

Презентация по лабораторной работе №2

Моделирование сетей передачи данных

Еюбоглу Тимур

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Российский университет дружбы народов, Москва, Россия

- Еюбоглу Тимур
- Студент группы НПИбд-01-22
- Студ. билет 1032224357
- Российский университет дружбы народов имени Патриса Лумумбы

- Познакомиться с инструментом для измерения пропускной способности сети в режиме реального времени — iPerf3, а также получить навыки проведения интерактивного эксперимента по измерению пропускной способности моделируемой сети в среде Mininet.

Выполнение лабораторной работы

Установка необходимого программного обеспечения

```
mininet@mininet-vn:~$ sudo apt-get install iperf3
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following additional packages will be installed:
  libiperf0 libsctp1
Suggested packages:
  lksctp-tools
The following NEW packages will be installed:
  iperf3 libiperf0 libsctp1
0 upgraded, 3 newly installed, 0 to remove and 395 not upgraded.
Need to get 94.1 kB of archives.
After this operation, 331 kB of additional disk space will be used.
Do you want to continue? [Y/n] Y
Get:1 http://us.archive.ubuntu.com/ubuntu focal/main amd64 libsctp1 amd64 1.0.18+dfsg-1 [7,876 B]
Get:2 http://us.archive.ubuntu.com/ubuntu focal/universe amd64 libiperf0 amd64 3.7-3 [72.0 kB]
Get:3 http://us.archive.ubuntu.com/ubuntu focal/universe amd64 iperf3 amd64 3.7-3 [14.2 kB]
Fetched 94.1 kB in 1s (159 kB/s)
Selecting previously unselected package libsctp1:amd64.
(Reading database ... 102329 files and directories currently installed.)
Preparing to unpack .../libsctp1_1.0.18+dfsg-1_amd64.deb ...
Unpacking libsctp1:amd64 (1.0.18+dfsg-1) ...
Selecting previously unselected package libiperf0:amd64.
Preparing to unpack .../libiperf0_3.7-3_amd64.deb ...
Unpacking libiperf0:amd64 (3.7-3) ...
Selecting previously unselected package iperf3.
Preparing to unpack .../iperf3_3.7-3_amd64.deb ...
Unpacking iperf3 (3.7-3) ...
```

Рис. 1: Обновление репозитория программного обеспечения

```
mininet@mininet-vm:~$ sudo apt-get install iperf3
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following additional packages will be installed:
  libiperf0 libsctp1
Suggested packages:
  lksctp-tools
The following NEW packages will be installed:
  iperf3 libiperf0 libsctp1
0 upgraded, 3 newly installed, 0 to remove and 395 not upgraded.
Need to get 94.1 kB of archives.
After this operation, 331 kB of additional disk space will be used.
```

Установка необходимого программного обеспечения

```
mininet@mininet-vm:~$ sudo apt-get install git jq gnuplot-nox evince
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following additional packages will be installed:
  aglfn aspell aspell-en bubblewrap enchant-2 evince-common fonts-liberation gnome-desktop3-data
  gnuplot-data groff hunspell-en-us imagemagick imagemagick-6.q16 libarchive13 libaspell15
  libdjvulibre-text libdjvulibre21 libenchant-2-2 libevdocument3-4 libevview3-3
  libgnome-desktop-3-19 libgspell-1-2 libgspell-1-common libgxps2 libhunspell-1.7-0 libilmbase24
  libjq1 libkpathsea6 liblua5.3-0 libmagickcore-6.q16-6-extra libnautilus-extension1a libnetpbm10
  libnspr4 libnss3 libonig5 libopenexr24 libpoppler-glib8 libpoppler97 libsecret-1-0
  libsecret-common libspectre1 libsyntax2 libumf0.2-7 netpbm psutils
Suggested packages:
  aspell-doc spellutils gvfs nautilus-sendto unrar git-daemon-run | git-daemon-sysvinit git-doc
  git-el git-email git-gui gitweb git-cvs git-mediawiki git-svn gnuplot-doc hunspell
  openoffice.org-hunspell | openoffice.org-core imagemagick-doc autotrace cups-bsd | lpr | lprng
  curl enscript ffmpeg gimp grads graphviz hp2xx htm2ps libumf-bin nplayer povray radiance
  sane-utils texlive-base-bin transfig ufrau-batch xdg-utils lrzip libenchant-2-voikko inkscape
  libjxr-tools libumf0.2-7-gtk
The following NEW packages will be installed:
  aglfn aspell aspell-en bubblewrap enchant-2 evince evince-common fonts-liberation
  gnome-desktop3-data gnuplot-data gnuplot-nox groff hunspell-en-us imagemagick imagemagick-6.q16
  jq libarchive13 libaspell15 libdjvulibre-text libdjvulibre21 libenchant-2-2 libevdocument3-4
  libevview3-3 libgnome-desktop-3-19 libgspell-1-2 libgspell-1-common libgxps2 libhunspell-1.7-0
  libilmbase24 libjq1 libkpathsea6 liblua5.3-0 libmagickcore-6.q16-6-extra libnautilus-extension1a
  libnetpbm10 libnspr4 libnss3 libonig5 libopenexr24 libpoppler-glib8 libpoppler97 libsecret-1-0
  libsecret-common libspectre1 libsyntax2 libumf0.2-7 netpbm psutils
The following packages will be upgraded:
  git
```

Рис. 3: Установка необходимого дополнительного программного обеспечения на виртуальную машину

```
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 | 1.04 MiB/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$
```



```
mininet@mininet-vm:/tmp/iperf3_plotter$ xauth list $DISPLAY
mininet-vm/unix:12 MIT-MAGIC-COOKIE-1 6a2c7f8e8b69ea601b845ba4952f5d02
mininet@mininet-vm:/tmp/iperf3_plotter$ sudo -i
root@mininet-vm:~# xauth add mininet-vm/unix:12 MIT-MAGIC-COOKIE-1 6a2c7f8e8b6
9ea601b845ba4952f5d02
root@mininet-vm:~# xauth list $DISPLAY
mininet-vm/unix:12 MIT-MAGIC-COOKIE-1 6a2c7f8e8b69ea601b845ba4952f5d02
```

Интерактивные эксперименты

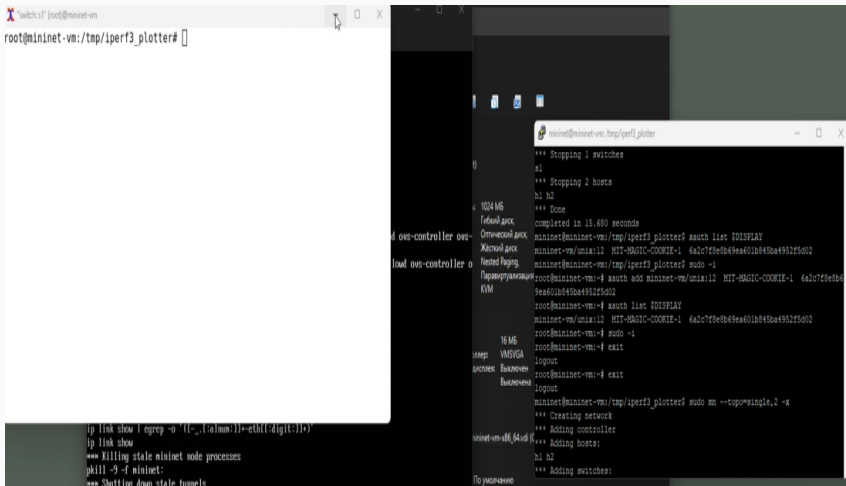


Рис. 6: Создание простейшей топологии, состоящей из двух хостов и коммутатора

```
*** Configuring hosts
h1 h2
*** Running terms on localhost:12.0
*** Starting controller
c0
*** Starting 1 switches
s1 ...
*** Starting CLI:
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=15833>
<Host h2: h2-eth0:10.0.0.2 pid=15835>
<OVSSwitch s1: lo:127.0.0.1,s1-eth1:None,s1-eth2:None pid=15840>
<Controller c0: 127.0.0.1:6653 pid=15826>
mininet> █
```

Рис. 7: Просмотр параметров топологии



host h2@mininet-vm

```
root@mininet-vm:/tmp/iperf3_plotter# iperf3 -s
```

```
warning: this system does not seem to support IPv6 - trying IPv4
```

```
.....
```

```
Server listening on 5201
```

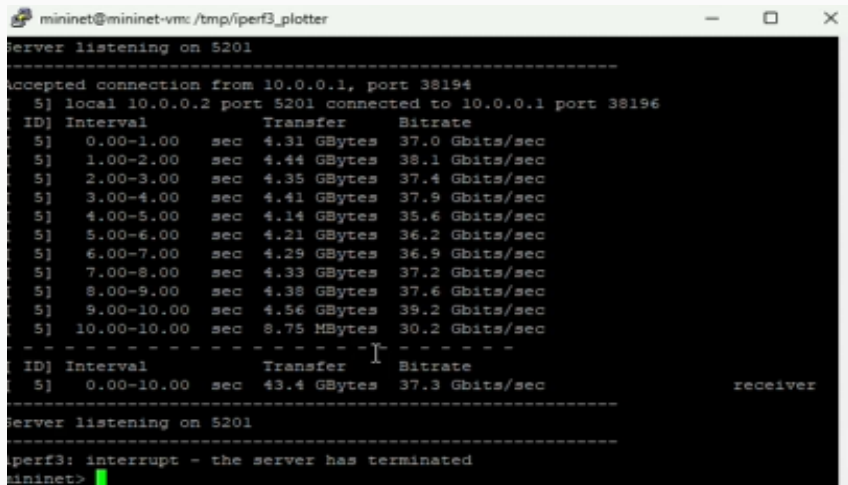
```
root@mininet-vm:/tmp/iperf3_plotter# iperf3 -c 10.0.0.2
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 38192 connected to 10.0.0.2 port 5201
[ ID] Interval           Transfer     Bitrate      Retr    Cwnd
[ 7]  0.00-1.00    sec  4.29 GBytes  36.9 Gbits/sec    0   8.35 MBytes
[ 7]  1.00-2.00    sec  4.17 GBytes  35.8 Gbits/sec    0   8.35 MBytes
[ 7]  2.00-3.00    sec  4.22 GBytes  36.3 Gbits/sec    0   8.35 MBytes
[ 7]  3.00-4.00    sec  4.11 GBytes  35.4 Gbits/sec    0   8.35 MBytes
[ 7]  4.00-5.00    sec  4.36 GBytes  37.4 Gbits/sec    0   8.35 MBytes
[ 7]  5.00-6.00    sec  4.25 GBytes  36.5 Gbits/sec    0   8.35 MBytes
[ 7]  6.00-7.00    sec  4.35 GBytes  37.5 Gbits/sec    0   8.35 MBytes
[ 7]  7.00-8.00    sec  4.57 GBytes  39.2 Gbits/sec    0   8.35 MBytes
[ 7]  8.00-9.00    sec  4.31 GBytes  37.1 Gbits/sec    0   8.35 MBytes
[ 7]  9.00-10.00   sec  4.47 GBytes  38.4 Gbits/sec    0   8.35 MBytes
- - - - -
[ ID] Interval           Transfer     Bitrate      Retr
[ 7]  0.00-10.00   sec  43.1 GBytes  37.0 Gbits/sec    0
[ 7]  0.00-10.00   sec  43.1 GBytes  37.0 Gbits/sec    0
sender
receiver

iperf Done.
root@mininet-vm:/tmp/iperf3_plotter#
```

Рис. 9: Запуск клиента iperf3 в терминале хоста h1

```
host: h2@mininet-vm
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 38190
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 38192
[ ID] Interval          Transfer    Bitrate
[ 7]  0.00-1.00      sec  4.29 GBytes 36.9 Gbits/sec
[ 7]  1.00-2.00      sec  4.17 GBytes 35.8 Gbits/sec
[ 7]  2.00-3.00      sec  4.22 GBytes 36.2 Gbits/sec
[ 7]  3.00-4.00      sec  4.12 GBytes 35.3 Gbits/sec
[ 7]  4.00-5.00      sec  4.36 GBytes 37.4 Gbits/sec
[ 7]  5.00-6.00      sec  4.25 GBytes 36.5 Gbits/sec
[ 7]  6.00-7.00      sec  4.36 GBytes 37.5 Gbits/sec
[ 7]  7.00-8.00      sec  4.56 GBytes 39.2 Gbits/sec
[ 7]  8.00-9.00      sec  4.32 GBytes 37.1 Gbits/sec
[ 7]  9.00-10.00     sec  4.47 GBytes 38.4 Gbits/sec
[ 7] 10.00-10.00     sec  1.75 MBytes 12.2 Gbits/sec
-----
[ ID] Interval          Transfer    Bitrate
[ 7]  0.00-10.00     sec  43.1 GBytes 37.0 Gbits/sec
-----
Server listening on 5201
-----
^Ciperf3: interrupt - the server has terminated
root@mininet-vm:/tmp/iperf3 plotter#
```

Рис. 10: Остановка сервера iPerf3 в терминале хоста h2



```
mininet@mininet-vm: /tmp/iperf3_plotter
server listening on 5201
-----
accepted connection from 10.0.0.1, port 38194
  S] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 38196
  ID] Interval          Transfer    Bitrate
  S]  0.00-1.00      sec  4.31 GBytes  37.0 Gbits/sec
  S]  1.00-2.00      sec  4.44 GBytes  38.1 Gbits/sec
  S]  2.00-3.00      sec  4.35 GBytes  37.4 Gbits/sec
  S]  3.00-4.00      sec  4.41 GBytes  37.9 Gbits/sec
  S]  4.00-5.00      sec  4.14 GBytes  35.6 Gbits/sec
  S]  5.00-6.00      sec  4.21 GBytes  36.2 Gbits/sec
  S]  6.00-7.00      sec  4.29 GBytes  36.9 Gbits/sec
  S]  7.00-8.00      sec  4.33 GBytes  37.2 Gbits/sec
  S]  8.00-9.00      sec  4.38 GBytes  37.6 Gbits/sec
  S]  9.00-10.00     sec  4.56 GBytes  39.2 Gbits/sec
  S] 10.00-10.00     sec  8.75 MBytes  30.2 Gbits/sec
-----
  ID] Interval          Transfer    Bitrate
  S]  0.00-10.00     sec  43.4 GBytes  37.3 Gbits/sec
-----
server listening on 5201
-----
iperf3: interrupt - the server has terminated
mininet>
```

Рис. 11: Запуск сервера iperf3 на хосте h2, запуск клиента iperf3 на хосте h1, остановка серверного процесса

```
root@mininet-vm:/tmp/iperf3_plotter# iperf3 -s  
warning: this system does not seem to support IPv6 - trying IPv4  
  
.....  
  
Server listening on 5201  
  
.....
```



```
root@mininet-vm:/tmp/iperf3_plotter# iperf3 -c 10.0.0.2 -t 5
```

```
Connecting to host 10.0.0.2, port 5201
```

```
[ 7] local 10.0.0.1 port 38204 connected to 10.0.0.2 port 5201
```

[ID]	Interval	Transfer	Bitrate	Retr	Cwnd
-------	----------	----------	---------	------	------

[7]	0.00-1.00 sec	4.56 GBytes	39.2 Gbits/sec	9	4.18 MBytes
------	---------------	-------------	----------------	---	-------------

[7]	1.00-2.00 sec	3.65 GBytes	31.3 Gbits/sec	0	4.18 MBytes
------	---------------	-------------	----------------	---	-------------

[7]	0.00-2.00 sec	8.21 GBytes	35.3 Gbits/sec	9	4.18 MBytes
------	---------------	-------------	----------------	---	-------------

```
root@mininet-vm:/tmp/iperf3_plotter# iperf3 -s -i 2  
warning: this system does not seem to support IPv6 - trying IPv4  
  
.....  
  
Server listening on 5201
```

```
et-vm:/tmp/iperf3_plotter# iperf3 -c 10.0.0.2 -i 2  
to host 10.0.0.2, port 5201  
10.0.0.1 port 38208 connected to 10.0.0.2 port 5201  
Interval      Transfer      Bitrate      Retr  Cwnd  
0.00-2.00    sec  8.99 GBytes  38.6 Gbits/sec    0   8.00 MBytes  
0.00-4.00    sec  8.78 GBytes  37.7 Gbits/sec    0   8.00 MBytes  
0.00-6.00    sec  8.94 GBytes  38.4 Gbits/sec    0   8.00 MBytes  
Error - unable to write to stream socket: Connection reset by peer  
10.0.0.1:38208->10.0.0.2:5201: #
```

```
root@mininet-vm:/tmp/iperf3_plotter# iperf3 -s
```

```
warning: this system does not seem to support IPv6 - trying IPv4
```

```
.....I.....
```

```
Server listening on 5201
```

```
.....
```

```
root@mininet-vm:/tmp/iperf3_plotter# iperf3 -c 10.0.0.2 -n 16G
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 38212 connected to 10.0.0.2 port 5201
[ ID] Interval           Transfer     Bitrate      Retr  Cwnd
[ 7]  0.00-1.00   sec  4.27 GBytes  36.7 Gbits/sec    0   8.25 MBytes
[ 7]  1.00-2.00   sec  4.41 GBytes  37.8 Gbits/sec    0   8.25 MBytes
[ 7]  2.00-3.00   sec  4.39 GBytes  37.8 Gbits/sec    0   8.25 MBytes
[ 7]  3.00-3.67   sec  2.93 GBytes  37.8 Gbits/sec    0   8.25 MBytes
.....
[ ID] Interval           Transfer     Bitrate      Retr
[ 7]  0.00-3.67   sec  16.0 GBytes  37.5 Gbits/sec    0
[ 7]  0.00-3.67   sec  16.0 GBytes  37.5 Gbits/sec    0
sender
receiver
```

Рис. 17: Запуск клиента iperf3 в терминале h1 с объёмом данных 16 Гбайт

```
root@mininet-vm:/tmp/iperf3_plotter# iperf3 -s  
warning: this system does not seem to support IPv6 - trying IPv4  
.....  
Server listening on 5201  
.....
```

```
*host: h1@mininet-vm
root@mininet-vm:/tmp/iperf3_plotter# iperf3 -c 10.0.0.2 -u
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 55437 connected to 10.0.0.2 port 5201
[ ID] Interval          Transfer    Bitrate    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      127 KBytes  1.04 Mbits/sec  90
[ 7] 6.00-7.00 sec      129 KBytes  1.05 Mbits/sec  91
[ 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
```

Рис. 19: Запуск клиента iperf3 в терминале h1 с протоколом UDP

```
root@mininet-vm:/tmp/iperf3_plotter# iperf3 -s -p 3250
```

```
warning: this system does not seem to support IPv6 - trying IPv4
```

```
.....
```

```
Server listening on 3250
```

```
.....
```



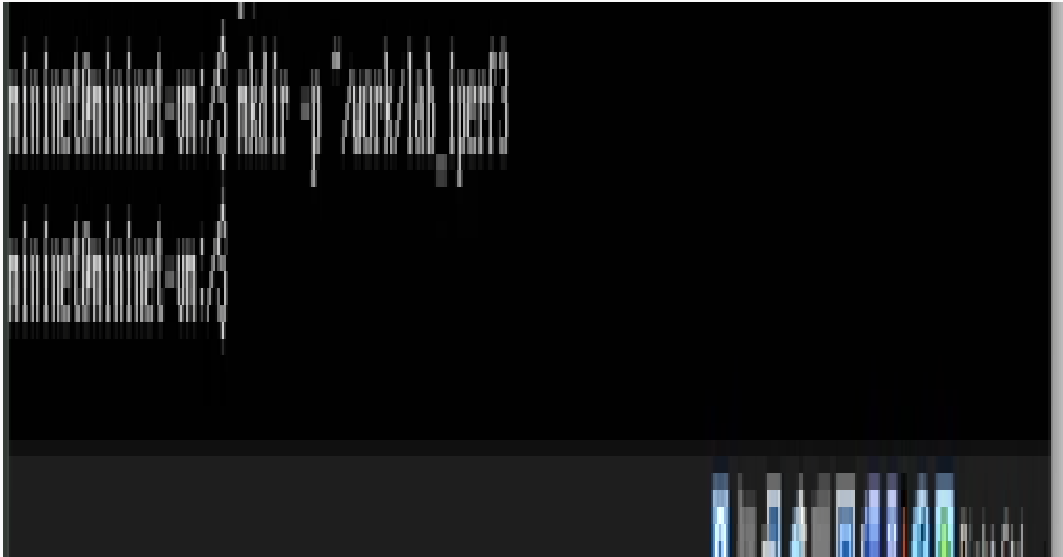

```
*host: h1*@mininet-vm
root@mininet-vm:/tmp/iperf3_plotter# iperf3 -c 10.0.0.2 -p 3250
Connecting to host 10.0.0.2, port 3250
[ 7] local 10.0.0.1 port 54342 connected to 10.0.0.2 port 3250
[ ID] Interval           Transfer     Bitrate      Retr  Cwnd
[ 7]  0.00-1.00   sec  4.27 GBytes  36.5 Gbits/sec    0   8.04 MBytes
[ 7]  1.00-2.00   sec  4.45 GBytes  38.3 Gbits/sec    0   8.04 MBytes
[ 7]  2.00-3.00   sec  4.44 GBytes  38.2 Gbits/sec    0   8.04 MBytes
[ 7]  3.00-4.00   sec  4.49 GBytes  38.6 Gbits/sec    0   8.04 MBytes
[ 7]  4.00-5.00   sec  4.39 GBytes  37.7 Gbits/sec    0   8.04 MBytes
[ 7]  5.00-6.00   sec  4.38 GBytes  37.7 Gbits/sec    0   8.04 MBytes
[ 7]  6.00-7.00   sec  4.35 GBytes  37.3 Gbits/sec    0   8.04 MBytes
[ 7]  7.00-8.00   sec  4.44 GBytes  38.2 Gbits/sec    0   8.04 MBytes
[ 7]  8.00-9.00   sec  4.53 GBytes  38.9 Gbits/sec    0   8.04 MBytes
[ 7]  9.00-10.00  sec  4.51 GBytes  38.7 Gbits/sec    0   8.04 MBytes
```

Рис. 21: Запуск клиента iperf3 в терминале h1 с портом

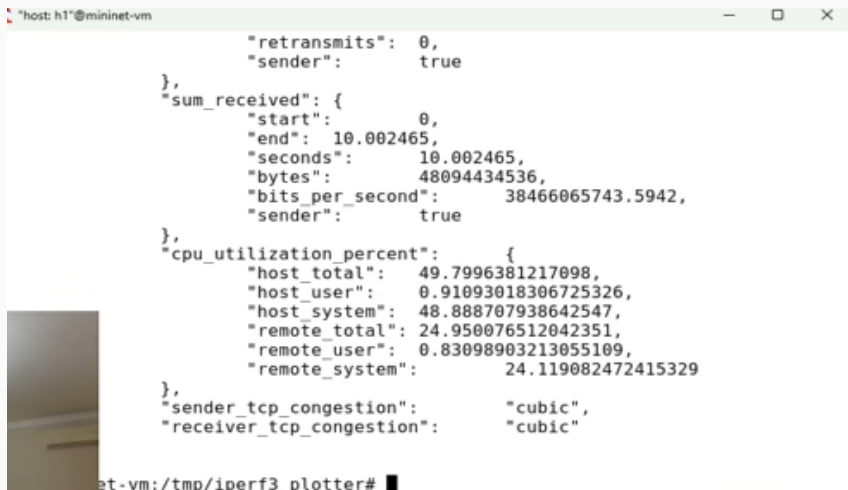
```
root@mininet-vm:/tmp/iperf3_plotter# iperf3 -s -1  
warning: this system does not seem to support IPv6 - trying IPv4  
  
.....  
  
Server listening on 5201  
  
.....
```

```
iperf Done.  
root@mininet-vm:/tmp/iperf3_plotter# iperf3 -c 10.0.0.2  
Connecting to host 10.0.0.2, port 5201  
[ 7] local 10.0.0.1 port 38222 connected to 10.0.0.2 port 5201  
[ ID] Interval           Transfer     Bitrate        Retr   Cwnd  
[  0] 00-1.00      sec  5.12 GBytes  44.0 Gbits/sec    9   4.18 MBytes  
[  1] 00-2.00      sec  4.36 GBytes  37.4 Gbits/sec    0   4.18 MBytes  
[  2] 00-3.00      sec  4.29 GBytes  36.9 Gbits/sec    0   4.18 MBytes  
[  3] 00-4.00      sec  4.33 GBytes  37.2 Gbits/sec    0   4.18 MBytes  
[  4] 00-5.00      sec  4.44 GBytes  38.2 Gbits/sec    0   4.18 MBytes  
[  5] 00-6.00      sec  4.32 GBytes  37.1 Gbits/sec    0   4.18 MBytes  
[  6] 00-7.00      sec  4.40 GBytes  37.8 Gbits/sec    0   4.18 MBytes  
[  7] 00-8.00      sec  4.25 GBytes  36.5 Gbits/sec    0   4.18 MBytes
```

Рис. 23: Запуск клиента iperf3 в терминале h1



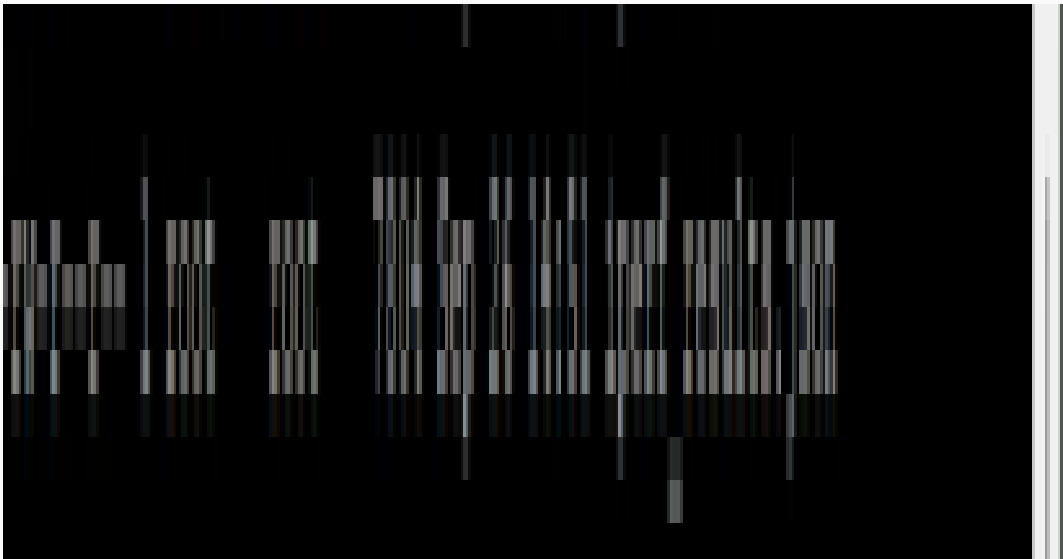
```
root@mininet-vm:/tmp/iperf3_plotter# iperf3 -s  
warning: this system does not seem to support IPv6 - trying IPv4  
  
.....  
  
Server listening on 5201  
  
.....
```



```
host: h1@mininet-vm
{
  "retransmits": 0,
  "sender": true
},
"sum_received": {
  "start": 0,
  "end": 10.002465,
  "seconds": 10.002465,
  "bytes": 48094434536,
  "bits_per_second": 38466065743.5942,
  "sender": true
},
"cpu_utilization_percent": {
  "host_total": 49.7996381217098,
  "host_user": 0.91093018306725326,
  "host_system": 48.888707938642547,
  "remote_total": 24.950076512042351,
  "remote_user": 0.83098903213055109,
  "remote_system": 24.119082472415329
},
"sender_tcp_congestion": "cubic",
"receiver_tcp_congestion": "cubic"
}
et-vm:/tmp/iperf3 plotter#
```

Рис. 26: Запуск клиента iperf3 в терминале h1 с параметром -J (отображение вывода в формате JSON)






```
mininet> exit
*** Stopping 1 controllers
c0
*** Stopping 8 terms
*** Stopping 2 links
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
```

```
mininet@mininet-vm:~/work/lab_iperf3$ sudo chown -R mininet:mininet ~/work
mininet@mininet-vm:~/work/lab_iperf3$ ls -l
total 16
-rw-rw-r-- 1 mininet mininet    1 Sep 26 14:47 iperf.csv
-rw-r--r-- 1 mininet mininet 7804 Sep 26 14:51 iperf_results.json
drwxrwxr-x 2 mininet mininet 4096 Sep 26 14:47 results
```

```
mininet@mininet-vm:~/work/lab_iperf3$ ls -l results/
total 88
-rw-rw-r-- 1 mininet mininet 487 Sep 26 15:01 1.dat
-rw-rw-r-- 1 mininet mininet 9874 Sep 26 15:01 bytes.pdf
-rw-rw-r-- 1 mininet mininet 9616 Sep 26 15:01 cwnd.pdf
-rw-rw-r-- 1 mininet mininet 9036 Sep 26 15:01 MTU.pdf
-rw-rw-r-- 1 mininet mininet 8978 Sep 26 15:01 retransmits.pdf
-rw-rw-r-- 1 mininet mininet 9047 Sep 26 15:01 RTT.pdf
-rw-rw-r-- 1 mininet mininet 9135 Sep 26 15:01 RTT_Var.pdf
-rw-rw-r-- 1 mininet mininet 9568 Sep 26 15:01 throughput.pdf
mininet@mininet-vm:~/work/lab_iperf3$
```

Рис. 31: Генерация выходных данных и последующая проверка

Вывод

- В ходе выполнения лабораторной работы познакомились с инструментом для измерения пропускной способности сети в режиме реального времени — iPerf3, а также получили навыки проведения интерактивного эксперимента по измерению пропускной способности моделируемой сети в среде Mininet.

Список литературы. Библиография

[1] Mininet: <https://mininet.org/>