

# 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:
  aglfn aspell aspell-en bubblewrap enchant-2 evince-common fonts-liberation gnome-desktop3-data gnuplot-data groff hunsp
  libdjuvulibre21 libenchant-2-2 libevdocument3-4 libevview3-3 libgnome-desktop-3-19 libgspell-1-2 libgspell-1-common libg
  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-el git-email git-gui
  | openoffice.org-core imagemagick-doc autotrace cups-bsd | lpr | lprng curl enscript ffmpeg gimp grads graphviz hp2xx h
  udraw-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 gnup
  libdjuvulibre-text libdjuvulibre21 libenchant-2-2 libevdocument3-4 libevview3-3 libgnome-desktop-3-19 libgspell-1-2 libgs
  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.

```
"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
-----
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 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
[ 7]  0.00-10.00     sec  48.0 GBytes  41.2 Gbits/sec
-----
iperf Done.
root@mininet-vm:/home/mininet# ^C
root@mininet-vm:/home/mininet#
```

Рис. 2: Интерактивный эксперимент

```

"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 Mbits/sec
-----
[ ID] Interval          Transfer      Bitrate
[ 7] 0.00-5.00      sec  23.9 GBytes  41.0 Gbits/sec
-----
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    0
-----
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
[ 7] 0.00-5.00      sec  23.9 GBytes  41.0 Gbits/sec    0
-----
iperf Done.
root@mininet-vm:/home/mininet#

```

Рис. 3: Указание периода времени  $t=5$

```
"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
-----
Server listening on 5201
-----
^Ciperf3: interrupt - the server has terminated
root@mininet-vm:/home/mininet#

"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
[ 7]  0.00-5.00      sec  23.9 GBytes    41.0 Gbits/sec    0
-----
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
[ 7]  0.00-10.00     sec  51.8 GBytes    44.4 Gbits/sec    0
-----
iperf Done.
root@mininet-vm:/home/mininet#
```

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



```

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

```

Рис. 5: Задание определенного объема данных

```
"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
-----

"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



```

"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
-----
Server listening on 3250
-----
"host: h1"@mininet-vm
iver

lperf 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
[ 7]  0.00-10.00     sec  50.8 GBytes  43.6 Gbits/sec
-----
lperf Done.
root@mininet-vm:/home/mininet#

```

Рис. 7: Изменение номера порта для приема/отправки

```
"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#

"host: h1"@mininet-vm
[ 7] 0.00-10.00 sec     50.8 GBytes    43.6 Gbits/sec
receiver

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

```
"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
-----
Server listening on 5201
-----
^Ciperf3: interrupt - the server has terminated
root@mininet-vm:/home/mininet#

"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