

Отчёт по лабораторной работе №2

**Измерение и тестирование пропускной способности сети.
Интерактивный эксперимент**

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1 Цель работы

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.

2 Выполнение лабораторной работы

2.1 Установка необходимого программного обеспечения

1. Запустите виртуальную среду с mininet.
2. Из основной ОС подключитесь к виртуальной машине, после подключения к виртуальной машине mininet посмотрите IP-адреса машины:

```
mininet@mininet-vm:~$ ifconfig
eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.56.104 netmask 255.255.255.0 broadcast 192.168.56.255
    ether 08:00:27:fd:d6:ca txqueuelen 1000 (Ethernet)
    RX packets 82 bytes 13191 (13.1 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 76 bytes 12506 (12.5 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 10.0.2.15 netmask 255.255.255.0 broadcast 10.0.2.255
    ether 08:00:27:86:d6:24 txqueuelen 1000 (Ethernet)
    RX packets 295 bytes 38439 (38.4 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 293 bytes 27144 (27.1 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 Loopback)
    RX packets 31 bytes 3154 (3.1 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 31 bytes 3154 (3.1 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

Рис. 2.1: Посмотрите IP-адреса машины

3. Обновите репозитории программного обеспечения на виртуальной машине:

```

mininet@mininet-wm1:~$ sudo apt-get update
Get:1 http://security.ubuntu.com/ubuntu focal-security InRelease [114 kB]
Hit:2 http://us.archive.ubuntu.com/ubuntu focal InRelease
Get:3 http://us.archive.ubuntu.com/ubuntu focal-updates InRelease [114 kB]
Get:4 http://us.archive.ubuntu.com/ubuntu focal-backports InRelease [109 kB]
Get:5 http://security.ubuntu.com/ubuntu focal-security/main amd64 Packages [2,590 kB]
Get:6 http://us.archive.ubuntu.com/ubuntu focal-updates/main amd64 Packages [2,960 kB]
Get:7 http://security.ubuntu.com/ubuntu focal-security/main i386 Packages [679 kB]
Get:8 http://security.ubuntu.com/ubuntu focal-security/main Translation-en [401 kB]
Get:9 http://security.ubuntu.com/ubuntu focal-security/main amd64 c-n-f Metadata [12.2 kB]
Get:10 http://security.ubuntu.com/ubuntu focal-security/restricted i386 Packages [34.7 kB]
Get:11 http://security.ubuntu.com/ubuntu focal-security/restricted amd64 Packages [2,399 kB]
Get:12 http://security.ubuntu.com/ubuntu focal-security/restricted Translation-en [335 kB]
Get:13 http://us.archive.ubuntu.com/ubuntu focal-updates/main i386 Packages [911 kB]
Get:14 http://security.ubuntu.com/ubuntu focal-security/restricted amd64 c-n-f Metadata [552 B]
Get:15 http://security.ubuntu.com/ubuntu focal-security/universe amd64 Packages [901 kB]
Get:16 http://security.ubuntu.com/ubuntu focal-security/universe i386 Packages [623 kB]
Get:17 http://us.archive.ubuntu.com/ubuntu focal-updates/main Translation-en [484 kB]
Get:18 http://security.ubuntu.com/ubuntu focal-security/universe Translation-en [189 kB]
Get:19 http://security.ubuntu.com/ubuntu focal-security/universe amd64 c-n-f Metadata [19.2 kB]
Get:20 http://security.ubuntu.com/ubuntu focal-security/multiverse i386 Packages [7,188 B]
Get:21 http://security.ubuntu.com/ubuntu focal-security/multiverse amd64 Packages [23.6 kB]
Get:22 http://security.ubuntu.com/ubuntu focal-security/multiverse Translation-en [5,504 B]
Get:23 http://security.ubuntu.com/ubuntu focal-security/multiverse amd64 c-n-f Metadata [548 B]
Get:24 http://us.archive.ubuntu.com/ubuntu focal-updates/main amd64 c-n-f Metadata [17.2 kB]
Get:25 http://us.archive.ubuntu.com/ubuntu focal-updates/restricted amd64 Packages [2,511 kB]

```

Рис. 2.2: Обновление программного обеспечения на виртуальной машине

4. Установите iperf3:

```

mininet@mininet-wm1:~$ sudo apt-get install iperf3
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following additional packages will be installed:
  libiperf0 libiscpl
Suggested packages:
  lksctp-tools
The following NEW packages will be installed:
  iperf3 libiperf0 libiscpl
0 upgraded, 3 newly installed, 0 to remove and 378 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 libiscpl 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 (97.7 kB/s)
Selecting previously unselected package libiscpl:amd64.
(Reading database ... 102146 files and directories currently installed.)
Preparing to unpack .../libiscpl_1.0.18+dfsg-1_amd64.deb ...
Unpacking libiscpl: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 ...

```

Рис. 2.3: Установка iperf3

5. Установите необходимое дополнительное программное обеспечение на виртуальную машину:

```

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 libgspa2 libhunspell-1.7-0
  libilmbase24 libjgl libkpathsea6 liblua5.3-0 libmagickcore-6.q16-6-extra libnautilus-extensions1 libnetpbm10 libnspr4
  libnss3 libonig5 libopenexr24 libpoppler-glib8 libpoppler97 libsecret-1-0 libsecret-common libspectre1 libsynctex2
  libwmf0.2-7 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 html2ps libwmf-bin mplayer povray
  radiance sane-utils texlive-base-bin transfig ufrax-batch xdg-utils lrzip libenchant-2-voikko inkscape libjxr-tools
  libwmf0.2-7-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
  libgspa2 libhunspell-1.7-0 libilmbase24 libjgl libkpathsea6 liblua5.3-0 libmagickcore-6.q16-6-extra
  libnautilus-extensions1 libnetpbm10 libnspr4 libnss3 libonig5 libopenexr24 libpoppler-glib8 libpoppler97 libsecret-1-0
  libsecret-common libspectre1 libsynctex2 libwmf0.2-7 netpbm psutils
The following packages will be upgraded:
  git
1 upgraded, 48 newly installed, 0 to remove and 377 not upgraded.
Need to get 18.8 MB of archives.
After this operation, 51.3 MB of additional disk space will be used.
Do you want to continue? [Y/n] Y

```

Рис. 2.4: Установка дополнительное программное обеспечение

6. Разверните iperf3_plotter. Для этого:

- перейдите во временный каталог и скачайте репозиторий
- установите iperf3_plotter

```

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
Unpacking objects: 100% (74/74), 100.09 KiB | 648.00 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

```

Рис. 2.5: Разверните iperf3_plotter

2.2 Интерактивные эксперименты

1. Задайте простейшую топологию, состоящую из двух хостов и коммутатора с назначенной по умолчанию mininet сетью 10.0.0.0/8, и посмотрите параметры запущенной в интерактивном режиме топологии:

```

mininet@mininet-vm:~$ sudo mn --topo=single,2 -x
*** 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> 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=1469>
<Host h2: h2-eth0:10.0.0.2 pid=1471>
<OVSSwitch s1: lo:127.0.0.1,s1-eth1:None,s1-eth2:None pid=1476>
<Controller c0: 127.0.0.1:6653 pid=1462>

```

Рис. 2.6: Задайте топологию

2. Проведите простейший интерактивный эксперимент по измерению пропускной способности с помощью iPerf3:


```
host h2@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 60866
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 60866
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-1.00 sec  2.06 GBytes  17.7 Gbits/sec
[ 7] 1.00-2.00 sec  2.06 GBytes  17.7 Gbits/sec
[ 7] 2.00-3.00 sec  1.52 GBytes  13.0 Gbits/sec
[ 7] 3.00-4.00 sec  2.10 GBytes  18.0 Gbits/sec
[ 7] 4.00-5.00 sec  2.10 GBytes  18.1 Gbits/sec
[ 7] 5.00-6.00 sec  2.07 GBytes  17.8 Gbits/sec
[ 7] 6.00-7.00 sec  2.08 GBytes  17.9 Gbits/sec
[ 7] 7.00-8.00 sec  2.09 GBytes  18.0 Gbits/sec
[ 7] 8.00-9.00 sec  2.07 GBytes  17.7 Gbits/sec
[ 7] 9.00-10.00 sec 2.11 GBytes  18.1 Gbits/sec
-----
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-10.00 sec 20.3 GBytes  17.4 Gbits/sec
-----
Server listening on 5201

host 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 60866 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer      Bitrate      Retr  Cwnd
[ 7] 0.00-1.00 sec  2.09 GBytes  17.9 Gbits/sec  21    4.08 MBytes
[ 7] 1.00-2.00 sec  2.06 GBytes  17.7 Gbits/sec  13    4.08 MBytes
[ 7] 2.00-3.00 sec  1.52 GBytes  13.0 Gbits/sec  7     4.08 MBytes
[ 7] 3.00-4.00 sec  2.10 GBytes  18.0 Gbits/sec  11    4.08 MBytes
[ 7] 4.00-5.00 sec  2.10 GBytes  18.1 Gbits/sec  9     4.08 MBytes
[ 7] 5.00-6.00 sec  2.07 GBytes  17.8 Gbits/sec  14    4.08 MBytes
[ 7] 6.00-7.00 sec  2.08 GBytes  17.9 Gbits/sec  11    4.08 MBytes
[ 7] 7.00-8.00 sec  2.09 GBytes  18.0 Gbits/sec  12    4.08 MBytes
[ 7] 8.00-9.00 sec  2.07 GBytes  17.8 Gbits/sec  7     4.08 MBytes
[ 7] 9.00-10.00 sec 2.11 GBytes  18.1 Gbits/sec  14    4.08 MBytes
-----
[ ID] Interval      Transfer      Bitrate      Retr  sender receiver
[ 7] 0.00-10.00 sec 20.3 GBytes  17.4 Gbits/sec  119
[ 7] 0.00-10.00 sec 20.3 GBytes  17.4 Gbits/sec
iperf Done.
root@mininet-vm:/home/mininet#
```

Рис. 2.7: Проведите простейший интерактивный эксперимент

3. Проведите аналогичный эксперимент в интерфейсе mininet.


```

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 60874
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 60876
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-1.00 sec  2.04 GBytes  17.5 Gbits/sec
[ 7] 1.00-2.00 sec  1.96 GBytes  16.8 Gbits/sec
[ 7] 2.00-3.00 sec  1.99 GBytes  16.3 Gbits/sec
[ 7] 3.00-4.00 sec  2.02 GBytes  17.4 Gbits/sec
[ 7] 4.00-5.00 sec  2.13 GBytes  18.3 Gbits/sec
[ 7] 5.00-5.02 sec  9.62 MBytes  4.19 Gbits/sec
-----
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-5.02 sec  10.1 GBytes  17.2 Gbits/sec
-----
Server listening on 5201
^Ciperf3: interrupt - the server has terminated
root@mininet-vm:/home/mininet# iperf3 -s -i 2
warning: this system does not seem to support IPv6 - trying IPv4
-----
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 60876 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer      Bitrate      Retr  Cwnd
[ 7] 0.00-1.00 sec  2.07 GBytes  17.7 Gbits/sec    7   4.36 MBytes
[ 7] 1.00-2.00 sec  1.96 GBytes  16.8 Gbits/sec   14   6.94 MBytes
[ 7] 2.00-3.00 sec  1.89 GBytes  16.3 Gbits/sec   15   6.94 MBytes
[ 7] 3.00-4.00 sec  2.02 GBytes  17.4 Gbits/sec   12   6.94 MBytes
[ 7] 4.00-5.00 sec  2.12 GBytes  18.2 Gbits/sec    8   8.04 MBytes
-----
[ ID] Interval      Transfer      Bitrate      Retr
[ 7] 0.00-5.00 sec  10.1 GBytes  17.3 Gbits/sec    56
[ 7] 0.00-5.02 sec  10.1 GBytes  17.2 Gbits/sec
-----
iperf Done.
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 60880 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer      Bitrate      Retr  Cwnd
[ 7] 0.00-2.00 sec  4.17 GBytes  17.9 Gbits/sec   17   4.88 MBytes
[ 7] 2.00-4.00 sec  4.08 GBytes  17.5 Gbits/sec   10   4.88 MBytes
[ 7] 4.00-6.00 sec  4.12 GBytes  17.7 Gbits/sec   11   4.88 MBytes
[ 7] 6.00-8.00 sec  4.17 GBytes  17.9 Gbits/sec   15   4.88 MBytes
[ 7] 8.00-10.00 sec  4.14 GBytes  17.8 Gbits/sec    5   4.88 MBytes
-----

```

Рис. 2.9: Передача использовать ключ -t

5. Настройте клиент iPerf3 для выполнения теста пропускной способностис 2-секундным интервалом времени отсчёта как на клиенте, так и на сервере. Используйте опцию -i для установки интервала между отсчётами, измеряемого в секундах:

```

host h2@mininet-vm
Server listening on 5201
^Ciperf3: interrupt - the server has terminated
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 60878
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 60880
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-2.00 sec  4.15 GBytes  17.8 Gbits/sec
[ 7] 2.00-4.00 sec  4.08 GBytes  17.5 Gbits/sec
[ 7] 4.00-6.00 sec  4.12 GBytes  17.7 Gbits/sec
[ 7] 6.00-8.00 sec  4.17 GBytes  17.9 Gbits/sec
[ 7] 8.00-10.00 sec 4.14 GBytes  17.8 Gbits/sec
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-10.00 sec 20.7 GBytes  17.7 Gbits/sec
Server listening on 5201
^Ciperf3: interrupt - the server has terminated
root@mininet-vm:/home/mininet#

host h1@mininet-vm
iperf Done.
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 60880 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer      Bitrate      Retr      Cwnd
[ 7] 0.00-2.00 sec  4.17 GBytes  17.9 Gbits/sec  17        4.88 MBytes
[ 7] 2.00-4.00 sec  4.08 GBytes  17.5 Gbits/sec  10        4.88 MBytes
[ 7] 4.00-6.00 sec  4.12 GBytes  17.7 Gbits/sec  11        4.88 MBytes
[ 7] 6.00-8.00 sec  4.17 GBytes  17.9 Gbits/sec  15        4.88 MBytes
[ 7] 8.00-10.00 sec 4.14 GBytes  17.8 Gbits/sec   5        4.88 MBytes
[ ID] Interval      Transfer      Bitrate      Retr
[ 7] 0.00-10.00 sec 20.7 GBytes  17.8 Gbits/sec  58
[ 7] 0.00-10.00 sec 20.7 GBytes  17.7 Gbits/sec
iperf Done.
root@mininet-vm:/home/mininet#

```

Рис. 2.10: Передача использовать ключ -i

6. Задайте на клиенте iPerf3 отправку определённого объёма данных. Используйте опцию -n для установки количества байт для передачи:

```

^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 60882
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 60884
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-1.00 sec  2.16 GBytes  18.6 Gbits/sec
[ 7] 1.00-2.00 sec  1.98 GBytes  17.0 Gbits/sec
[ 7] 2.00-3.00 sec  2.02 GBytes  17.3 Gbits/sec
[ 7] 3.00-4.00 sec  1.95 GBytes  16.7 Gbits/sec
[ 7] 4.00-5.00 sec  1.61 GBytes  13.8 Gbits/sec
[ 7] 5.00-6.00 sec  1.91 GBytes  16.4 Gbits/sec
[ 7] 6.00-7.00 sec  1.90 GBytes  16.4 Gbits/sec
[ 7] 7.00-8.00 sec  1.90 GBytes  16.3 Gbits/sec
[ 7] 8.00-8.30 sec   562 MBytes  15.8 Gbits/sec
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-8.30 sec  16.0 GBytes  16.5 Gbits/sec
Server listening on 5201

[ ID] Interval      Transfer      Bitrate      Retr      sender receiver
[ 7] 0.00-10.00 sec  20.7 GBytes  17.8 Gbits/sec  58
[ 7] 0.00-10.00 sec  20.7 GBytes  17.7 Gbits/sec
iperf Done.
root@mininet-vm:/home/mininet# iperf3 -c 10.0.0.2 -n 166
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 60884 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer      Bitrate      Retr      Cwnd
[ 7] 0.00-1.00 sec  2.17 GBytes  18.6 Gbits/sec  3      8.13 MBytes
[ 7] 1.00-2.00 sec  2.00 GBytes  17.2 Gbits/sec  9      8.13 MBytes
[ 7] 2.00-3.00 sec  2.02 GBytes  17.3 Gbits/sec  12     8.13 MBytes
[ 7] 3.00-4.00 sec  1.95 GBytes  16.7 Gbits/sec  1      8.13 MBytes
[ 7] 4.00-5.00 sec  1.61 GBytes  13.8 Gbits/sec  4      8.13 MBytes
[ 7] 5.00-6.00 sec  1.91 GBytes  16.4 Gbits/sec  5      8.13 MBytes
[ 7] 6.00-7.00 sec  1.90 GBytes  16.4 Gbits/sec  4      8.13 MBytes
[ 7] 7.00-8.00 sec  1.90 GBytes  16.3 Gbits/sec  0      8.13 MBytes
[ 7] 8.00-8.30 sec   562 MBytes  15.7 Gbits/sec  0      8.13 MBytes
[ ID] Interval      Transfer      Bitrate      Retr
[ 7] 0.00-8.30 sec  16.0 GBytes  16.6 Gbits/sec  38
[ 7] 0.00-8.30 sec  16.0 GBytes  16.5 Gbits/sec
iperf Done.

```

Рис. 2.11: Передача использовать опцию -n

- Измените в тесте измерения пропускной способности iPerf3 протокол передачи данных с TCP (установлен по умолчанию) на UDP. iPerf3 автоматически определяет протокол транспортного уровня на стороне сервера. Для изменения протокола используйте опцию -u на стороне клиента iPerf3:

```

host: h2@mininet-vm
-----
Accepted connection from 10.0.0.1, port 60886
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 34608
[ ID] Interval      Transfer      Bitrate      Jitter      Lost/Total Datagrams
[ 7] 0.00-1.00 sec  129 KBytes    1.05 Mbits/sec  0.035 ms    0/91 (0%)
[ 7] 1.00-2.00 sec  127 KBytes    1.04 Mbits/sec  0.049 ms    0/90 (0%)
[ 7] 2.00-3.00 sec  129 KBytes    1.05 Mbits/sec  0.052 ms    0/91 (0%)
[ 7] 3.00-4.00 sec  127 KBytes    1.04 Mbits/sec  0.031 ms    0/90 (0%)
[ 7] 4.00-5.00 sec  129 KBytes    1.05 Mbits/sec  0.053 ms    0/91 (0%)
[ 7] 5.00-6.00 sec  127 KBytes    1.04 Mbits/sec  0.057 ms    0/90 (0%)
[ 7] 6.00-7.00 sec  129 KBytes    1.05 Mbits/sec  0.038 ms    0/91 (0%)
[ 7] 7.00-8.00 sec  127 KBytes    1.04 Mbits/sec  0.050 ms    0/90 (0%)
[ 7] 8.00-9.00 sec  129 KBytes    1.05 Mbits/sec  0.029 ms    0/91 (0%)
[ 7] 9.00-10.00 sec 129 KBytes    1.05 Mbits/sec  0.042 ms    0/91 (0%)
[ ID] Interval      Transfer      Bitrate      Jitter      Lost/Total Datagrams
[ 7] 0.00-10.00 sec 1.25 MBytes    1.05 Mbits/sec  0.042 ms    0/906 (0%)
Server listening on 5201
-----

host: h1@mininet-vm
root@mininet-vm:/home/mininet# iperf3 -c 10.0.0.2 -u
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 34608 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  127 KBytes    1.04 Mbits/sec  90
[ 7] 4.00-5.00 sec  129 KBytes    1.05 Mbits/sec  91
[ 7] 5.00-6.00 sec  129 KBytes    1.05 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/Total Datagrams
[ 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  0.042 ms    0/906 (0%) receive
iperf Done.
root@mininet-vm:/home/mininet#

```

Рис. 2.12: Передача по протоколу UDP

- В тесте измерения пропускной способности iPerf3 измените номер порта для отправки/получения пакетов или датаграмм через указанный порт. Используйте для этого опцию -p:

The image shows two terminal windows. The top window is the server (host: h2) and the bottom window is the client (host: h1).

Server Terminal (host: h2):

```
warning: this system does not seem to support IPv6 - trying IPv4
Server listening on 3250
Accepted connection from 10.0.0.1, port 56566
[ 7] local 10.0.0.2 port 3250 connected to 10.0.0.1 port 56568
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-1.00 sec  2.12 GBytes  18.2 Gbits/sec
[ 7] 1.00-2.00 sec  2.12 GBytes  18.2 Gbits/sec
[ 7] 2.00-3.00 sec  2.11 GBytes  18.1 Gbits/sec
[ 7] 3.00-4.00 sec  2.12 GBytes  18.2 Gbits/sec
[ 7] 4.00-5.00 sec  2.11 GBytes  18.2 Gbits/sec
[ 7] 5.00-6.00 sec  2.09 GBytes  18.0 Gbits/sec
[ 7] 6.00-7.00 sec  2.14 GBytes  18.4 Gbits/sec
[ 7] 7.00-8.00 sec  2.17 GBytes  18.6 Gbits/sec
[ 7] 8.00-9.00 sec  2.14 GBytes  18.4 Gbits/sec
[ 7] 9.00-10.00 sec 2.09 GBytes  18.0 Gbits/sec
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-10.00 sec 21.2 GBytes  18.2 Gbits/sec
Server listening on 3250
```

Client Terminal (host: h1):

```
iperf Done.
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 56568 connected to 10.0.0.2 port 3250
[ ID] Interval      Transfer      Bitrate      Retr  Cwnd
[ 7] 0.00-1.00 sec  2.15 GBytes  18.4 Gbits/sec  13    6.24 MBytes
[ 7] 1.00-2.00 sec  2.12 GBytes  18.2 Gbits/sec  20    6.24 MBytes
[ 7] 2.00-3.00 sec  2.11 GBytes  18.1 Gbits/sec  14    6.24 MBytes
[ 7] 3.00-4.00 sec  2.12 GBytes  18.2 Gbits/sec  11    6.24 MBytes
[ 7] 4.00-5.00 sec  2.11 GBytes  18.2 Gbits/sec  13    6.24 MBytes
[ 7] 5.00-6.00 sec  2.09 GBytes  18.0 Gbits/sec  12    6.24 MBytes
[ 7] 6.00-7.00 sec  2.14 GBytes  18.4 Gbits/sec  17    6.24 MBytes
[ 7] 7.00-8.00 sec  2.17 GBytes  18.6 Gbits/sec  15    6.24 MBytes
[ 7] 8.00-9.00 sec  2.14 GBytes  18.4 Gbits/sec  10    6.24 MBytes
[ 7] 9.00-10.00 sec  2.09 GBytes  18.0 Gbits/sec  19    6.24 MBytes
[ ID] Interval      Transfer      Bitrate      Retr
[ 7] 0.00-10.00 sec 21.2 GBytes  18.2 Gbits/sec  144
[ 7] 0.00-10.00 sec 21.2 GBytes  18.2 Gbits/sec
iperf Done.
root@mininet-vm:/home/mininet#
```

Рис. 2.13: Передача использовать опцию -p

- По умолчанию после запуска сервер iPerf3 постоянно прослушивает входящие соединения. В тесте измерения пропускной способности iPerf3 задайте для сервера параметр обработки данных только от одного клиента с остановкой сервера по завершении теста. Для этого используйте опцию -1 на сервере iPerf3:

```
host: h2@mininet-vm
-----
^Ciperf3: interrupt - the server has terminated
root@mininet-vm:/home/mininet# iperf3 -s -l
warning: this system does not seem to support IPv6 - trying IPv4
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 60892
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 60894
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-1.00 sec  2.02 GBytes  17.4 Gbits/sec
[ 7] 1.00-2.00 sec  2.05 GBytes  17.6 Gbits/sec
[ 7] 2.00-3.00 sec  2.01 GBytes  17.3 Gbits/sec
[ 7] 3.00-4.00 sec  1.92 GBytes  16.5 Gbits/sec
[ 7] 4.00-5.00 sec  1.91 GBytes  16.4 Gbits/sec
[ 7] 5.00-6.00 sec  1.93 GBytes  16.6 Gbits/sec
[ 7] 6.00-7.00 sec  1.92 GBytes  16.5 Gbits/sec
[ 7] 7.00-8.00 sec  1.96 GBytes  16.9 Gbits/sec
[ 7] 8.00-9.00 sec  2.06 GBytes  17.7 Gbits/sec
[ 7] 9.00-10.00 sec 2.05 GBytes  17.6 Gbits/sec
-----
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-10.00 sec 19.8 GBytes  17.0 Gbits/sec
root@mininet-vm:/home/mininet# receiver

host: h1@mininet-vm
iperf Done.
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 60894 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer      Bitrate      Retr  Cwnd
[ 7] 0.00-1.00 sec  2.05 GBytes  17.6 Gbits/sec    2   7.98 MBytes
[ 7] 1.00-2.00 sec  2.05 GBytes  17.6 Gbits/sec   12   7.98 MBytes
[ 7] 2.00-3.00 sec  2.01 GBytes  17.3 Gbits/sec   13   7.98 MBytes
[ 7] 3.00-4.00 sec  1.92 GBytes  16.5 Gbits/sec   11   7.98 MBytes
[ 7] 4.00-5.00 sec  1.91 GBytes  16.4 Gbits/sec    7   7.98 MBytes
[ 7] 5.00-6.00 sec  1.93 GBytes  16.6 Gbits/sec   12   7.98 MBytes
[ 7] 6.00-7.00 sec  1.92 GBytes  16.5 Gbits/sec    6   7.98 MBytes
[ 7] 7.00-8.00 sec  1.96 GBytes  16.9 Gbits/sec   15   7.98 MBytes
[ 7] 8.00-9.00 sec  2.06 GBytes  17.7 Gbits/sec   16   7.98 MBytes
[ 7] 9.00-10.00 sec 2.05 GBytes  17.6 Gbits/sec    9   7.98 MBytes
-----
[ ID] Interval      Transfer      Bitrate      Retr
[ 7] 0.00-10.00 sec 19.8 GBytes  17.0 Gbits/sec   103
[ 7] 0.00-10.00 sec 19.8 GBytes  17.0 Gbits/sec
-----
iperf Done.
root@mininet-vm:/home/mininet#
```

Рис. 2.14: Передача использовать параметр -l

Видим что после завершения этого теста сервер iPerf3 немедленно останавливается.

10. Экпортируйте результаты теста измерения пропускной способности iPerf3 в файл JSON:

- В виртуальной машине mininet создайте каталог для работы над проектом:
`mkdir -p ~/work/lab_iperf3`


```

warning: this system does not seem to support IPv6 - trying IPv4
Server listening on 5201
Accepted connection from 10.0.0.1, port 60896
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 60898
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-1.00 sec  2.05 GBytes 17.6 Gbits/sec
[ 7] 1.00-2.00 sec  2.08 GBytes 17.8 Gbits/sec
[ 7] 2.00-3.00 sec  2.11 GBytes 18.2 Gbits/sec
[ 7] 3.00-4.00 sec  2.10 GBytes 18.1 Gbits/sec
[ 7] 4.00-5.00 sec  2.14 GBytes 18.4 Gbits/sec
[ 7] 5.00-6.00 sec  2.11 GBytes 18.1 Gbits/sec
[ 7] 6.00-7.00 sec  2.14 GBytes 18.4 Gbits/sec
[ 7] 7.00-8.00 sec  2.16 GBytes 18.6 Gbits/sec
[ 7] 8.00-9.00 sec  2.14 GBytes 18.4 Gbits/sec
[ 7] 9.00-10.00 sec 2.12 GBytes 18.2 Gbits/sec
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-10.00 sec 21.2 GBytes 18.2 Gbits/sec
Server listening on 5201

{
  "retransmits": 144,
  "sender": true,
  "sum_received": {
    "start": 0,
    "end": 10.000165,
    "seconds": 10.000165,
    "bytes": 22718879784,
    "bits_per_second": 18174803942.93494,
    "sender": true
  },
  "cpu_utilization_percent": {
    "host_total": 33.222572824643514,
    "host_user": 0.951447708955361,
    "host_system": 32.271115133966681,
    "remote_total": 23.411903389813723,
    "remote_user": 0.64875092546915425,
    "remote_system": 22.763141891078657
  },
  "sender_tcp_congestion": "cubic",
  "receiver_tcp_congestion": "cubic"
}

```

Рис. 2.15: Параметр -J

- Экспортируйте вывод результатов теста в файл, перенаправив стандартный вывод в файл:

The image shows two terminal windows. The top window, titled "host: h2" @mininet-vm, displays the output of a receiver process. It shows a connection from 10.0.0.1 on port 60900 to 10.0.0.2 on port 5201. A table of 10-second intervals shows transfer rates around 18 Gbps. The bottom window, titled "host: h1" @mininet-vm, shows the execution of the command `iperf3 -c 10.0.0.2 -J > /home/mininet/work/lab_iperf3/iperf_results.json`. It then shows the contents of the generated JSON file, which includes fields like `remote_user`, `remote_system`, `sender_tcp_congestion`, and `receiver_tcp_congestion`, along with a list of files in the directory.

```

[ 7] 0.00-10.00 sec 21.2 GBytes 18.2 Gbits/sec
-----
Server listening on 5201
Accepted connection from 10.0.0.1, port 60900
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 60902
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-1.00 sec  2.10 GBytes 18.0 Gbits/sec
[ 7] 1.00-2.00 sec  2.02 GBytes 17.3 Gbits/sec
[ 7] 2.00-3.00 sec  2.07 GBytes 17.7 Gbits/sec
[ 7] 3.00-4.00 sec  2.08 GBytes 17.8 Gbits/sec
[ 7] 4.00-5.00 sec  2.12 GBytes 18.2 Gbits/sec
[ 7] 5.00-6.00 sec  2.07 GBytes 17.7 Gbits/sec
[ 7] 6.00-7.00 sec  2.21 GBytes 19.0 Gbits/sec
[ 7] 7.00-8.00 sec  2.24 GBytes 19.2 Gbits/sec
[ 7] 8.00-9.00 sec  2.07 GBytes 17.8 Gbits/sec
[ 7] 9.00-10.00 sec 2.09 GBytes 18.0 Gbits/sec
-----
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-10.00 sec 21.1 GBytes 18.1 Gbits/sec
-----
Server listening on 5201

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# ls -l
total 32
-rw-r--r-- 1 root root 1671 Nov 16 02:33 lab1.mn
drwxrwxr-x 11 mininet mininet 4096 Nov 16 01:47 mininet
drwxrwxr-x 11 mininet mininet 4096 Feb 10 2021 mininet.orig
drwxrwxr-x 14 mininet mininet 4096 Feb 10 2021 oflops
drwxrwxr-x 11 mininet mininet 4096 Feb 10 2021 oftest
drwxrwxr-x 19 mininet mininet 4096 Feb 10 2021 openflow
drwxrwxr-x 7 mininet mininet 4096 Feb 10 2021 pox
drwxrwxr-x 3 mininet mininet 4096 Nov 23 02:08 work
root@mininet-vm:/home/mininet# cat /home/mininet/work/lab_iperf3/iperf_results.json
{"remote_user": "0.64875092546915425",
  "remote_system": "22.763141891078657",
  "sender_tcp_congestion": "cubic",
  "receiver_tcp_congestion": "cubic"}
root@mininet-vm:/home/mininet#

```

Рис. 2.16: Экспортируйте вывод результатов теста в файл JSON

11. Визуализируйте результаты эксперимента:

- Проверьте и скорректируйте права доступа к файлу JSON:
- Сгенерируйте выходные данные для файла JSON iPerf3: `plot_iperf.sh iperf_results.json`
- Убедитесь, что файлы с данными и графиками сформировались:

```

mininet@mininet-vm:~$ cd ~/work/lab_iperf3
mininet@mininet-vm:~/work/lab_iperf3$ ls -l
total 8
-rw-r--r-- 1 root root 7806 Nov 23 02:48 iperf_results.json
mininet@mininet-vm:~/work/lab_iperf3$ sudo chown -R mininet:mininet ~/work
mininet@mininet-vm:~/work/lab_iperf3$ ls -l
total 8
-rw-r--r-- 1 mininet mininet 7806 Nov 23 02:48 iperf_results.json
mininet@mininet-vm:~/work/lab_iperf3$ plot iperf.sh iperf3_results.json
Error: iperf3_results.json is not a file. Quitting...
mininet@mininet-vm:~/work/lab_iperf3$ plot iperf.sh iperf_results.json
mininet@mininet-vm:~/work/lab_iperf3$ ls -l
total 16
-rw-rw-r-- 1 mininet mininet 954 Nov 23 03:01 iperf.csv
-rw-r--r-- 1 mininet mininet 7806 Nov 23 02:48 iperf_results.json
drwxrwxr-x 2 mininet mininet 4096 Nov 23 03:01 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 482 Nov 23 03:01 1.dat
-rw-rw-r-- 1 mininet mininet 9715 Nov 23 03:01 bytes.pdf
-rw-rw-r-- 1 mininet mininet 9628 Nov 23 03:01 cwnd.pdf
-rw-rw-r-- 1 mininet mininet 9036 Nov 23 03:01 MTU.pdf
-rw-rw-r-- 1 mininet mininet 9103 Nov 23 03:01 retransmits.pdf
-rw-rw-r-- 1 mininet mininet 9029 Nov 23 03:01 RTT.pdf
-rw-rw-r-- 1 mininet mininet 9256 Nov 23 03:01 RTT_Var.pdf
-rw-rw-r-- 1 mininet mininet 9658 Nov 23 03:01 throughput.pdf

```

Рис. 2.17: Сгенерированный файл данных и графика

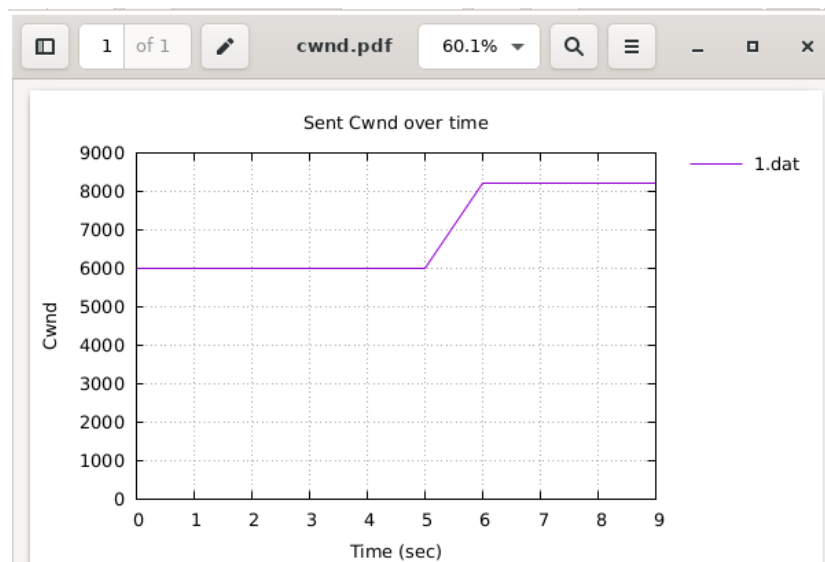


Рис. 2.18: Окно перегрузки

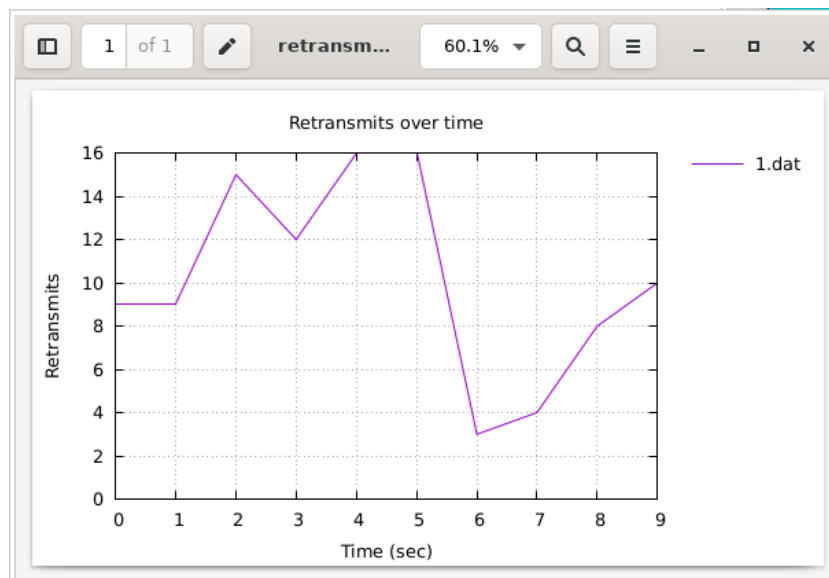


Рис. 2.19: Повторная передача

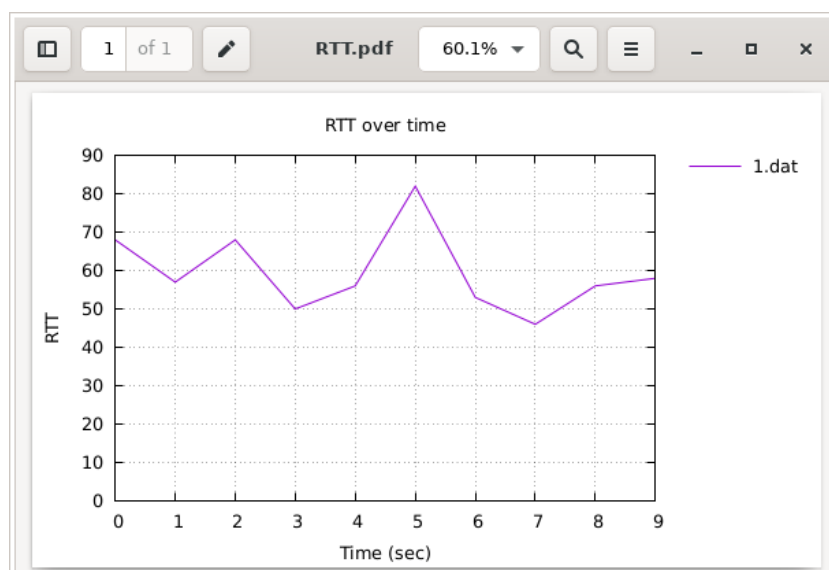


Рис. 2.20: Время приема-передачи

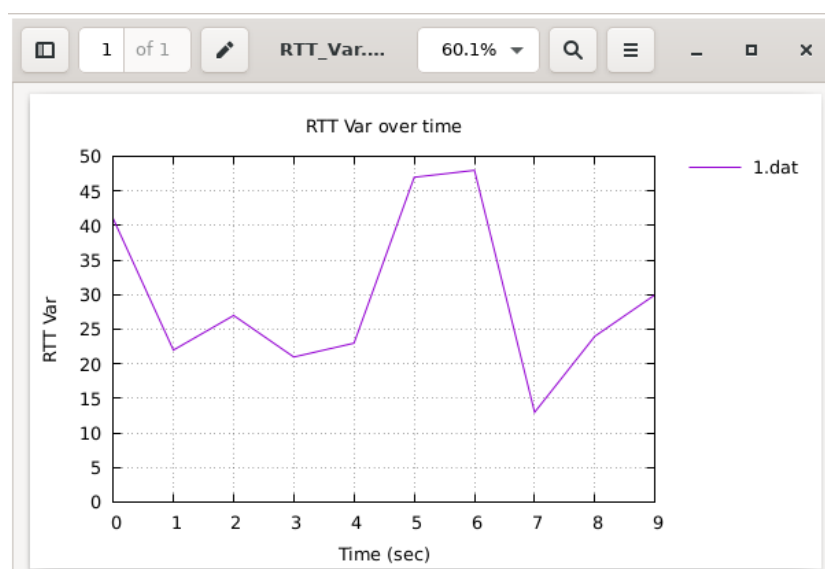


Рис. 2.21: Отклонение времени приема-передачи

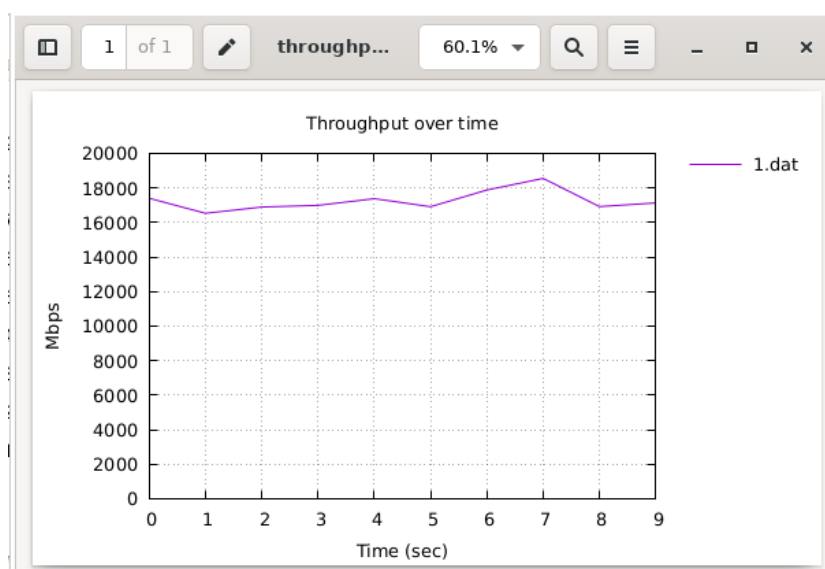


Рис. 2.22: Пропускная способность

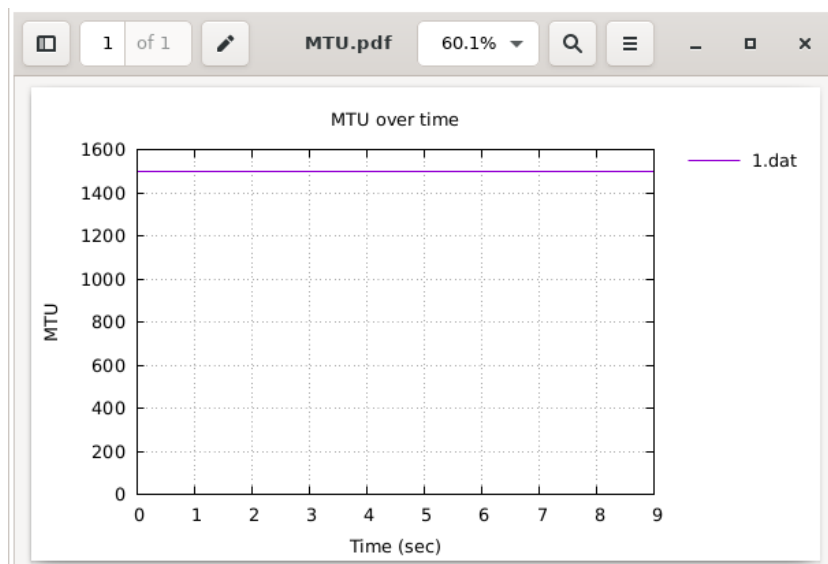


Рис. 2.23: Максимальная единица передачи

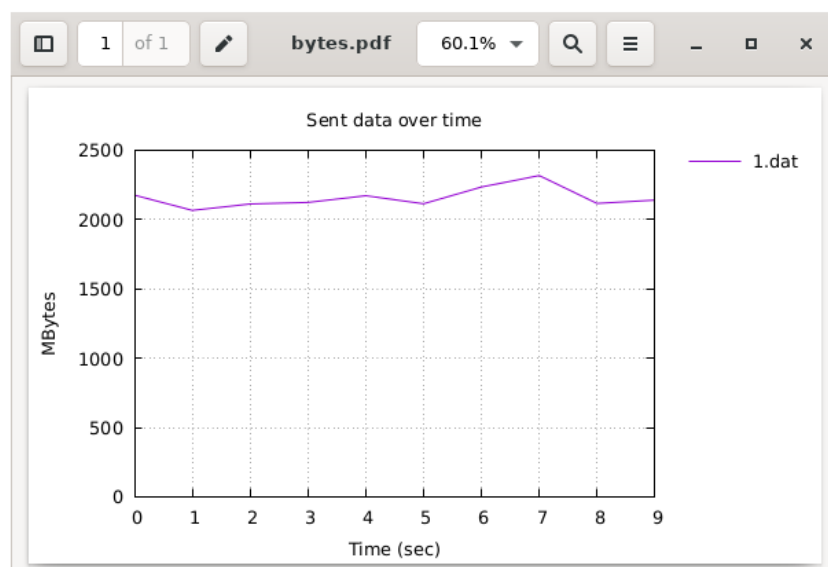


Рис. 2.24: Количество переданных байтов

3 Вывод

Я познакомилась 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.