

Лабораторная работа №2 Измерение и тестирование пропускной способности сети

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Цель работы

Основной целью работы является:

- Знакомство с инструментом iPerf3
- Проведение интерактивного эксперимента по измерению пропускной способности
- Изучение анализа результатов и визуализации

Задание

- Установить iPerf3 и дополнительное ПО на виртуальную машину Mininet
- Провести серию тестов пропускной способности
- Визуализировать результаты экспериментов

Теоретическое введение

iPerf3 — кроссплатформенное клиент-серверное приложение для измерения пропускной способности сети.

Протоколы:

- TCP и SCTP: измерение пропускной способности, MSS/MTU, CWnd
- UDP: измерение пропускной способности, потери пакетов, jitter, multicast

Mininet — эмулятор сети для развертывания виртуальных хостов, коммутаторов и тестирования сетевых протоколов.

Установка iPerf3

Запускаем виртуальную машину Mininet 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)
```

Установка программного обеспечения

Обновляем репозитории и устанавливаем iPerf3 и дополнительные утилиты.

```
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-en bubblewrap enchant-2 evince-common fonts-liberation gnome-desktop3-data gnuplot-data groff hunspell libdjvu libre21 libenchant-2-2 libevdocument3-4 libevview3-3 libgnome-desktop-3-19 libgspell-1-2 libgspell-1-common 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 | lpngr 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-en bubblewrap enchant-2 evince evince-common fonts-liberation gnome-desktop3-data gnuplot-data hunspell libdjvu libre21 libenchant-2-2 libevdocument3-4 libevview3-3 libgnome-desktop-3-19 libgspell-1-2 libgspell-1-common 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/ekfouri/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$
```

Настройка топологии

Создаем минимальную топологию из двух хостов и одного коммутатора (10.0.0.0/8).

```
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
```

Настройка параметров iPerf3

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

```
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#
```

Интервал отсчетов

Устанавливаем интервал 2 секунды (-i 2) для клиента и сервера.

```
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
```

Передача определенного объема данных

Используем ключ -n для задания объема данных.

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

Изменение протокола на UDP

Опция -u для клиента iPerf3.

```
"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 Datag
ramps
[ 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 Datag
ramps
[ 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   128 KBytes   1.05 Mbits/sec  91
```

Изменение номера порта

Задаем другой порт для передачи/приема пакетов.

```
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
-----
```

```
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
```

Сервер для одного клиента

Опция -1 для остановки сервера после завершения теста.

```
"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
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
```

Экспорт результатов

Сохраняем результаты в JSON файл.

```
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,
```

Проверка созданного файла

Проверяем наличие файла iperf_results.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$ |
```

Исправление прав X-соединения

Копируем MIT magic cookie для пользователя root.

```
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:~# |
```

Визуализация результатов

Проверяем права доступа и визуализируем результаты эксперимента.

```
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$
```

Вывод

В ходе работы:

- Освоен инструмент iPerf3
- Проведены интерактивные эксперименты по измерению пропускной способности
- Проанализированы результаты и визуализированы графики
- Получены практические навыки работы с Mininet и сетевыми инструментами