

Лабораторная работы №2

Измерение и тестирование пропускной способности сети. Интерактивный эксперимент

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Информация

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Теоретическое введение

Mininet - это эмулятор компьютерной сети. Под компьютерной сетью подразумеваются простые компьютеры — хосты, коммутаторы, а так же OpenFlow-контроллеры. С помощью простейшего синтаксиса в примитивном интерпретаторе команд можно разворачивать сети из произвольного количества хостов, коммутаторов в различных топологиях и все это в рамках одной виртуальной машины(VM). На всех хостах можно изменять сетевую конфигурацию, пользоваться стандартными утилитами(ifconfig, ping) и даже получать доступ к терминалу. На коммутаторы можно добавлять различные правила и маршрутизировать трафик.

Ход работы

Установка необходимого программного обеспечения

Установка необходимого программного обеспечения

```
mininet@mininet-vm:~$ ssh -Y mininet@192.168.56.113
mininet@192.168.56.113's password:
Welcome to Ubuntu 20.04.1 LTS (GNU/Linux 5.4.0-42-generic x86_64)

 * Documentation:  https://help.ubuntu.com
 * Management:    https://landscape.canonical.com
 * Support:       https://ubuntu.com/advantage

New release '22.04.5 LTS' available.
Run 'do-release-upgrade' to upgrade to it.

Last login: Sun Sep 21 05:05:49 2025 from 192.168.56.1
mininet@mininet-vm:~$ ifconfig
eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.56.113 netmask 255.255.255.0 broadcast 192.168.56.255
    ether 08:00:27:4b:bd:6c txqueuelen 1000 (Ethernet)
    RX packets 129 bytes 15387 (15.3 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 80 bytes 12497 (12.4 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:e5:93:e7 txqueuelen 1000 (Ethernet)
    RX packets 285 bytes 37360 (37.3 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 292 bytes 26829 (26.8 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 97 bytes 12542 (12.5 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 97 bytes 12542 (12.5 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

Рис. 1: Подключение к mininet по ssh


```
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 (104 kB/s)
```

Рис. 2: Установка ПО

```
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 | 1014.00 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
mininet@mininet-vm:/tmp/iperf3_plotter$
```

Рис. 3: Развертывание iperf3_plotter

Интерактивные эксперименты

Простейшая топология

```
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:11.0
*** Starting controller
c0
*** Starting 1 switches
s1 ...
```

Рис. 4: Задание простейшей топологии



```
"host: h2"@mininet-vm
root@mininet-vm:/home/mininet#

"host: h1"@mininet-vm
root@mininet-vm:/home/mininet#
```

Рис. 5: Задание простейшей топологии

Параметры запущенной в интерактивном режиме топологии

```
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)
```

Рис. 6: Параметры запущенной в интерактивном режиме топологии

```
mininet> dump
<Host h1: h1-eth0:10.0.0.1 pid=30201>
<Host h2: h2-eth0:10.0.0.2 pid=30203>
<OVSSwitch s1: lo:127.0.0.1,s1-eth1:None,s1-eth2:None pid=30208>
<Controller c0: 127.0.0.1:6653 pid=30194>
```

Рис. 7: Параметры запущенной в интерактивном режиме топологии

Тестовое соединение между хостами

```
root@mininet-vx:/home/mininet# iperf3 -c 10.0.0.2
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 43202 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer    Bitrate      Retr  Cwnd
[ 7] 0.00-1.00 sec  1.27 GBytes 10.9 Gbits/sec  0    178 KBytes
[ 7] 1.00-2.00 sec  1.24 GBytes 10.6 Gbits/sec  0    178 KBytes
[ 7] 2.00-3.00 sec  1.32 GBytes 11.3 Gbits/sec  0    178 KBytes
[ 7] 3.00-4.00 sec  1.21 GBytes 10.4 Gbits/sec  0    178 KBytes
[ 7] 4.00-5.00 sec  1.26 GBytes 10.9 Gbits/sec  0    178 KBytes
[ 7] 5.00-6.00 sec  1.18 GBytes 10.1 Gbits/sec  0    178 KBytes
[ 7] 6.00-7.00 sec  1.26 GBytes 10.8 Gbits/sec  0    178 KBytes
[ 7] 7.00-8.00 sec  1.26 GBytes 10.8 Gbits/sec  0    178 KBytes
[ 7] 8.00-9.00 sec  1.29 GBytes 11.1 Gbits/sec  0    178 KBytes
[ 7] 9.00-10.00 sec 1.26 GBytes 10.9 Gbits/sec  0    178 KBytes
-----
[ ID] Interval      Transfer    Bitrate      Retr  se
[ 7] 0.00-10.00 sec 12.6 GBytes 10.8 Gbits/sec  0
[ 7] 0.00-10.00 sec 12.6 GBytes 10.8 Gbits/sec
Ioerf Done.
```

Рис. 8: Тестовое соединение между хостами

```
root@mininet-vx:/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 43200
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 43202
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-1.00 sec  1.27 GBytes 10.9 Gbits/sec
[ 7] 1.00-2.00 sec  1.24 GBytes 10.6 Gbits/sec
[ 7] 2.00-3.00 sec  1.32 GBytes 11.3 Gbits/sec
[ 7] 3.00-4.00 sec  1.21 GBytes 10.4 Gbits/sec
[ 7] 4.00-5.00 sec  1.26 GBytes 10.9 Gbits/sec
[ 7] 5.00-6.00 sec  1.18 GBytes 10.1 Gbits/sec
[ 7] 6.00-7.00 sec  1.26 GBytes 10.8 Gbits/sec
[ 7] 7.00-8.00 sec  1.26 GBytes 10.8 Gbits/sec
[ 7] 8.00-9.00 sec  1.29 GBytes 11.1 Gbits/sec
[ 7] 9.00-10.00 sec 1.26 GBytes 10.9 Gbits/sec
[ 7] 10.00-10.00 sec 1.25 MBytes 6.72 Gbits/sec
-----
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-10.00 sec 12.6 GBytes 10.8 Gbits/sec
Server listening on 5201
```

Рис. 9: Тестовое соединение между хостами

Эксперимент в интерфейсе mininet

```
mininet> h2 iperf3 -s &
mininet> h1 iperf3 -c h2
Connecting to host 10.0.0.2, port 5201
[ 5] local 10.0.0.1 port 43210 connected to 10.0.0.2 port 5201
[ ID] Interval          Transfer      Bitrate      Retr  Cwnd
[ 5]  0.00-1.00    sec  1.20 GBytes  10.3 Gbits/sec    0   191 KBytes
[ 5]  1.00-2.00    sec  1.24 GBytes  10.7 Gbits/sec    0   191 KBytes
[ 5]  2.00-3.00    sec  1.13 GBytes  9.73 Gbits/sec    0   191 KBytes
[ 5]  3.00-4.00    sec  1.22 GBytes  10.5 Gbits/sec    0   191 KBytes
[ 5]  4.00-5.00    sec  1.24 GBytes  10.6 Gbits/sec    0   191 KBytes
[ 5]  5.00-6.00    sec  1.15 GBytes  9.92 Gbits/sec    0   191 KBytes
[ 5]  6.00-7.00    sec  1.15 GBytes  9.86 Gbits/sec    0   191 KBytes
[ 5]  7.00-8.00    sec  1.22 GBytes  10.5 Gbits/sec    0   191 KBytes
[ 5]  8.00-9.00    sec  1.32 GBytes  11.3 Gbits/sec    0   191 KBytes
[ 5]  9.00-10.00   sec  1.30 GBytes  11.2 Gbits/sec    0   191 KBytes
- - - - -
[ ID] Interval          Transfer      Bitrate      Retr
[ 5]  0.00-10.00   sec  12.2 GBytes  10.5 Gbits/sec    0
[ 5]  0.00-10.00   sec  12.2 GBytes  10.5 Gbits/sec
sender
receiver

iperf Done.
```

Рис. 10: Эксперимент в интерфейсе mininet

```
mininet> h2 killall iperf3
warning: this system does not seem to support IPv6 - trying IPv4
-----
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 43208
[ 5] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 43210
[ ID] Interval      Transfer    Bitrate
[ 5]  0.00-1.00    sec  1.20 GBytes  10.3 Gbits/sec
[ 5]  1.00-2.00    sec  1.24 GBytes  10.7 Gbits/sec
[ 5]  2.00-3.00    sec  1.13 GBytes  9.74 Gbits/sec
[ 5]  3.00-4.00    sec  1.22 GBytes  10.5 Gbits/sec
[ 5]  4.00-5.00    sec  1.24 GBytes  10.6 Gbits/sec
[ 5]  5.00-6.00    sec  1.15 GBytes  9.92 Gbits/sec
[ 5]  6.00-7.00    sec  1.15 GBytes  9.86 Gbits/sec
[ 5]  7.00-8.00    sec  1.22 GBytes  10.5 Gbits/sec
[ 5]  8.00-9.00    sec  1.32 GBytes  11.3 Gbits/sec
[ 5]  9.00-10.00   sec  1.31 GBytes  11.2 Gbits/sec
[ 5] 10.00-10.00   sec  1.06 MBytes  9.39 Gbits/sec
-----
[ ID] Interval      Transfer    Bitrate
[ 5]  0.00-10.00   sec  12.2 GBytes  10.5 Gbits/sec
-----
Server listening on 5201
-----
iperf3: interrupt - the server has terminated
```

Рис. 11: Завершение процесса на сервере

iPerf3 период времени для передачи

```
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 43226 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer    Bitrate      Retr  Cwnd
[ 7]  0.00-1.00 sec  1.25 GBytes 10.7 Gbits/sec  0   1.19 MBytes
[ 7]  1.00-2.00 sec  1.21 GBytes 10.4 Gbits/sec  0   1.19 MBytes
[ 7]  2.00-3.00 sec  1.16 GBytes 9.97 Gbits/sec  0   1.19 MBytes
[ 7]  3.00-4.00 sec  1.28 GBytes 11.0 Gbits/sec  0   1.19 MBytes
[ 7]  4.00-5.00 sec  1.25 GBytes 10.8 Gbits/sec  0   1.19 MBytes
- - - - -
[ ID] Interval      Transfer    Bitrate      Retr  Cwnd
[ 7]  0.00-5.00 sec  6.15 GBytes 10.6 Gbits/sec  0
[ 7]  0.00-5.00 sec  6.15 GBytes 10.6 Gbits/sec  0
iperf Done.
```

Рис. 12: Период времени передачи

```
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 43224
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 43226
[ ID] Interval      Transfer    Bitrate      Retr  Cwnd
[ 7]  0.00-1.00 sec  1.25 GBytes 10.7 Gbits/sec  0
[ 7]  1.00-2.00 sec  1.21 GBytes 10.4 Gbits/sec  0
[ 7]  2.00-3.00 sec  1.16 GBytes 9.96 Gbits/sec  0
[ 7]  3.00-4.00 sec  1.28 GBytes 11.0 Gbits/sec  0
[ 7]  4.00-5.00 sec  1.26 GBytes 10.8 Gbits/sec  0
- - - - -
[ ID] Interval      Transfer    Bitrate
[ 7]  0.00-5.00 sec  6.15 GBytes 10.6 Gbits/sec
Server listening on 5201
-----
```

Рис. 13: Период времени передачи

Тест пропускной способности с 2-секундным интервалом

```
root@mininet-vms:/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 43242 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer    Bitrate      Retr  Cwnd
[ 7]  0.00-2.00 sec  2.42 GBytes 10.4 Gbits/sec  0    229 Kbytes
[ 7]  2.00-4.00 sec  2.50 GBytes 10.7 Gbits/sec  0    229 Kbytes
[ 7]  4.00-6.00 sec  2.53 GBytes 10.9 Gbits/sec  0    229 Kbytes
[ 7]  6.00-8.00 sec  2.40 GBytes 10.3 Gbits/sec  0    229 Kbytes
[ 7]  8.00-10.00 sec 2.30 GBytes 9.87 Gbits/sec  0    229 Kbytes
- - - - -
[ ID] Interval      Transfer    Bitrate      Retr
[ 7]  0.00-10.00 sec 12.1 GBytes 10.4 Gbits/sec  0
[ 7]  0.00-10.00 sec 12.1 GBytes 10.4 Gbits/sec
iperf Done.
```

Рис. 14: Тест пропускной способности с 2-секундным интервалом

```
root@mininet-vms:/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 43240
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 43242
[ ID] Interval      Transfer    Bitrate
[ 7]  0.00-2.00 sec  2.42 GBytes 10.4 Gbits/sec
[ 7]  2.00-4.00 sec  2.50 GBytes 10.7 Gbits/sec
[ 7]  4.00-6.00 sec  2.53 GBytes 10.9 Gbits/sec
[ 7]  6.00-8.00 sec  2.40 GBytes 10.3 Gbits/sec
[ 7]  8.00-10.00 sec 2.30 GBytes 9.87 Gbits/sec
[ 7] 10.00-10.00 sec 897 Kbytes 4.45 Gbits/sec
- - - - -
[ ID] Interval      Transfer    Bitrate
[ 7]  0.00-10.00 sec 12.1 GBytes 10.4 Gbits/sec
Server Listening on 5201
```

Рис. 15: Тест пропускной способности с 2-секундным интервалом

Тест определённого объёма данных

```
root@mininet-vx:/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 43258 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer      Bitrate      Retr      Cwnd
[ 7] 0.00-1.00 sec  1.34 GBytes  11.5 Gbits/sec  0      622 KBytes
[ 7] 1.00-2.00 sec  1.30 GBytes  11.2 Gbits/sec  0      622 KBytes
[ 7] 2.00-3.00 sec  1.17 GBytes  10.0 Gbits/sec  0      622 KBytes
[ 7] 3.00-4.00 sec  1.22 GBytes  10.5 Gbits/sec  0      622 KBytes
[ 7] 4.00-5.00 sec  1.30 GBytes  11.2 Gbits/sec  0      622 KBytes
[ 7] 5.00-6.00 sec  1.24 GBytes  10.7 Gbits/sec  0      622 KBytes
[ 7] 6.00-7.00 sec  1.27 GBytes  10.9 Gbits/sec  0      622 KBytes
[ 7] 7.00-8.00 sec  1.27 GBytes  10.9 Gbits/sec  0      622 KBytes
[ 7] 8.00-9.00 sec  1.27 GBytes  10.9 Gbits/sec  0      622 KBytes
[ 7] 9.00-10.00 sec  1.25 GBytes  10.7 Gbits/sec  0      622 KBytes
[ 7] 10.00-11.00 sec  1.24 GBytes  10.7 Gbits/sec  0      622 KBytes
[ 7] 11.00-12.00 sec  1.19 GBytes  10.2 Gbits/sec  0      622 KBytes
[ 7] 12.00-12.74 sec  962 MBytes  11.0 Gbits/sec  0      622 KBytes
-----
[ ID] Interval      Transfer      Bitrate      Retr      se
[ 7] 0.00-12.74 sec  16.0 GBytes  10.8 Gbits/sec  0      re
[ 7] 0.00-12.74 sec  16.0 GBytes  10.8 Gbits/sec

iperf Done.
```

Рис. 16: Задание в тесте определённого объёма данных

```
root@h2:/mininet-ux
Accepted connection from 10.0.0.1, port 43256
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 43258
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-1.00 sec  1.33 GBytes  11.5 Gbits/sec
[ 7] 1.00-2.00 sec  1.30 GBytes  11.2 Gbits/sec
[ 7] 2.00-3.00 sec  1.17 GBytes  10.0 Gbits/sec
[ 7] 3.00-4.00 sec  1.22 GBytes  10.5 Gbits/sec
[ 7] 4.00-5.00 sec  1.30 GBytes  11.2 Gbits/sec
[ 7] 5.00-6.00 sec  1.24 GBytes  10.7 Gbits/sec
[ 7] 6.00-7.00 sec  1.27 GBytes  10.9 Gbits/sec
[ 7] 7.00-8.00 sec  1.27 GBytes  10.9 Gbits/sec
[ 7] 8.00-9.00 sec  1.27 GBytes  10.9 Gbits/sec
[ 7] 9.00-10.00 sec  1.25 GBytes  10.7 Gbits/sec
[ 7] 10.00-11.00 sec  1.24 GBytes  10.7 Gbits/sec
[ 7] 11.00-12.00 sec  1.19 GBytes  10.2 Gbits/sec
[ 7] 12.00-12.74 sec  963 MBytes  11.0 Gbits/sec
-----
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-12.74 sec  16.0 GBytes  10.8 Gbits/sec
-----
Server listening on 5201
```

Рис. 17: Задание в тесте определённого объёма данных

Протокол транспортного уровня на стороне сервера

```
root@mininet-vms:/home/mininet# iperf3 -c 10.0.0.2 -u
iperf3: error - unable to connect to server: Connection refused
root@mininet-vms:/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 41239 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer      Bitrate      Total Data
[ 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
rams
[ 7] 0.00-10.00 sec  1.25 MBytes    1.05 Mbits/sec  0.000
er
[ 7] 0.00-10.00 sec  1.25 MBytes    1.05 Mbits/sec  0.011
iver

iperf Done.
```

Рис. 18: Протокол передачи данных

```
root@mininet-vms:/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 43274
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 41239
[ ID] Interval      Transfer      Bitrate      Jitter
rams
[ 7] 0.00-1.00 sec    129 KBytes    1.05 Mbits/sec  0.070 ms
[ 7] 1.00-2.00 sec    127 KBytes    1.04 Mbits/sec  0.019
[ 7] 2.00-3.00 sec    129 KBytes    1.05 Mbits/sec  0.041
[ 7] 3.00-4.00 sec    127 KBytes    1.04 Mbits/sec  0.018
[ 7] 4.00-5.00 sec    129 KBytes    1.05 Mbits/sec  0.079
[ 7] 5.00-6.00 sec    127 KBytes    1.04 Mbits/sec  0.012
[ 7] 6.00-7.00 sec    129 KBytes    1.05 Mbits/sec  0.014
[ 7] 7.00-8.00 sec    127 KBytes    1.04 Mbits/sec  0.010
[ 7] 8.00-9.00 sec    129 KBytes    1.05 Mbits/sec  0.035
[ 7] 9.00-10.00 sec   127 KBytes    1.04 Mbits/sec  0.009
[ 7] 10.00-10.00 sec   1.41 KBytes    3.47 Mbits/sec  0.011
- - - - -
[ ID] Interval      Transfer      Bitrate      Jitter
rams
[ 7] 0.00-10.00 sec  1.25 MBytes    1.05 Mbits/sec  0.011
iver
```

Рис. 19: Протокол передачи данных

Тест измерения пропускной способности iPerf3

```
X Node h1@mininet-vm
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 43962 connected to 10.0.0.2 port 3250
[ ID] Interval      Transfer    Bitrate      Retr  Cwnd
[ 7]  0.00-1.00 sec   1.30 GBytes 11.2 Gbits/sec  0    583 Kbytes
[ 7]  1.00-2.00 sec   1.30 GBytes 11.2 Gbits/sec  0    583 Kbytes
[ 7]  2.00-3.00 sec   1.16 GBytes  9.98 Gbits/sec  0    583 Kbytes
[ 7]  3.00-4.00 sec   1.16 GBytes 10.6 Gbits/sec  0    583 Kbytes
[ 7]  4.00-5.00 sec   1.16 GBytes  9.93 Gbits/sec  0    583 Kbytes
[ 7]  5.00-6.00 sec   1.30 GBytes 11.1 Gbits/sec  0    583 Kbytes
[ 7]  6.00-7.00 sec   1.31 GBytes 11.2 Gbits/sec  0    583 Kbytes
[ 7]  7.00-8.00 sec   1.31 GBytes 11.2 Gbits/sec  0    583 Kbytes
[ 7]  8.00-9.00 sec   1.27 GBytes 10.9 Gbits/sec  0    583 Kbytes
[ 7]  9.00-10.00 sec  1.23 GBytes 10.6 Gbits/sec  0    583 Kbytes
- - - - -
[ ID] Interval      Transfer    Bitrate      Retr
[ 7]  0.00-10.00 sec 12.5 GBytes 10.7 Gbits/sec  0
[ 7]  0.00-10.00 sec 12.5 GBytes 10.7 Gbits/sec  0
iperf Done.
```

Рис. 20: Номер порта для отправки/получения пакетов

```
X Node h2@mininet-vm
-----
Server listening on 3250
-----
Accepted connection from 10.0.0.1, port 43960
[ 7] local 10.0.0.2 port 3250 connected to 10.0.0.1 port 43962
[ ID] Interval      Transfer    Bitrate      Retr  Cwnd
[ 7]  0.00-1.00 sec   1.30 GBytes 11.2 Gbits/sec  0    583 Kbytes
[ 7]  1.00-2.00 sec   1.30 GBytes 11.2 Gbits/sec  0    583 Kbytes
[ 7]  2.00-3.00 sec   1.16 GBytes  9.98 Gbits/sec  0    583 Kbytes
[ 7]  3.00-4.00 sec   1.16 GBytes 10.6 Gbits/sec  0    583 Kbytes
[ 7]  4.00-5.00 sec   1.16 GBytes  9.94 Gbits/sec  0    583 Kbytes
[ 7]  5.00-6.00 sec   1.29 GBytes 11.1 Gbits/sec  0    583 Kbytes
[ 7]  6.00-7.00 sec   1.31 GBytes 11.2 Gbits/sec  0    583 Kbytes
[ 7]  7.00-8.00 sec   1.31 GBytes 11.2 Gbits/sec  0    583 Kbytes
[ 7]  8.00-9.00 sec   1.27 GBytes 10.9 Gbits/sec  0    583 Kbytes
[ 7]  9.00-10.00 sec  1.23 GBytes 10.6 Gbits/sec  0    583 Kbytes
[ 7] 10.00-10.00 sec  1.38 Mbytes  6.54 Gbits/sec  0    583 Kbytes
- - - - -
[ ID] Interval      Transfer    Bitrate
[ 7]  0.00-10.00 sec 12.5 GBytes 10.7 Gbits/sec
-----
Server listening on 3250
-----
```

Рис. 21: Номер порта для отправки/получения пакетов

Параметр обработки данных только от одного клиента с остановкой сервера по завершении теста

```
root@mininet-vn:/home/mininet# iperf3 -c 10.0.0.2
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 43306 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer    Bitrate      Retr  Cwnd
[ 7] 0.00-1.00 sec  1.33 GBytes 11.4 Gbits/sec  0    215 KBytes
[ 7] 1.00-2.00 sec  1.21 GBytes 10.4 Gbits/sec  0    215 KBytes
[ 7] 2.00-3.00 sec  1.22 GBytes 10.5 Gbits/sec  0    215 KBytes
[ 7] 3.00-4.00 sec  1.37 GBytes 11.0 Gbits/sec  0    215 KBytes
[ 7] 4.00-5.00 sec  1.17 GBytes 10.1 Gbits/sec  0    215 KBytes
[ 7] 5.00-6.00 sec  1.23 GBytes 10.6 Gbits/sec  0    215 KBytes
[ 7] 6.00-7.00 sec  1.18 GBytes 10.1 Gbits/sec  0    215 KBytes
[ 7] 7.00-8.00 sec  1.22 GBytes 10.5 Gbits/sec  0    215 KBytes
[ 7] 8.00-9.00 sec  1.24 GBytes 10.7 Gbits/sec  0    215 KBytes
[ 7] 9.00-10.00 sec 1.25 GBytes 10.7 Gbits/sec  0    215 KBytes
- - - - -
[ ID] Interval      Transfer    Bitrate      Retr  se
[ 7] 0.00-10.00 sec 12.4 GBytes 10.7 Gbits/sec  0      se
[ 7] 0.00-10.00 sec 12.4 GBytes 10.7 Gbits/sec              re

iperf Done.
```

Рис. 22: Параметр обработки данных только от одного клиента с остановкой сервера по завершении теста

```
root@mininet-vn:/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 43304
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 43306
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-1.00 sec  1.33 GBytes 11.4 Gbits/sec
[ 7] 1.00-2.00 sec  1.21 GBytes 10.4 Gbits/sec
[ 7] 2.00-3.00 sec  1.22 GBytes 10.5 Gbits/sec
[ 7] 3.00-4.00 sec  1.37 GBytes 11.0 Gbits/sec
[ 7] 4.00-5.00 sec  1.17 GBytes 10.1 Gbits/sec
[ 7] 5.00-6.00 sec  1.23 GBytes 10.6 Gbits/sec
[ 7] 6.00-7.00 sec  1.18 GBytes 10.1 Gbits/sec
[ 7] 7.00-8.00 sec  1.22 GBytes 10.5 Gbits/sec
[ 7] 8.00-9.00 sec  1.24 GBytes 10.7 Gbits/sec
[ 7] 9.00-10.00 sec 1.25 GBytes 10.7 Gbits/sec
[ 7] 10.00-10.00 sec 1.12 Mbytes 4.57 Gbits/sec
- - - - -
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-10.00 sec 12.4 GBytes 10.7 Gbits/sec
```

Рис. 23: Параметр обработки данных только от одного клиента с остановкой сервера по завершении теста

Результаты теста измерения пропускной способности iPerf3 в файл JSON.

```
Node h1@mininet-vm
{
  "retransmits": 0,
  "sender": true
},
"sum_received": {
  "start": 0,
  "end": 10.001408,
  "seconds": 10.001408,
  "bytes": 12263959168,
  "bits_per_second": 10008953593.734083,
  "sender": true
},
"cpu_utilization_percent": {
  "host_total": 52.658902971520348,
  "host_user": 2.1362741667406511,
  "host_system": 50.528618818120876,
  "remote_total": 24.391068910135228,
  "remote_user": 2.9284485161657842,
  "remote_system": 21.462584370498885
},
"sender_tcp_congestion": "cubic",
"receiver_tcp_congestion": "cubic"
}
```

Рис. 24: Экспорт результатов теста измерения пропускной способности iPerf3 в файл JSON

```
Node h2@mininet-vm
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 43320
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 43320
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-1.00 sec  1.25 GBytes 10.7 Gbits/sec
[ 7] 1.00-2.00 sec  1.20 GBytes 10.3 Gbits/sec
[ 7] 2.00-3.00 sec  1.23 GBytes 10.5 Gbits/sec
[ 7] 3.00-4.00 sec  1.21 GBytes 10.4 Gbits/sec
[ 7] 4.00-5.00 sec  1.33 GBytes 11.4 Gbits/sec
[ 7] 5.00-6.00 sec  1.18 GBytes 10.1 Gbits/sec
[ 7] 6.00-7.00 sec  1.23 GBytes 10.6 Gbits/sec
[ 7] 7.00-8.00 sec  1.28 GBytes 11.0 Gbits/sec
[ 7] 8.00-9.00 sec  1.17 GBytes 10.0 Gbits/sec
[ 7] 9.00-10.00 sec 1.28 GBytes 11.0 Gbits/sec
[ 7] 10.00-10.00 sec 768 KBytes  4.84 Gbits/sec
-----
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-10.00 sec 12.4 GBytes 10.6 Gbits/sec
-----
Server listening on 5201
```

Рис. 25: Экспорт результатов теста измерения пропускной способности iPerf3 в файл JSON

```
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# cd /home/mininet/work/lab_iperf3
root@mininet-vm:/home/mininet/work/lab_iperf3# ls -l
total 8
-rw-r--r-- 1 root root 7792 Sep 21 08:19 iperf_results.json
```

Рис. 26: Проверка создания файла iperf_results.json


```
mininet@mininet-vm:~$ xauth list $DISPLAY
mininet-vm/unix:11 MIT-MAGIC-COOKIE-1 6ea604d21b9b822852c1d9eb6bd8da5b
mininet@mininet-vm:~$ sudo -i
root@mininet-vm:~# xauth list $DISPLAY
root@mininet-vm:~# xauth add mininet-vm/unix:11 MIT-MAGIC-COOKIE-1 6ea604d21b9b8
22852c1d9eb6bd8da5b
root@mininet-vm:~# xauth list $DISPLAY
mininet-vm/unix:11 MIT-MAGIC-COOKIE-1 6ea604d21b9b822852c1d9eb6bd8da5b
root@mininet-vm:~# logout
```

Рис. 27: Исправление прав запуска X-соединения

Визуализируем результаты эксперимента

```
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  946 Sep 21 08:28 iperf.csv
-rw-r--r-- 1 mininet mininet 7792 Sep 21 08:19 iperf_results.json
drwxrwxr-x 2 mininet mininet 4096 Sep 21 08:28 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 Sep 21 08:28 1.dat
-rw-rw-r-- 1 mininet mininet 9791 Sep 21 08:28 bytes.pdf
-rw-rw-r-- 1 mininet mininet 9654 Sep 21 08:28 cwnd.pdf
-rw-rw-r-- 1 mininet mininet 9036 Sep 21 08:28 MTU.pdf
-rw-rw-r-- 1 mininet mininet 8978 Sep 21 08:28 retransmits.pdf
-rw-rw-r-- 1 mininet mininet 8920 Sep 21 08:28 RTT.pdf
-rw-rw-r-- 1 mininet mininet 9104 Sep 21 08:28 RTT_Var.pdf
-rw-rw-r-- 1 mininet mininet 9532 Sep 21 08:28 throughput.pdf
```

Рис. 28: Визуализация результатов эксперимента

Выводы

В результате выполнения данной лабораторной работы я познакомилась с инструментом для измерения пропускной способности сети в режиме реального времени — iPerf3, а также получила навыки проведения интерактивного эксперимента по измерению пропускной способности моделируемой сети в среде Mininet.

Спасибо за внимание!