной работы

The screenshot shows a terminal window with two panes. The left pane is titled "switch: s1" (root)@mininet-vm and displays the configuration of a TBF queue on interface s1-eth2. The right pane is titled "host: h2" (root)@mininet-vm and shows the results of an iperf3 test between host h1 and h2.

Left Pane (switch: s1) Configuration:

```
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
init 2000000
root@mininet-vm:/home/mininet#
```

Right Pane (host: h2) Test Results:

```
[ 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
[ 7] [ ID] Interval Transfer Bitrate Retr Cwnd
[ 7] 0.00-1.00 sec 212 MBytes 1.77 Gbytes/sec 225 3.26 MBytes
[ 7] 1.00-2.00 sec 229 MBytes 1.92 Gbytes/sec 0 3.50 MBytes
[ 7] 2.00-3.00 sec 229 MBytes 1.91 Gbytes/sec 0 3.70 MBytes
[ 7] 3.00-4.00 sec 228 MBytes 1.91 Gbytes/sec 90 2.73 MBytes
[ 7] 4.00-5.00 sec 229 MBytes 1.92 Gbytes/sec 0 2.87 MBytes
[ 7] 5.00-6.00 sec 228 MBytes 1.91 Gbytes/sec 0 2.97 MBytes
[ 7] 6.00-7.00 sec 229 MBytes 1.92 Gbytes/sec 0 3.06 MBytes
[ 7] 7.00-8.00 sec 208 MBytes 1.74 Gbytes/sec 405 2.25 MBytes
[ 7] 8.00-9.00 sec 215 MBytes 1.80 Gbytes/sec 0 2.36 MBytes
[ 7] 9.00-10.00 sec 225 MBytes 1.89 Gbytes/sec 0 2.45 MBytes
[ 7] [ ID] Interval Transfer Bitrate Retr Cwnd
[ 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
sender receiver
perf Done.
root@mininet-vm:/home/mininet#
```

Bottom Status Bar:

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

Рис. 6: Объединение NETEM и TBF

Выполнение лабораторной работы

```
GNU nano 4.8                               lab_neterm_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

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. 8: Скрипт для отрисовки графика

Выполнение лабораторной работы

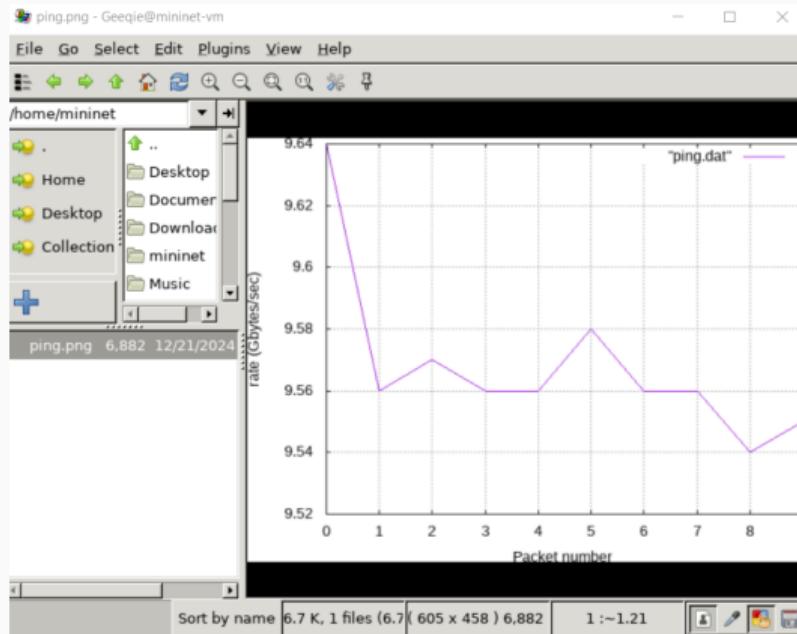


Рис. 9: График изменения скорости передачи

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.

Спасибо за внимание!