

# Лабораторная работа №2. Измерение и тестирование пропускной способности сети

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## 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.

## Задание

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

## Теоретическое введение

Mininet — это эмулятор компьютерной сети. Под компьютерной сетью подразумеваются простые компьютеры — хосты, коммутаторы, а также OpenFlow-контроллеры. С помощью простейшего синтаксиса в интерпретаторе команд можно разворачивать сети из произвольного количества хостов и коммутаторов в различных топологиях, всё это в одной виртуальной машине (ВМ). На хостах можно изменять сетевую конфигурацию, пользоваться утилитами `ifconfig`, `ping` и даже получать доступ к терминалу. На коммутаторы можно добавлять правила и маршрутизировать трафик.

iPerf3 — это кроссплатформенное клиент-серверное приложение с открытым исходным кодом, которое измеряет пропускную способность между двумя устройствами.

Протоколы:

- TCP и SCTP: измеряет пропускную способность, задает MSS/MTU, отслеживает размер окна перегрузки TCP (CWnd).
- UDP: измеряет пропускную способность, потери пакетов, jitter и поддерживает multicast.

# Выполнение лабораторной работы

## Установка необходимого программного обеспечения

Запустим виртуальную среду с Mininet.

Подключаемся по SSH к виртуальной машине и активируем второй интерфейс для выхода в сеть.

```
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.
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 (130 kB/s)
Selecting previously unselected package libsctp1:amd64.
(Reading database ... 102146 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) ...
Setting up libsctp1:amd64 (1.0.18+dfsg-1) ...
Setting up libiperf0:amd64 (3.7-3) ...
Setting up iperf3 (3.7-3) ...
Processing triggers for man-db (2.9.1-1) ...
Processing triggers for libc-bin (2.31-0ubuntu9) ...
```

Рис. 1: Установка iPerf3

Обновим репозитории и установим iPerf3 и дополнительное ПО:

```
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:
  aspell aspell-en bubblewrap enchant-2 evince-common fonts-liberation gnome-desktop3-data gnuplot-data groff hunspell
  libdjvu21 libenchant-2-2 libevdocument3-4 libevview3-3 libgnome-desktop-3-19 libgspell-1-2 libgspell-1-common libgsm
  libmagickcore-6.q16-6-extra libnautilus-extension1a libnetpbm10 libnspr4 libnss3 libonig5 libopenexr24 libpoppler-glib8
  netpbm psutils
Suggested packages:
  aspell-doc spellutils gvfs nautilus-sendto unrar git-daemon-run | git-daemon-sysvinit git-doc git-email git-gui
  | openoffice.org-core imagemagick-doc autotrace cups-bsd | lpr | lprng curl enscript ffmpeg gimp grads graphviz hp2xx hufraw-
  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
  libdjvu21 libenchant-2-2 libevdocument3-4 libevview3-3 libgnome-desktop-3-19 libgspell-1-2 libgsm
  libmagickcore-6.q16-6-extra libnautilus-extension1a libnetpbm10 libnspr4 libnss3 libonig5 libopenexr24 libpoppler-glib8
  netpbm psutils
The following packages will be upgraded:
```

```
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 | 976.00 KiB/s, done.
mininet@mininet-vm:/tmp$
```

## Интерактивные эксперименты

Задаем простейшую топологию из двух хостов и одного коммутатора (сеть 10.0.0.0/8):

Настройки iPerf3:

- ID соединения
- Интервал отчета (Interval)
- Передача (Transfer)
- Пропускная способность (Bitrate)
- Повторная передача (Retr)
- Размер окна перегрузки (Cwnd)

Указание времени передачи с помощью -t:

Установка интервала отсчетов -i 2:

Передача определенного объема данных -n:

Изменение протокола на UDP -u:

Изменение номера порта:

Настройка сервера для одного клиента -1:

Экспорт результатов в JSON:

Проверка создания файла:

Исправление прав запуска X-соединения:

Визуализация результатов эксперимента:

## Выводы

В результате выполнения лабораторной работы я познакомился с инструментом для измерения пропускной способности сети в реальном времени — iPerf3, а также получил навыки проведения интерактивного эксперимента по измерению пропускной способности в среде Mininet.

```

X "host: h2"@mininet-vm

-----
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 32802
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 32804
[ ID] Interval Transfer Bitrate
[ 7] 0.00-1.00 sec 5.12 GBytes 44.0 Gbits/sec
[ 7] 1.00-2.00 sec 5.01 GBytes 43.0 Gbits/sec
[ 7] 2.00-3.00 sec 4.95 GBytes 42.5 Gbits/sec
[ 7] 3.00-4.00 sec 4.85 GBytes 41.6 Gbits/sec
[ 7] 4.00-5.00 sec 4.69 GBytes 40.3 Gbits/sec
[ 7] 5.00-6.00 sec 4.62 GBytes 39.6 Gbits/sec
[ 7] 6.00-7.00 sec 4.62 GBytes 39.7 Gbits/sec
[ 7] 7.00-8.00 sec 4.80 GBytes 41.2 Gbits/sec
[ 7] 8.00-9.00 sec 4.72 GBytes 40.6 Gbits/sec
[ 7] 9.00-10.00 sec 4.59 GBytes 39.4 Gbits/sec
[ 7] 10.00-10.00 sec 12.0 MBytes 30.8 Gbits/sec
-----
[ ID] Interval Transfer Bitrate
[ 7] 0.00-10.00 sec 48.0 GBytes 41.2 Gbits/sec
                                         receiver
-----
Server listening on 5201
-----
X "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 32804 connected to 10.0.0.2 port 5201
[ ID] Interval Transfer Bitrate Retr Cwnd
[ 7] 0.00-1.00 sec 5.12 GBytes 44.0 Gbits/sec 0 8.10 MBytes
[ 7] 1.00-2.00 sec 5.01 GBytes 43.0 Gbits/sec 0 8.10 MBytes
[ 7] 2.00-3.00 sec 4.95 GBytes 42.5 Gbits/sec 0 8.10 MBytes
[ 7] 3.00-4.00 sec 4.85 GBytes 41.6 Gbits/sec 0 8.10 MBytes
[ 7] 4.00-5.00 sec 4.68 GBytes 40.3 Gbits/sec 0 8.10 MBytes
[ 7] 5.00-6.00 sec 4.62 GBytes 39.7 Gbits/sec 0 8.10 MBytes
[ 7] 6.00-7.00 sec 4.62 GBytes 39.7 Gbits/sec 0 8.10 MBytes
[ 7] 7.00-8.00 sec 4.80 GBytes 41.3 Gbits/sec 0 8.10 MBytes
[ 7] 8.00-9.00 sec 4.71 GBytes 40.4 Gbits/sec 0 8.10 MBytes
[ 7] 9.00-10.00 sec 4.60 GBytes 39.5 Gbits/sec 0 8.10 MBytes
-----
[ ID] Interval Transfer Bitrate Retr
[ 7] 0.00-10.00 sec 48.0 GBytes 41.2 Gbits/sec 0
                                         sender
[ 7] 0.00-10.00 sec 48.0 GBytes 41.2 Gbits/sec
                                         receiver

iperf Done.
root@mininet-vm:/home/mininet# ^C
root@mininet-vm:/home/mininet# █

```

Рис. 2: Интерактивный эксперимент

```

X "host: h2"@mininet-vm
^Ciperf3: interrupt - the server has terminated
root@mininet-vm:/home/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 32810
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 32812
[ ID] Interval Transfer Bitrate
[ 7] 0.00-1.00 sec 4.96 GBytes 42.6 Gbits/sec
[ 7] 1.00-2.00 sec 4.78 GBytes 41.1 Gbits/sec
[ 7] 2.00-3.00 sec 4.80 GBytes 41.2 Gbits/sec
[ 7] 3.00-4.00 sec 4.67 GBytes 40.1 Gbits/sec
[ 7] 4.00-5.00 sec 4.66 GBytes 40.0 Gbits/sec
[ 7] 5.00-5.00 sec 320 KBytes 983 Mbytes/sec
-----
[ ID] Interval Transfer Bitrate
[ 7] 0.00-5.00 sec 23.9 GBytes 41.0 Gbits/sec
                                             receiver
-----
Server listening on 5201
-----
^Ciperf3: interrupt - the server has terminated
root@mininet-vm:/home/mininet# █
[ 7] 9.00-10.00 sec 4.60 GBytes 39.5 Gbits/sec 0 8.10 MBytes
-----
[ ID] Interval Transfer Bitrate Retr
[ 7] 0.00-10.00 sec 48.0 GBytes 41.2 Gbits/sec 0
[ 7] 0.00-10.00 sec 48.0 GBytes 41.2 Gbits/sec
                                             sender
                                             receiver
iperf Done.
root@mininet-vm:/home/mininet# ^C
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 32812 connected to 10.0.0.2 port 5201
[ ID] Interval Transfer Bitrate Retr Cwnd
[ 7] 0.00-1.00 sec 4.96 GBytes 42.5 Gbits/sec 0 8.37 MBytes
[ 7] 1.00-2.00 sec 4.79 GBytes 41.3 Gbits/sec 0 8.37 MBytes
[ 7] 2.00-3.00 sec 4.80 GBytes 41.2 Gbits/sec 0 8.37 MBytes
[ 7] 3.00-4.00 sec 4.66 GBytes 40.1 Gbits/sec 0 8.37 MBytes
[ 7] 4.00-5.00 sec 4.66 GBytes 40.0 Gbits/sec 0 8.37 MBytes
-----
[ ID] Interval Transfer Bitrate Retr
[ 7] 0.00-5.00 sec 23.9 GBytes 41.0 Gbits/sec 0
                                             sender
                                             receiver
iperf Done.
root@mininet-vm:/home/mininet# █

```

Рис. 3: Указание периода времени t=5

```

X "host: h2"@mininet-vm

-----
^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 32814
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 32816
[ ID] Interval Transfer Bitrate
[ 7] 0.00-2.00 sec 11.3 GBytes 48.7 Gbits/sec
[ 7] 2.00-4.00 sec 9.92 GBytes 42.6 Gbits/sec
[ 7] 4.00-6.00 sec 10.3 GBytes 44.3 Gbits/sec
[ 7] 6.00-8.00 sec 10.1 GBytes 43.3 Gbits/sec
[ 7] 8.00-10.00 sec 10.1 GBytes 43.3 Gbits/sec
[ 7] 10.00-10.00 sec 1.00 MBytes 3.04 Gbits/sec
-----  

[ ID] Interval Transfer Bitrate
[ 7] 0.00-10.00 sec 51.8 GBytes 44.4 Gbits/sec
-----  

receiver  

-----  

Server listening on 5201  

-----  

^Ciperf3: interrupt - the server has terminated
root@mininet-vm:/home/mininet#   

X "host: h1"@mininet-vm
-----  

[ 7] 3.00-4.00 sec 4.66 GBytes 40.1 Gbits/sec 0 8.37 MBytes
[ 7] 4.00-5.00 sec 4.66 GBytes 40.0 Gbits/sec 0 8.37 MBytes
-----  

[ ID] Interval Transfer Bitrate Retr
[ 7] 0.00-5.00 sec 23.9 GBytes 41.0 Gbits/sec 0
-----  

sender  

[ 7] 0.00-5.00 sec 23.9 GBytes 41.0 Gbits/sec
-----  

receiver  

-----  

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 32816 connected to 10.0.0.2 port 5201
[ ID] Interval Transfer Bitrate Retr Cwnd
[ 7] 0.00-2.00 sec 11.3 GBytes 48.7 Gbits/sec 72 3.02 MBytes
[ 7] 2.00-4.00 sec 9.93 GBytes 42.6 Gbits/sec 0 3.46 MBytes
[ 7] 4.00-6.00 sec 10.3 GBytes 44.3 Gbits/sec 0 4.14 MBytes
[ 7] 6.00-8.00 sec 10.1 GBytes 43.3 Gbits/sec 0 4.46 MBytes
[ 7] 8.00-10.00 sec 10.1 GBytes 43.3 Gbits/sec 0 4.88 MBytes
-----  

[ ID] Interval Transfer Bitrate Retr
[ 7] 0.00-10.00 sec 51.8 GBytes 44.4 Gbits/sec 72
-----  

sender  

[ 7] 0.00-10.00 sec 51.8 GBytes 44.4 Gbits/sec
-----  

receiver  

-----  

iperf Done.  

root@mininet-vm:/home/mininet# 

```

Рис. 4: Отправка сигналов с 2-ух секундным интервалом

```

X "host h2"@mininet-vm
[ 7] 0.00-10.00 sec 51.8 GBytes 44.4 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 32818
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 32820
[ ID] Interval          Transfer     Bitrate
[ 7]  0.00-1.00   sec  5.15 GBytes  44.2 Gbits/sec
[ 7]  1.00-2.00   sec  5.23 GBytes  44.9 Gbits/sec
[ 7]  2.00-3.00   sec  5.34 GBytes  45.9 Gbits/sec
[ 7]  3.00-3.05   sec  285 MBytes  44.0 Gbits/sec
-----
[ ID] Interval          Transfer     Bitrate
[ 7]  0.00-3.05   sec  16.0 GBytes  45.0 Gbits/sec                                receiver
-----
Server listening on 5201
-----
X "host h1"@mininet-vm
[ 7] 4.00-6.00   sec 10.3 GBytes 44.3 Gbits/sec    0  4.14 MBytes
[ 7] 6.00-8.00   sec 10.1 GBytes 43.3 Gbits/sec    0  4.46 MBytes
[ 7] 8.00-10.00  sec 10.1 GBytes 43.3 Gbits/sec   0  4.88 MBytes
-----
[ ID] Interval          Transfer     Bitrate     Retr
[ 7]  0.00-10.00  sec  51.8 GBytes  44.4 Gbits/sec  72
[ 7]  0.00-10.00  sec  51.8 GBytes  44.4 Gbits/sec                                sender
                                                               receiver
iperf Done.
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 32820 connected to 10.0.0.2 port 5201
[ ID] Interval          Transfer     Bitrate     Retr  Cwnd
[ 7]  0.00-1.00   sec  5.16 GBytes  44.3 Gbits/sec  0  8.04 MBytes
[ 7]  1.00-2.00   sec  5.23 GBytes  44.9 Gbits/sec  0  8.04 MBytes
[ 7]  2.00-3.00   sec  5.35 GBytes  45.9 Gbits/sec  0  8.04 MBytes
[ 7]  3.00-3.05   sec  269 MBytes  44.1 Gbits/sec  0  8.04 MBytes
-----
[ ID] Interval          Transfer     Bitrate     Retr
[ 7]  0.00-3.05   sec  16.0 GBytes  45.0 Gbits/sec  0
[ 7]  0.00-3.05   sec  16.0 GBytes  45.0 Gbits/sec                                sender
                                                               receiver
iperf Done.
root@mininet-vm:/home/mininet# 

```

Рис. 5: Задание определенного объема данных

```

X "host: h2"@mininet-vm
-----
Accepted connection from 10.0.0.1, port 32822
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 37590
[ ID] Interval Transfer Bitrate Jitter Lost/Total Datagrams
[ 7] 0.00-1.00 sec 129 KBytes 1.05 Mbits/sec 0.009 ms 0/91 (0%)
[ 7] 1.00-2.00 sec 127 KBytes 1.04 Mbits/sec 0.013 ms 0/90 (0%)
[ 7] 2.00-3.00 sec 129 KBytes 1.05 Mbits/sec 0.088 ms 0/91 (0%)
[ 7] 3.00-4.00 sec 127 KBytes 1.04 Mbits/sec 0.037 ms 0/90 (0%)
[ 7] 4.00-5.00 sec 129 KBytes 1.05 Mbits/sec 0.039 ms 0/91 (0%)
[ 7] 5.00-6.00 sec 127 KBytes 1.04 Mbits/sec 0.034 ms 0/90 (0%)
[ 7] 6.00-7.00 sec 129 KBytes 1.05 Mbits/sec 0.054 ms 0/91 (0%)
[ 7] 7.00-8.00 sec 127 KBytes 1.04 Mbits/sec 0.034 ms 0/90 (0%)
[ 7] 8.00-9.00 sec 129 KBytes 1.05 Mbits/sec 0.024 ms 0/91 (0%)
[ 7] 9.00-10.00 sec 129 KBytes 1.05 Mbits/sec 0.018 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 0.018 ms 0/906 (0%) receiver
-----
Server listening on 5201
-----
X "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 37590 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 1.06 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 1.05 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%) sender
[ 7] 0.00-10.00 sec 1.25 MBytes 1.05 Mbits/sec 0.018 ms 0/906 (0%) receiver
iperf Done.
root@mininet-vm:/home/mininet# 
```

Рис. 6: Изменение протокола передачи

```

X "host h2"@mininet-vm
-----
Server listening on 3250
-----
Accepted connection from 10.0.0.1, port 41138
[ 7] local 10.0.0.2 port 3250 connected to 10.0.0.1 port 41140
[ ID] Interval Transfer Bitrate
[ 7] 0.00-1.00 sec 4.81 GBytes 41.3 Gbits/sec
[ 7] 1.00-2.00 sec 5.15 GBytes 44.2 Gbits/sec
[ 7] 2.00-3.00 sec 5.37 GBytes 46.2 Gbits/sec
[ 7] 3.00-4.00 sec 5.15 GBytes 44.3 Gbits/sec
[ 7] 4.00-5.00 sec 5.15 GBytes 44.2 Gbits/sec
[ 7] 5.00-6.00 sec 5.19 GBytes 44.6 Gbits/sec
[ 7] 6.00-7.00 sec 4.95 GBytes 42.5 Gbits/sec
[ 7] 7.00-8.00 sec 5.31 GBytes 45.6 Gbits/sec
[ 7] 8.00-9.00 sec 4.80 GBytes 41.3 Gbits/sec
[ 7] 9.00-10.00 sec 4.93 GBytes 42.3 Gbits/sec
[ 7] 10.00-10.00 sec 2.56 MBytes 17.4 Gbits/sec
-----
[ ID] Interval Transfer Bitrate
[ 7] 0.00-10.00 sec 50.8 GBytes 43.6 Gbits/sec
                                                receiver
-----
Server listening on 3250
-----
]
X "host h1"@mininet-vm
Liver
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 41140 connected to 10.0.0.2 port 3250
[ ID] Interval Transfer Bitrate Retr Cwnd
[ 7] 0.00-1.00 sec 4.81 GBytes 41.3 Gbits/sec 0 8.04 MBytes
[ 7] 1.00-2.00 sec 5.15 GBytes 44.3 Gbits/sec 0 8.04 MBytes
[ 7] 2.00-3.00 sec 5.37 GBytes 46.0 Gbits/sec 0 8.04 MBytes
[ 7] 3.00-4.00 sec 5.15 GBytes 44.3 Gbits/sec 0 8.04 MBytes
[ 7] 4.00-5.00 sec 5.15 GBytes 44.2 Gbits/sec 0 8.04 MBytes
[ 7] 5.00-6.00 sec 5.19 GBytes 44.6 Gbits/sec 0 8.04 MBytes
[ 7] 6.00-7.00 sec 4.96 GBytes 42.6 Gbits/sec 0 8.04 MBytes
[ 7] 7.00-8.00 sec 5.31 GBytes 45.5 Gbits/sec 0 8.04 MBytes
[ 7] 8.00-9.00 sec 4.79 GBytes 41.3 Gbits/sec 0 8.04 MBytes
[ 7] 9.00-10.00 sec 4.93 GBytes 42.3 Gbits/sec 0 8.04 MBytes
-----
[ ID] Interval Transfer Bitrate Retr
[ 7] 0.00-10.00 sec 50.8 GBytes 43.7 Gbits/sec 0
                                                sender
[ 7] 0.00-10.00 sec 50.8 GBytes 43.6 Gbits/sec
                                                receiver
iperf Done.
root@mininet-vm:/home/mininet# █

```

Рис. 7: Изменение номера порта для приема/отправки

```

X "host h2"@mininet-vm
^Ciperf3: interrupt - the server has terminated
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 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 4.97 GBytes 42.7 Gbits/sec
[ 7] 1.00-2.00 sec 5.21 GBytes 44.7 Gbits/sec
[ 7] 2.00-3.00 sec 5.15 GBytes 44.2 Gbits/sec
[ 7] 3.00-4.00 sec 5.04 GBytes 43.3 Gbits/sec
[ 7] 4.00-5.00 sec 4.94 GBytes 42.4 Gbits/sec
[ 7] 5.00-6.00 sec 4.76 GBytes 40.9 Gbits/sec
[ 7] 6.00-7.00 sec 4.77 GBytes 40.9 Gbits/sec
[ 7] 7.00-8.00 sec 4.96 GBytes 42.6 Gbits/sec
[ 7] 8.00-9.00 sec 4.80 GBytes 41.2 Gbits/sec
[ 7] 9.00-10.00 sec 4.95 GBytes 42.5 Gbits/sec
[ 7] 10.00-10.00 sec 1.13 MBytes 4.14 Gbits/sec
-----
[ ID] Interval Transfer Bitrate
[ 7] 0.00-10.00 sec 49.5 GBytes 42.5 Gbits/sec
root@mininet-vm:/home/mininet# 
X "host h1"@mininet-vm
[ 7] 0.00-10.00 sec 50.8 GBytes 43.6 Gbits/sec
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 32830 connected to 10.0.0.2 port 5201
[ ID] Interval Transfer Bitrate Retr Cwnd
[ 7] 0.00-1.00 sec 4.97 GBytes 42.7 Gbits/sec 27 2.33 MBytes
[ 7] 1.00-2.00 sec 5.21 GBytes 44.7 Gbits/sec 0 2.34 MBytes
[ 7] 2.00-3.00 sec 5.15 GBytes 44.2 Gbits/sec 0 3.01 MBytes
[ 7] 3.00-4.00 sec 5.04 GBytes 43.3 Gbits/sec 0 3.02 MBytes
[ 7] 4.00-5.00 sec 4.94 GBytes 42.4 Gbits/sec 0 3.31 MBytes
[ 7] 5.00-6.00 sec 4.76 GBytes 40.8 Gbits/sec 0 3.62 MBytes
[ 7] 6.00-7.00 sec 4.77 GBytes 40.9 Gbits/sec 0 3.79 MBytes
[ 7] 7.00-8.00 sec 4.95 GBytes 42.6 Gbits/sec 0 4.05 MBytes
[ 7] 8.00-9.00 sec 4.80 GBytes 41.2 Gbits/sec 0 4.22 MBytes
[ 7] 9.00-10.00 sec 4.94 GBytes 42.5 Gbits/sec 0 4.45 MBytes
-----
[ ID] Interval Transfer Bitrate Retr
[ 7] 0.00-10.00 sec 49.5 GBytes 42.5 Gbits/sec 27
[ 7] 0.00-10.00 sec 49.5 GBytes 42.5 Gbits/sec
sender
receiver

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

```

Рис. 8: Параметр обработки данных только от одного клиента

```

X "host h2"@mininet-vm
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 32832
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 32834
[ ID] Interval Transfer Bitrate
[ 7] 0.00-1.00 sec 4.36 GBytes 37.3 Gbits/sec
[ 7] 1.00-2.00 sec 4.50 GBytes 38.8 Gbits/sec
[ 7] 2.00-3.00 sec 4.45 GBytes 38.2 Gbits/sec
[ 7] 3.00-4.00 sec 4.39 GBytes 37.7 Gbits/sec
[ 7] 4.00-5.00 sec 4.52 GBytes 38.9 Gbits/sec
[ 7] 5.00-6.00 sec 4.53 GBytes 38.9 Gbits/sec
[ 7] 6.00-7.00 sec 4.59 GBytes 39.4 Gbits/sec
[ 7] 7.00-8.00 sec 4.52 GBytes 38.9 Gbits/sec
[ 7] 8.00-9.00 sec 4.65 GBytes 40.0 Gbits/sec
[ 7] 9.00-10.00 sec 4.46 GBytes 38.3 Gbits/sec
[ 7] 10.00-10.00 sec 1.13 MBytes 2.71 Gbits/sec
-----
[ ID] Interval Transfer Bitrate
[ 7] 0.00-10.00 sec 45.0 GBytes 38.6 Gbits/sec           receiver
-----
Server listening on 5201
-----
^Ciperf3: interrupt - the server has terminated
root@mininet-vm:/home/mininet# 

X "host h1"@mininet-vm
{
    "retransmits": 0,
    "sender": true
},
"sum_received": {
    "start": 0,
    "end": 10.003496,
    "seconds": 10.003496,
    "bytes": 48295387960,
    "bits_per_second": 38622807834.3811,
    "sender": true
},
"cpu_utilization_percent": {
    "host_total": 49.927598402621975,
    "host_user": 0.49908827803012146,
    "host_system": 49.428510124591853,
    "remote_total": 22.135543124307414,
    "remote_user": 1.1310876892456372,
    "remote_system": 21.004450958272429
},
"sender_tcp_congestion": "cubic",
"receiver_tcp_congestion": "cubic"
}
root@mininet-vm:/home/mininet#

```

Рис. 9: Экспорт результатов теста iPerf3 в файл JSON

```
mininet@mininet-vm:~$ cd /home/mininet/work/lab_iperf3
mininet@mininet-vm:~/work/lab_iperf3$ ls -l
total 8
-rw-r--r-- 1 root root 7782 Feb  4 12:58 iperf_results.json
mininet@mininet-vm:~/work/lab_iperf3$ |
```

Рис. 10: Проверка создания файла iperf\_results.json

```
mininet@mininet-vm:~/work/lab_iperf3$ xauth list $DISPLAY
mininet-vm/unix:10  MIT-MAGIC-COOKIE-1  fc04f721fac8ad00af30da488e9b15bd
mininet@mininet-vm:~/work/lab_iperf3$ sudo -i
root@mininet-vm:~# xauth list
mininet-vm/unix:10  MIT-MAGIC-COOKIE-1  fc04f721fac8ad00af30da488e9b15bd
root@mininet-vm:~# |
```

Рис. 11: Исправление прав запуска X-соединения

```
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 492 Feb  4 13:03 1.dat
-rw-rw-r-- 1 mininet mininet 9878 Feb  4 13:03 bytes.pdf
-rw-rw-r-- 1 mininet mininet 9620 Feb  4 13:03 cwnd.pdf
-rw-rw-r-- 1 mininet mininet 9036 Feb  4 13:03 MTU.pdf
-rw-rw-r-- 1 mininet mininet 8978 Feb  4 13:03 retransmits.pdf
-rw-rw-r-- 1 mininet mininet 8946 Feb  4 13:03 RTT.pdf
-rw-rw-r-- 1 mininet mininet 9220 Feb  4 13:03 RTT_Var.pdf
-rw-rw-r-- 1 mininet mininet 9576 Feb  4 13:03 throughput.pdf
mininet@mininet-vm:~/work/lab_iperf3/results$
```

Рис. 12: Визуализация результатов эксперимента