

## Лабораторная работа № 2

Измерение и тестирование пропускной способности сети. Интерактивный эксперимент

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## Информация

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Основной целью работы является знакомство с инструментом для измерения пропускной способности сети в режиме реального времени — iPerf3, а также получение навыков проведения интерактивного эксперимента по измерению пропускной способности моделируемой сети в среде Mininet.

1. Установить на виртуальную машину mininet iPerf3 и дополнительное программное обеспечения для визуализации и обработки данных.
2. Провести ряд интерактивных экспериментов по измерению пропускной способности с помощью iPerf3 с построением графиков.

## Выполнение лабораторной работы

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# Установка необходимого программного обеспечения

```
mininet@mininet-vm: ~  
RX errors 0 dropped 0 overruns 0 frame 0  
TX packets 22 bytes 2204 (2.2 KB)  
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0  
  
mininet@mininet-vm:~$ sudo dhclient eth1  
mininet@mininet-vm:~$ ifconfig  
eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500  
    inet 192.168.11.128 netmask 255.255.255.0 broadcast 192.168.11.255  
    ether 00:0c:29:be:cc:10 txqueuelen 1000 (Ethernet)  
    RX packets 156 bytes 17459 (17.4 KB)  
    RX errors 0 dropped 0 overruns 0 frame 0  
    TX packets 139 bytes 18393 (18.3 KB)  
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0  
  
eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500  
    inet 192.168.35.128 netmask 255.255.255.0 broadcast 192.168.35.255  
    ether 00:0c:29:be:cc:1a txqueuelen 1000 (Ethernet)  
    RX packets 1 bytes 342 (342.0 B)  
    RX errors 0 dropped 0 overruns 0 frame 0  
    TX packets 1 bytes 342 (342.0 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 22 bytes 2204 (2.2 KB)  
    RX errors 0 dropped 0 overruns 0 frame 0  
    TX packets 22 bytes 2204 (2.2 KB)  
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

Рис. 1: Подключение к mininet по ssh

## Установка необходимого программного обеспечения

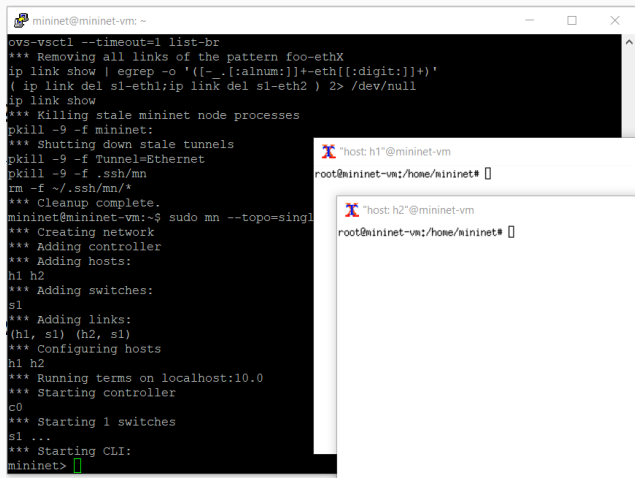
```
mininet@mininet-vm:~$ sudo apt-get update
Hit:1 http://us.archive.ubuntu.com/ubuntu focal InRelease
Get:2 http://us.archive.ubuntu.com/ubuntu focal-updates InRelease [128 kB]
Get:3 http://us.archive.ubuntu.com/ubuntu focal-backports InRelease [128 kB]
Get:4 http://us.archive.ubuntu.com/ubuntu focal-updates/main amd64 Packages [3,680 kB]
Get:5 http://us.archive.ubuntu.com/ubuntu focal-updates/main i386 Packages [1,054 kB]
Get:6 http://us.archive.ubuntu.com/ubuntu focal-updates/main Translation-en [563 kB]
Get:7 http://us.archive.ubuntu.com/ubuntu focal-updates/main amd64 c-n-f Metadata [17.8 kB]
Get:8 http://us.archive.ubuntu.com/ubuntu focal-updates/restricted amd64 Packages [3,379 kB]
Get:9 http://us.archive.ubuntu.com/ubuntu focal-updates/restricted i386 Packages [39.9 kB]
Get:10 http://us.archive.ubuntu.com/ubuntu focal-updates/restricted Translation-en [473 kB]
Get:11 http://us.archive.ubuntu.com/ubuntu focal-updates/restricted amd64 c-n-f Metadata [17.8 kB]
Get:12 http://us.archive.ubuntu.com/ubuntu focal-updates/universe amd64 Packages [1,238 kB]
Get:13 http://us.archive.ubuntu.com/ubuntu focal-updates/universe i386 Packages [810 kB]
Get:14 http://us.archive.ubuntu.com/ubuntu focal-updates/universe Translation-en [297 kB]
Get:15 http://us.archive.ubuntu.com/ubuntu focal-updates/universe amd64 c-n-f Metadata [17.8 kB]
```

Рис. 2: Установка ПО



```
mininet@mininet-vm:~$ cd /tmp
mininet@mininet-vm:/tmp$ git clone https://github.com/ekfoury/iperf3_plotter.git
Cloning into 'iperf3_plotter'...
remote: Enumerating objects: 74, done.
remote: Total 74 (delta 0), reused 0 (delta 0), pack-reused 74 (from 1)
Unpacking objects: 100% (74/74), 100.09 KiB | 683.00 KiB/s, done.
mininet@mininet-vm:/tmp$ cd /tmp/iperf3_plotter
mininet@mininet-vm:/tmp/iperf3_plotter$ sudo cp plot_* /usr/bin
mininet@mininet-vm:/tmp/iperf3_plotter$ sudo cp *.sh /usr/bin
mininet@mininet-vm:/tmp/iperf3_plotter$
```

Рис. 3: Развертывание iperf3\_plotter



```
mininet@mininet-vm: ~  
ovs-vsctl --timeout=1 list-br  
*** Removing all links of the pattern foo-ethX  
ip link show | egrep -o '([-_[:alnum:]]+-eth[[:digit:]]+)'  
( ip link del s1-eth1; ip link del s1-eth2 ) 2> /dev/null  
ip link show  
*** Killing stale mininet node processes  
pkill -9 -f mininet:  
*** Shutting down stale tunnels  
pkill -9 -f Tunnel=Ethernet  
pkill -9 -f .ssh/mn  
rm -f ~/.ssh/mn/*  
*** Cleanup complete.  
mininet@mininet-vm:~$ sudo mn --topo=singl  
*** Creating network  
*** Adding controller  
*** Adding hosts:  
h1 h2  
*** Adding switches:  
s1  
*** Adding links:  
(h1, s1) (h2, s1)  
*** Configuring hosts  
h1 h2  
*** Running terms on localhost:10.0  
*** Starting controller  
c0  
*** Starting 1 switches  
s1 ...  
*** Starting CLI:  
mininet>
```

Рис. 4: Задание простейшей топологии

```
mininet> net
h1 h1-eth0:s1-eth1
h2 h2-eth0:s1-eth2
s1 lo: s1-eth1:h1-eth0 s1-eth2:h2-eth0
c0
mininet> links
h1-eth0<->s1-eth1 (OK OK)
h2-eth0<->s1-eth2 (OK OK)
mininet> dump
<Host h1: h1-eth0:10.0.0.1 pid=4160>
<Host h2: h2-eth0:10.0.0.2 pid=4164>
<OVSSwitch s1: lo:127.0.0.1,s1-eth1:None,s1-eth2:None pid=4169>
<Controller c0: 127.0.0.1:6653 pid=4153>
mininet> 
```

Рис. 5: Параметры запущенной в интерактивном режиме топологии

```
Node: h2" @mininet-vm
Server listening on 5201
Accepted connection from 10.0.0.1, port 49886
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 49886
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-1.00 sec  1.18 GBytes  10.1 Gbits/sec
[ 7] 1.00-2.00 sec  1.11 GBytes  9.54 Gbits/sec
[ 7] 2.00-3.00 sec  1.06 GBytes  9.14 Gbits/sec
[ 7] 3.00-4.00 sec   954 MBytes  8.00 Gbits/sec
[ 7] 4.00-5.00 sec   1.43 GBytes  12.3 Gbits/sec
[ 7] 5.00-6.00 sec   1.30 GBytes  11.2 Gbits/sec
[ 7] 6.00-7.00 sec   1.27 GBytes  10.9 Gbits/sec
[ 7] 7.00-8.00 sec   1.24 GBytes  10.7 Gbits/sec
[ 7] 8.00-9.00 sec   1.21 GBytes  10.4 Gbits/sec
[ 7] 9.00-10.00 sec  1.11 GBytes  9.52 Gbits/sec
[ 7] 10.00-10.00 sec  1.06 MBytes  8.45 Gbits/sec
-----
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-10.00 sec  11.8 GBytes  10.2 Gbits/sec
-----
Server listening on 5201

Node: h1" @mininet-vm
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 49888 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer      Bitrate      Retr  Cwnd
[ 7] 0.00-1.00 sec  1.18 GBytes  10.1 Gbits/sec    0   569 KBytes
[ 7] 1.00-2.00 sec  1.11 GBytes  9.54 Gbits/sec    0   700 KBytes
[ 7] 2.00-3.00 sec  1.06 GBytes  9.13 Gbits/sec    0   700 KBytes
[ 7] 3.00-4.00 sec   954 MBytes  8.01 Gbits/sec    0   851 KBytes
[ 7] 4.00-5.00 sec   1.43 GBytes  12.3 Gbits/sec    0   851 KBytes
[ 7] 5.00-6.00 sec   1.30 GBytes  11.2 Gbits/sec    0   851 KBytes
[ 7] 6.00-7.00 sec   1.27 GBytes  10.9 Gbits/sec    0   851 KBytes
[ 7] 7.00-8.00 sec   1.25 GBytes  10.7 Gbits/sec    0   1.29 MBytes
[ 7] 8.00-9.00 sec   1.21 GBytes  10.4 Gbits/sec    0   1.49 MBytes
[ 7] 9.00-10.00 sec  1.11 GBytes  9.53 Gbits/sec    0   1.49 MBytes
-----
[ ID] Interval      Transfer      Bitrate      Retr
[ 7] 0.00-10.00 sec  11.8 GBytes  10.2 Gbits/sec    0
[ 7] 0.00-10.00 sec  11.8 GBytes  10.2 Gbits/sec    0
-----
iperf Done.
root@mininet-vm:/home/mininet#
```

Рис. 6: Тестовое соединение между хостами

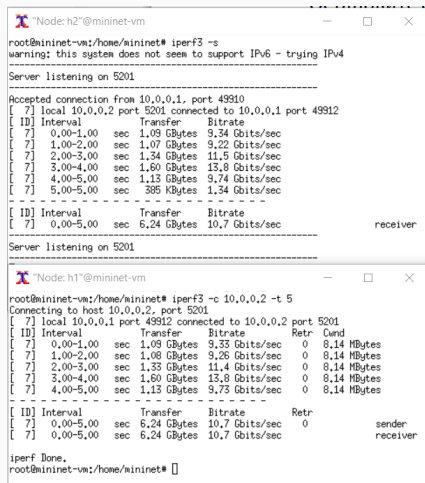
```
mininet> h2 iperf3 -s &
mininet> h1 iperf3 -c h2
Connecting to host 10.0.0.2, port 5201
[ 5] local 10.0.0.1 port 49896 connected to 10.0.0.2 port 5201
[ ID] Interval          Transfer    Bitrate      Retr  Cwnd
[ 5]  0.00-1.00      sec   1.69 GBytes  14.5 Gbits/sec    0   383 KBytes
[ 5]  1.00-2.00      sec   1.62 GBytes  13.9 Gbits/sec    0   383 KBytes
[ 5]  2.00-3.00      sec   1.64 GBytes  14.1 Gbits/sec    0   383 KBytes
[ 5]  3.00-4.00      sec   1.65 GBytes  14.2 Gbits/sec    0   383 KBytes
[ 5]  4.00-5.00      sec   1.66 GBytes  14.3 Gbits/sec    0   383 KBytes
[ 5]  5.00-6.00      sec   1.68 GBytes  14.5 Gbits/sec    0   383 KBytes
[ 5]  6.00-7.00      sec   1.65 GBytes  14.1 Gbits/sec    0   383 KBytes
[ 5]  7.00-8.00      sec   1.61 GBytes  13.8 Gbits/sec    0   383 KBytes
[ 5]  8.00-9.00      sec   1.67 GBytes  14.3 Gbits/sec    0   383 KBytes
[ 5]  9.00-10.00     sec   1.72 GBytes  14.7 Gbits/sec    0   383 KBytes
-----
[ ID] Interval          Transfer    Bitrate      Retr
[ 5]  0.00-10.00     sec   16.6 GBytes  14.3 Gbits/sec    0          sender
[ 5]  0.00-10.00     sec   16.6 GBytes  14.3 Gbits/sec          receiver

iperf Done.
mininet> █
```

Рис. 7: Эксперимент в интерфейсе mininet

```
mininet> h2 killall iperf3
warning: this system does not seem to support IPv6 - trying IPv4
-----
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 49894
[ 5] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 49896
[ ID] Interval      Transfer    Bitrate
[ 5]  0.00-1.00    sec  1.69 GBytes 14.5 Gbits/sec
[ 5]  1.00-2.00    sec  1.62 GBytes 13.9 Gbits/sec
[ 5]  2.00-3.00    sec  1.64 GBytes 14.1 Gbits/sec
[ 5]  3.00-4.00    sec  1.65 GBytes 14.2 Gbits/sec
[ 5]  4.00-5.00    sec  1.66 GBytes 14.3 Gbits/sec
[ 5]  5.00-6.00    sec  1.68 GBytes 14.5 Gbits/sec
[ 5]  6.00-7.00    sec  1.65 GBytes 14.1 Gbits/sec
[ 5]  7.00-8.00    sec  1.61 GBytes 13.8 Gbits/sec
[ 5]  8.00-9.00    sec  1.67 GBytes 14.3 Gbits/sec
[ 5]  9.00-10.00   sec  1.72 GBytes 14.7 Gbits/sec
[ 5] 10.00-10.00   sec  2.00 MBytes 14.5 Gbits/sec
-----
[ ID] Interval      Transfer    Bitrate
[ 5]  0.00-10.00   sec  16.6 GBytes 14.3 Gbits/sec
-----
Server listening on 5201
-----
iperf3: interrupt - the server has terminated
mininet> █
```

Рис. 8: Завершение процесса на сервере



The image shows two terminal windows from a Mininet VM. The top window is for node h2, where iperf3 is running as a server. The bottom window is for node h1, where iperf3 is running as a client. Both windows show a 6.24 Gbps transfer rate over a 5-second interval.

```
"Node: h2"@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 49910
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 49912
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-1.00 sec  1.09 GBytes  9.34 Gbits/sec
[ 7] 1.00-2.00 sec  1.07 GBytes  9.22 Gbits/sec
[ 7] 2.00-3.00 sec  1.34 GBytes  11.5 Gbits/sec
[ 7] 3.00-4.00 sec  1.60 GBytes  13.8 Gbits/sec
[ 7] 4.00-5.00 sec  1.13 GBytes  9.74 Gbits/sec
[ 7] 5.00-5.00 sec   385 KBytes  1.34 Gbits/sec
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-5.00 sec  6.24 GBytes  10.7 Gbits/sec
Server listening on 5201

"Node: h1"@mininet-vm
root@mininet-vm:/home/mininet# iperf3 -c 10.0.0.2 -t 5
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 49912 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer    Bitrate  Retr  Cwnd
[ 7] 0.00-1.00 sec  1.09 GBytes  9.33 Gbits/sec  0    8.14 MBytes
[ 7] 1.00-2.00 sec  1.08 GBytes  9.26 Gbits/sec  0    8.14 MBytes
[ 7] 2.00-3.00 sec  1.33 GBytes  11.4 Gbits/sec  0    8.14 MBytes
[ 7] 3.00-4.00 sec  1.60 GBytes  13.8 Gbits/sec  0    8.14 MBytes
[ 7] 4.00-5.00 sec  1.13 GBytes  9.73 Gbits/sec  0    8.14 MBytes
[ ID] Interval      Transfer    Bitrate  Retr
[ 7] 0.00-5.00 sec  6.24 GBytes  10.7 Gbits/sec  0
[ 7] 0.00-5.00 sec  6.24 GBytes  10.7 Gbits/sec  0
sender
receiver

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

Рис. 9: Указание периода времени передачи

```
"Node: h2"@mininet-vm
root@mininet-vm:/home/mininet# iperf3 -s -i 2
warning: this system does not seem to support IPv6 - trying IPv4
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 49922
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 49924
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-2.00 sec  2.83 GBytes  12.1 Gbits/sec
[ 7] 2.00-4.00 sec  2.69 GBytes  11.5 Gbits/sec
[ 7] 4.00-6.00 sec  3.40 GBytes  14.6 Gbits/sec
[ 7] 6.00-8.00 sec  2.95 GBytes  12.7 Gbits/sec
[ 7] 8.00-10.00 sec 3.15 GBytes  13.5 Gbits/sec
[ 7] 10.00-10.00 sec 832 KBytes   6.99 Gbits/sec
-----
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-10.00 sec 15.0 GBytes  12.9 Gbits/sec
-----
Server listening on 5201
[]

"Node: h1"@mininet-vm
root@mininet-vm:/home/mininet# iperf3 -c 10.0.0.2 -i 2
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 49924 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer      Bitrate    Retr    Cwnd
[ 7] 0.00-2.00 sec  2.83 GBytes  12.1 Gbits/sec    0    133 KBytes
[ 7] 2.00-4.00 sec  2.69 GBytes  11.5 Gbits/sec    0    986 KBytes
[ 7] 4.00-6.00 sec  3.40 GBytes  14.6 Gbits/sec    0    986 KBytes
[ 7] 6.00-8.00 sec  2.95 GBytes  12.7 Gbits/sec    0    986 KBytes
[ 7] 8.00-10.00 sec 3.15 GBytes  13.5 Gbits/sec    0    1.29 MBytes
-----
[ ID] Interval      Transfer      Bitrate    Retr
[ 7] 0.00-10.00 sec 15.0 GBytes  12.9 Gbits/sec    0
[ 7] 0.00-10.00 sec 15.0 GBytes  12.9 Gbits/sec    0
-----
sender
receiver

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

Рис. 10: Выполнения теста пропускной способности с 2-секундным интервалом



```
*Node: h2*@mininet-vm
-----
Accepted connection from 10.0.0.1, port 49934
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 49936
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-1.00 sec  1.27 GBytes 10.9 Gbits/sec
[ 7] 1.00-2.00 sec  1.08 GBytes 9.24 Gbits/sec
[ 7] 2.00-3.00 sec  1.24 GBytes 10.6 Gbits/sec
[ 7] 3.00-4.00 sec  1.46 GBytes 12.5 Gbits/sec
[ 7] 4.00-5.00 sec  1.37 GBytes 11.7 Gbits/sec
[ 7] 5.00-6.00 sec  1.38 GBytes 11.8 Gbits/sec
[ 7] 6.00-7.00 sec  1.27 GBytes 10.9 Gbits/sec
[ 7] 7.00-8.00 sec  1.14 GBytes 9.76 Gbits/sec
[ 7] 8.00-9.00 sec  1.22 GBytes 10.5 Gbits/sec
[ 7] 9.00-10.00 sec 1.34 GBytes 11.5 Gbits/sec
[ 7] 10.00-11.00 sec 1.32 GBytes 11.3 Gbits/sec
[ 7] 11.00-12.00 sec 1.55 GBytes 13.3 Gbits/sec
[ 7] 12.00-12.37 sec 381 MBytes 8.74 Gbits/sec
-----
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-12.37 sec 15.0 GBytes 11.1 Gbits/sec
-----
Server listening on 5201

*Node: h1*@mininet-vm
-----
root@mininet-vm:/home/mininet# iperf3 -c 10.0.0.2 -n 16G
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 49936 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer    Bitrate    Retr  Cwnd
[ 7] 0.00-1.00 sec  1.27 GBytes 10.9 Gbits/sec  0    428 KBytes
[ 7] 1.00-2.00 sec  1.08 GBytes 9.24 Gbits/sec  0    428 KBytes
[ 7] 2.00-3.00 sec  1.24 GBytes 10.6 Gbits/sec  0    428 KBytes
[ 7] 3.00-4.00 sec  1.46 GBytes 12.5 Gbits/sec  0    639 KBytes
[ 7] 4.00-5.00 sec  1.37 GBytes 11.7 Gbits/sec  0    639 KBytes
[ 7] 5.00-6.00 sec  1.38 GBytes 11.8 Gbits/sec  0    807 KBytes
[ 7] 6.00-7.00 sec  1.27 GBytes 10.9 Gbits/sec  0    1.11 MBytes
[ 7] 7.00-8.00 sec  1.14 GBytes 9.76 Gbits/sec  0    5.55 MBytes
[ 7] 8.00-9.00 sec  1.22 GBytes 10.5 Gbits/sec  0    8.21 MBytes
[ 7] 9.00-10.00 sec 1.34 GBytes 11.5 Gbits/sec  0    9.21 MBytes
[ 7] 10.00-11.00 sec 1.32 GBytes 11.4 Gbits/sec  0    8.21 MBytes
[ 7] 11.00-12.00 sec 1.55 GBytes 13.3 Gbits/sec  0    8.21 MBytes
[ 7] 12.00-12.37 sec 376 MBytes 8.61 Gbits/sec  0    8.21 MBytes
-----
[ ID] Interval      Transfer    Bitrate    Retr
[ 7] 0.00-12.37 sec 15.0 GBytes 11.1 Gbits/sec  0
[ 7] 0.00-12.37 sec 15.0 GBytes 11.1 Gbits/sec
-----
sender
receiver
```

Рис. 11: Задание в тесте определённого объёма данных

```
h2@mininet-vm:~$ iperf3 -c 10.0.0.2 -u
Accepted connection from 10.0.0.1, port 49946
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 51563
[ ID] Interval      Transfer      Bitrate      Jitter    Lost/Tot. Data
[ 7] 0.00-1.00  sec  129 KBytes  1.05 Mbits/sec  0.014 ms  0/91 (0%)
[ 7] 1.00-2.00  sec  127 KBytes  1.04 Mbits/sec  0.017 ms  0/90 (0%)
[ 7] 2.00-3.00  sec  129 KBytes  1.05 Mbits/sec  0.011 ms  0/91 (0%)
[ 7] 3.00-4.00  sec  127 KBytes  1.04 Mbits/sec  0.013 ms  0/90 (0%)
[ 7] 4.00-5.00  sec  129 KBytes  1.05 Mbits/sec  0.026 ms  0/91 (0%)
[ 7] 5.00-6.00  sec  127 KBytes  1.04 Mbits/sec  0.037 ms  0/90 (0%)
[ 7] 6.00-7.00  sec  129 KBytes  1.05 Mbits/sec  0.027 ms  0/91 (0%)
[ 7] 7.00-8.00  sec  127 KBytes  1.04 Mbits/sec  0.030 ms  0/90 (0%)
[ 7] 8.00-9.00  sec  129 KBytes  1.05 Mbits/sec  0.018 ms  0/91 (0%)
[ 7] 9.00-10.00 sec  129 KBytes  1.05 Mbits/sec  0.014 ms  0/91 (0%)
[ ID] Interval      Transfer      Bitrate      Jitter    Lost/Tot. Data
[ 7] 0.00-10.00 sec  1.25 MBytes  1.05 Mbits/sec  0.014 ms  0/906 (0%)
Server listening on 5201

h1@mininet-vm:~$ iperf3 -s 10.0.0.2 -u
connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 51563 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer      Bitrate      Jitter    Total Datagrams
[ 7] 0.00-1.00  sec  129 KBytes  1.05 Mbits/sec  91
[ 7] 1.00-2.00  sec  127 KBytes  1.04 Mbits/sec  90
[ 7] 2.00-3.00  sec  129 KBytes  1.05 Mbits/sec  91
[ 7] 3.00-4.00  sec  129 KBytes  1.05 Mbits/sec  91
[ 7] 4.00-5.00  sec  127 KBytes  1.04 Mbits/sec  90
[ 7] 5.00-6.00  sec  129 KBytes  1.06 Mbits/sec  91
[ 7] 6.00-7.00  sec  127 KBytes  1.04 Mbits/sec  90
[ 7] 7.00-8.00  sec  129 KBytes  1.05 Mbits/sec  91
[ 7] 8.00-9.00  sec  127 KBytes  1.04 Mbits/sec  90
[ 7] 9.00-10.00 sec  129 KBytes  1.05 Mbits/sec  91
[ ID] Interval      Transfer      Bitrate      Jitter    Lost/Tot. Data
[ 7] 0.00-10.00 sec  1.25 MBytes  1.05 Mbits/sec  0.000 ms  0/906 (0%) send
[ 7] 0.00-10.00 sec  1.25 MBytes  1.05 Mbits/sec  0.014 ms  0/906 (0%) receive
perf Done.
```

Рис. 12: Изменение протокола передачи данных

```
Node: h2@mininet-vm
-----
Server listening on 3250
-----
Accepted connection from 10.0.0.1, port 47088
[ 7] local 10.0.0.2 port 3250 connected to 10.0.0.1 port 47090
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-1.00    sec 1.45 GBytes 12.5 Gbits/sec
[ 7] 1.00-2.00    sec 1.45 GBytes 12.4 Gbits/sec
[ 7] 2.00-3.00    sec 1.37 GBytes 11.8 Gbits/sec
[ 7] 3.00-4.00    sec 1.19 GBytes 10.2 Gbits/sec
[ 7] 4.00-5.00    sec 1.71 GBytes 14.7 Gbits/sec
[ 7] 5.00-6.00    sec 1.10 GBytes 9.46 Gbits/sec
[ 7] 6.00-7.00    sec 1.31 GBytes 11.2 Gbits/sec
[ 7] 7.00-8.00    sec 1.28 GBytes 11.0 Gbits/sec
[ 7] 8.00-9.00    sec 1.13 GBytes 9.72 Gbits/sec
[ 7] 9.00-10.00   sec 1.39 GBytes 11.9 Gbits/sec
[ 7] 10.00-10.00  sec 1.19 MBytes 3.50 Gbits/sec
-----
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-10.00   sec 13.4 GBytes 11.5 Gbits/sec
-----
Server listening on 3250

Node: h1@mininet-vm
root@mininet-vm:/home/mininet# iperf3 -c 10.0.0.2 -p 3250
Connecting to host 10.0.0.2, port 3250
[ 7] local 10.0.0.1 port 47090 connected to 10.0.0.2 port 3250
[ ID] Interval      Transfer    Bitrate    Retr    Cwnd
[ 7] 0.00-1.00    sec 1.45 GBytes 12.5 Gbits/sec    0    426 KBytes
[ 7] 1.00-2.00    sec 1.45 GBytes 12.5 Gbits/sec    0    426 KBytes
[ 7] 2.00-3.00    sec 1.37 GBytes 11.8 Gbits/sec    0    426 KBytes
[ 7] 3.00-4.00    sec 1.19 GBytes 10.2 Gbits/sec    0    543 KBytes
[ 7] 4.00-5.00    sec 1.71 GBytes 14.7 Gbits/sec    0    629 KBytes
[ 7] 5.00-6.00    sec 1.10 GBytes 9.46 Gbits/sec    0    1.28 MBytes
[ 7] 6.00-7.00    sec 1.31 GBytes 11.2 Gbits/sec    0    1.28 MBytes
[ 7] 7.00-8.00    sec 1.28 GBytes 11.0 Gbits/sec    0    1.28 MBytes
[ 7] 8.00-9.00    sec 1.13 GBytes 9.72 Gbits/sec    0    1.80 MBytes
[ 7] 9.00-10.00   sec 1.39 GBytes 11.9 Gbits/sec    0    1.80 MBytes
-----
[ ID] Interval      Transfer    Bitrate    Retr
[ 7] 0.00-10.00   sec 13.4 GBytes 11.5 Gbits/sec    0
[ 7] 0.00-10.00   sec 13.4 GBytes 11.5 Gbits/sec
-----
iperf Done.
```

Рис. 13: Изменение номера порта для отправки/получения пакетов

```
*Node: h2*@mininet-vm
root@mininet-vm:/home/mininet# iperf3 -s -1
warning: this system does not seem to support IPv6 - trying IPv4
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 49968
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 49970
[ ID] Interval           Transfer         Bitrate
[ 7] 0.00-1.00 sec      1.24 GBytes    10.7 Gbits/sec
[ 7] 1.00-2.00 sec      1.32 GBytes    11.4 Gbits/sec
[ 7] 2.00-3.00 sec      1.02 GBytes     8.76 Gbits/sec
[ 7] 3.00-4.00 sec      1.17 GBytes     9.9 Gbits/sec
[ 7] 4.00-5.00 sec      1022 MBytes     8.57 Gbits/sec
[ 7] 5.00-6.00 sec       1.08 GBytes     9.31 Gbits/sec
[ 7] 6.00-7.00 sec       1.35 GBytes    11.6 Gbits/sec
[ 7] 7.00-8.00 sec       1.33 GBytes    11.4 Gbits/sec
[ 7] 8.00-9.00 sec       1.23 GBytes    10.5 Gbits/sec
[ 7] 9.00-10.00 sec      1.16 GBytes     9.95 Gbits/sec
[ 7] 10.00-10.00 sec      704 KBytes      4.67 Gbits/sec
-----
[ ID] Interval           Transfer         Bitrate
[ 7] 0.00-10.00 sec     11.9 GBytes    10.2 Gbits/sec
root@mininet-vm:/home/mininet#

*Node: h1*@mininet-vm
oot@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 49970 connected to 10.0.0.2 port 5201
[ ID] Interval           Transfer         Bitrate      Retr  Cwnd
[ 7] 0.00-1.00 sec      1.24 GBytes    10.7 Gbits/sec    0   489 KBytes
[ 7] 1.00-2.00 sec      1.32 GBytes    11.4 Gbits/sec    0   489 KBytes
[ 7] 2.00-3.00 sec      1.02 GBytes     8.76 Gbits/sec    0   759 KBytes
[ 7] 3.00-4.00 sec      1.17 GBytes     9.9 Gbits/sec    0   759 KBytes
[ 7] 4.00-5.00 sec      1022 MBytes     8.57 Gbits/sec    0   759 KBytes
[ 7] 5.00-6.00 sec       1.08 GBytes     9.32 Gbits/sec    0   969 KBytes
[ 7] 6.00-7.00 sec       1.35 GBytes    11.6 Gbits/sec    0   969 KBytes
[ 7] 7.00-8.00 sec       1.33 GBytes    11.4 Gbits/sec    0   969 KBytes
[ 7] 8.00-9.00 sec       1.23 GBytes    10.5 Gbits/sec    0   5.76 MBytes
[ 7] 9.00-10.00 sec      1.16 GBytes     9.95 Gbits/sec    0   8.10 MBytes
-----
[ ID] Interval           Transfer         Bitrate      Retr
[ 7] 0.00-10.00 sec     11.9 GBytes    10.2 Gbits/sec    0
[ 7] 0.00-10.00 sec     11.9 GBytes    10.2 Gbits/sec    0
sender
receiver

perf done.
oot@mininet-vm:/home/mininet#
```

Рис. 14: Параметр обработки данных только от одного клиента с остановкой сервера по завершении теста

```
"Node: h2"@mininet-vm
Server listening on 5201

Accepted connection from 10.0.0.1, port 49972
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 49974
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-1.00 sec   830 MBytes  6.96 Gbits/sec
[ 7] 1.00-2.00 sec   915 MBytes  7.67 Gbits/sec
[ 7] 2.00-3.00 sec   1.06 GBytes  9.14 Gbits/sec
[ 7] 3.00-4.00 sec   1.22 GBytes 10.5 Gbits/sec
[ 7] 4.00-5.00 sec   819 MBytes  6.87 Gbits/sec
[ 7] 5.00-6.00 sec  1007 MBytes  8.45 Gbits/sec
[ 7] 6.00-7.00 sec   1.45 GBytes 12.5 Gbits/sec
[ 7] 7.00-8.00 sec  1011 MBytes  8.48 Gbits/sec
[ 7] 8.00-9.00 sec   1.10 GBytes  9.47 Gbits/sec
[ 7] 9.00-10.00 sec  1017 MBytes  8.53 Gbits/sec
[ 7] 10.00-10.00 sec  1.12 MBytes  6.14 Gbits/sec
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-10.00 sec  10.3 GBytes  8.85 Gbits/sec

"Node: h1"@mininet-vm
{
  "retransmits": 0,
  "sender": true
},
{
  "sum_received": {
    "start": 0,
    "end": 10.001552,
    "seconds": 10.001552,
    "bytes": 11064579512,
    "bits_per_second": 8850290044.5850811,
    "sender": true
  },
  "cpu_utilization_percent": {
    "host_total": 50.877046153404173,
    "host_user": 0.75393130586528223,
    "host_system": 50.123094096386327,
    "remote_total": 18.708636149665531,
    "remote_user": 2.233903483233207,
    "remote_system": 16.474784963768403
  },
  "sender_tcp_congestion": "cubic",
  "receiver_tcp_congestion": "cubic"
}

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

Рис. 15: Экспорт результатов теста измерения пропускной способности iPerf3 в файл JSON

```
root@mininet-vm:/home/mininet# iperf3 -c 10.0.0.2 -J > /home/mininet/work/lab_iperf3/iperf_results.json
root@mininet-vm:/home/mininet# cd /home/mininet/work/lab_iperf3
root@mininet-vm:/home/mininet/work/lab_iperf3# ls -l
total 8
-rw-r--r-- 1 root root 7773 Nov 23 05:54 iperf_results.json
root@mininet-vm:/home/mininet/work/lab_iperf3#
```

Рис. 16: Проверка создания файла iperf\_results.json

```
mininet@mininet-vm:~$ xauth list $DISPLAY
mininet-vm/unix:10 MIT-MAGIC-COOKIE-1 ce76c2e08fe0edcefc5f47a66750ce46
mininet@mininet-vm:~$ sudo -i
root@mininet-vm:~# xauth list DISPLAY
xauth: (argv):1: bad display name "DISPLAY" in "list" command
root@mininet-vm:~# xauth list $DISPLAY
mininet-vm/unix:10 MIT-MAGIC-COOKIE-1 ce76c2e08fe0edcefc5f47a66750ce46
root@mininet-vm:~#
```

Рис. 17: Исправление прав запуска X-соединения

```
mininet@mininet-vm:~/work/lab_iperf3$ plot_iperf.sh iperf_results.json
mininet@mininet-vm:~/work/lab_iperf3$ ls -l

Command 'ls' not found, did you mean:

  command 'ils' from deb sleuthkit (4.6.7-1build1)
  command 'hls' from deb hfsutils (3.2.6-14)
  command 'ls' from deb coreutils (8.30-3ubuntu2)
  command 'bls' from deb bacula-sd (9.4.2-2ubuntu5)
  command 'fls' from deb sleuthkit (4.6.7-1build1)
  command 'jls' from deb sleuthkit (4.6.7-1build1)
  command 'ols' from deb speech-tools (1:2.5.0-8build1)
  command 'als' from deb atool (0.39.0-10)

Try: sudo apt install <deb name>

mininet@mininet-vm:~/work/lab_iperf3$ ls -l
total 16
-rw-rw-r-- 1 mininet mininet  940 Nov 23 06:01 iperf.csv
-rw-r--r-- 1 mininet mininet 7773 Nov 23 05:54 iperf_results.json
drwxrwxr-x 2 mininet mininet 4096 Nov 23 06:01 results
mininet@mininet-vm:~/work/lab_iperf3$ cd ~/work/lab_iperf3/results
mininet@mininet-vm:~/work/lab_iperf3/results$ ls -l
total 88
-rw-rw-r-- 1 mininet mininet  486 Nov 23 06:01 1.dat
-rw-rw-r-- 1 mininet mininet 9889 Nov 23 06:01 bytes.pdf
-rw-rw-r-- 1 mininet mininet 9580 Nov 23 06:01 cwnd.pdf
-rw-rw-r-- 1 mininet mininet 9036 Nov 23 06:01 MTU.pdf
-rw-rw-r-- 1 mininet mininet 8978 Nov 23 06:01 retransmits.pdf
-rw-rw-r-- 1 mininet mininet 8960 Nov 23 06:01 RTT.pdf
-rw-rw-r-- 1 mininet mininet 9165 Nov 23 06:01 RTT_Var.pdf
-rw-rw-r-- 1 mininet mininet 9587 Nov 23 06:01 throughput.pdf
mininet@mininet-vm:~/work/lab_iperf3/results$
```

Рис. 18: Визуализация результатов эксперимента



В результате выполнения данной лабораторной работы я познакомилась с инструментом для измерения пропускной способности сети в режиме реального времени — iPerf3, а также получила навыки проведения интерактивного эксперимента по измерению пропускной способности моделируемой сети в среде Mininet.

1. Mininet [Электронный ресурс]. Mininet Project Contributors. URL: <http://mininet.org/> (дата обращения: 17.11.2024).
2. IPerff [Электронный ресурс]. URL: <https://iperf.fr/>.