

Лабораторная работа №5

Эмуляция и измерение потерь пакетов в глобальных сетях

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Цели и задачи

Цель лабораторной работы

Основной целью работы является получение навыков проведения интерактивных экспериментов в среде Mininet по исследованию параметров сети, связанных с потерей, дублированием, изменением порядка и повреждением пакетов при передаче данных. Эти параметры влияют на производительность протоколов и сетей.

1. Задайте простейшую топологию, состоящую из двух хостов и коммутатора с назначенной по умолчанию mininet сетью 10.0.0.0/8.
2. Проведите интерактивные эксперименты по исследованию параметров сети, связанных с потерей, дублированием, изменением порядка и повреждением пакетов при передаче данных.
3. Реализуйте воспроизводимый эксперимент по добавлению правила отбрасывания пакетов в эмулируемой глобальной сети. На экран выведите сводную информацию о потерянных пакетах.
4. Самостоятельно реализуйте воспроизводимые эксперименты по исследованию параметров сети, связанных с потерей, изменением порядка и повреждением пакетов при передаче данных.

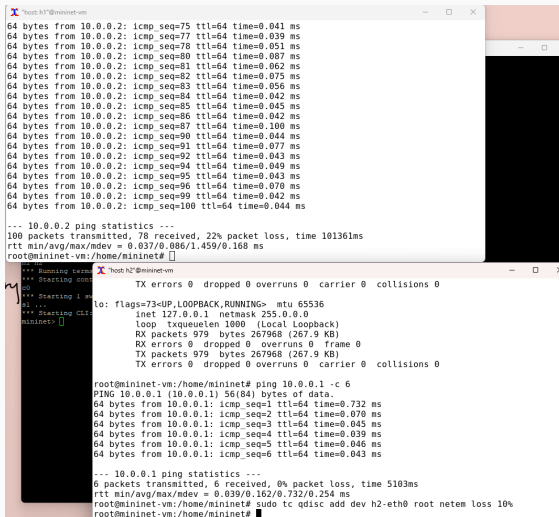
Процесс выполнения лабораторной работы

```
root@mininet-vm:/home/mininet# ping 10.0.0.2 -c 6
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=1.63 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.170 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.038 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.047 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.038 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.068 ms

--- 10.0.0.2 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5091ms
rtt min/avg/max/mdev = 0.038/0.332/1.631/0.582 ms
root@mininet-vm:/home/mininet#
```

Рис. 1: Проверка подключение от h1 к h2

Добавление потери пакетов на интерфейс, подключённый к эмулируемой глобальной сети



```
root@h1~# mininet-vn
64 bytes from 10.0.0.2: icmp_seq=75 ttl=64 time=0.041 ms
64 bytes from 10.0.0.2: icmp_seq=77 ttl=64 time=0.039 ms
64 bytes from 10.0.0.2: icmp_seq=78 ttl=64 time=0.051 ms
64 bytes from 10.0.0.2: icmp_seq=80 ttl=64 time=0.087 ms
64 bytes from 10.0.0.2: icmp_seq=81 ttl=64 time=0.062 ms
64 bytes from 10.0.0.2: icmp_seq=82 ttl=64 time=0.075 ms
64 bytes from 10.0.0.2: icmp_seq=83 ttl=64 time=0.056 ms
64 bytes from 10.0.0.2: icmp_seq=84 ttl=64 time=0.042 ms
64 bytes from 10.0.0.2: icmp_seq=85 ttl=64 time=0.045 ms
64 bytes from 10.0.0.2: icmp_seq=86 ttl=64 time=0.042 ms
64 bytes from 10.0.0.2: icmp_seq=87 ttl=64 time=0.100 ms
64 bytes from 10.0.0.2: icmp_seq=90 ttl=64 time=0.044 ms
64 bytes from 10.0.0.2: icmp_seq=91 ttl=64 time=0.077 ms
64 bytes from 10.0.0.2: icmp_seq=92 ttl=64 time=0.043 ms
64 bytes from 10.0.0.2: icmp_seq=94 ttl=64 time=0.049 ms
64 bytes from 10.0.0.2: icmp_seq=95 ttl=64 time=0.043 ms
64 bytes from 10.0.0.2: icmp_seq=96 ttl=64 time=0.070 ms
64 bytes from 10.0.0.2: icmp_seq=99 ttl=64 time=0.042 ms
64 bytes from 10.0.0.2: icmp_seq=100 ttl=64 time=0.044 ms

--- 10.0.0.2 ping statistics ---
100 packets transmitted, 78 received, 22% packet loss, time 101361ms
rtt min/avg/max/mdev = 0.037/0.086/1.459/0.168 ms
root@mininet-vn:/home/mininet#

*** Running command: 'cat /dev/null > /dev/null'
*** Starting command: 'cat /dev/null > /dev/null'
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

*** Starting 1 s
to: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
inet 127.0.0.1 netmask 255.0.0.0
loop txqueuelen 1000 (Local Loopback)
RX packets 979 bytes 267968 (267.9 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 979 bytes 267968 (267.9 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

root@mininet-vn:/home/mininet# ping 10.0.0.1 -c 6
PING 10.0.0.1 (10.0.0.1) 56(84) bytes of data:
64 bytes from 10.0.0.1: icmp_seq=1 ttl=64 time=0.732 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=0.070 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=0.045 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=0.039 ms
64 bytes from 10.0.0.1: icmp_seq=5 ttl=64 time=0.046 ms
64 bytes from 10.0.0.1: icmp_seq=6 ttl=64 time=0.043 ms

--- 10.0.0.1 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5103ms
rtt min/avg/max/mdev = 0.039/0.162/0.732/0.254 ms
root@mininet-vn:/home/mininet# sudo tc qdisc add dev h2-eth0 root netem loss 10%
root@mininet-vn:/home/mininet#
```

Рис. 2: Добавление 10% потери пакетов на хосте h2

Добавление значения корреляции для потери пакетов в эмулируемой глобальной сети

```
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root netem loss 50% 50%
root@mininet-vm:/home/mininet# ping 10.0.0.2 -c 50
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=0.788 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.656 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.156 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=0.071 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=0.049 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=0.055 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.065 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=0.055 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=0.117 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=0.054 ms
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=0.093 ms
64 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=0.041 ms
64 bytes from 10.0.0.2: icmp_seq=21 ttl=64 time=0.062 ms
64 bytes from 10.0.0.2: icmp_seq=24 ttl=64 time=0.043 ms
64 bytes from 10.0.0.2: icmp_seq=25 ttl=64 time=0.071 ms
64 bytes from 10.0.0.2: icmp_seq=27 ttl=64 time=0.052 ms
64 bytes from 10.0.0.2: icmp_seq=30 ttl=64 time=0.047 ms
64 bytes from 10.0.0.2: icmp_seq=31 ttl=64 time=0.042 ms
64 bytes from 10.0.0.2: icmp_seq=32 ttl=64 time=0.050 ms
64 bytes from 10.0.0.2: icmp_seq=33 ttl=64 time=0.364 ms
64 bytes from 10.0.0.2: icmp_seq=35 ttl=64 time=0.045 ms
64 bytes from 10.0.0.2: icmp_seq=36 ttl=64 time=0.042 ms
64 bytes from 10.0.0.2: icmp_seq=39 ttl=64 time=0.055 ms
64 bytes from 10.0.0.2: icmp_seq=40 ttl=64 time=0.042 ms
64 bytes from 10.0.0.2: icmp_seq=41 ttl=64 time=0.134 ms
64 bytes from 10.0.0.2: icmp_seq=43 ttl=64 time=0.151 ms
64 bytes from 10.0.0.2: icmp_seq=44 ttl=64 time=0.042 ms
64 bytes from 10.0.0.2: icmp_seq=45 ttl=64 time=0.043 ms
64 bytes from 10.0.0.2: icmp_seq=46 ttl=64 time=0.056 ms
64 bytes from 10.0.0.2: icmp_seq=48 ttl=64 time=0.085 ms
64 bytes from 10.0.0.2: icmp_seq=49 ttl=64 time=0.037 ms

--- 10.0.0.2 ping statistics ---
50 packets transmitted, 31 received, 38% packet loss, time 50138ms
rtt min/avg/max/mdev = 0.037/0.118/0.788/0.170 ms
root@mininet-vm:/home/mininet#
```

Рис. 3: Добавление значения корреляции

Добавление повреждения пакетов в эмулируемой глобальной сети

```
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root netem
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root netem corrupt 0.01%
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 52860 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer    Bitrate      Retr  Cwnd
[ 7] 0.00-1.00 sec  2.18 GBytes 18.7 Gbits/sec 17   3.07 MBytes
[ 7] 1.00-2.00 sec  2.18 GBytes 18.7 Gbits/sec 20   2.15 MBytes
[ 7] 2.00-3.00 sec  2.10 GBytes 18.0 Gbits/sec 17   2.15 MBytes
[ 7] 3.00-4.00 sec  2.15 GBytes 18.5 Gbits/sec 11   1.50 MBytes
[ 7] 4.00-5.00 sec  2.20 GBytes 18.9 Gbits/sec 12   1.50 MBytes
[ 7] 5.00-6.00 sec  2.15 GBytes 18.5 Gbits/sec 19   1.05 MBytes
[ 7] 6.00-7.00 sec  2.05 GBytes 17.6 Gbits/sec 16   1.05 MBytes
[ 7] 7.00-8.00 sec  1.74 GBytes 14.9 Gbits/sec 18    754 KBytes
[ 7] 8.00-9.00 sec  1.73 GBytes 14.9 Gbits/sec 19    617 KBytes
[ 7] 9.00-10.00 sec 1.94 GBytes 16.7 Gbits/sec 10    754 KBytes
- - - - -
[ ID] Interval      Transfer    Bitrate      Retr
[ 7] 0.00-10.00 sec 20.4 GBytes 17.6 Gbits/sec 159
[ 7] 0.00-10.00 sec 20.4 GBytes 17.5 Gbits/sec
sender
receiver
```

iperf Done.

```
root@mininet-vm:/home/mininet#
```

```
*** Starting connection
*** Starting listener
*** Starting CLI
mininet>
Warning: this system does not seem to support IPv6 - trying IPv4
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 52858
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 52860
[ ID] Interval      Transfer    Bitrate      Retr  Cwnd
[ 7] 0.00-1.00 sec  2.16 GBytes 18.5 Gbits/sec 17   3.07 MBytes
[ 7] 1.00-2.00 sec  2.18 GBytes 18.7 Gbits/sec 20   2.15 MBytes
[ 7] 2.00-3.00 sec  2.10 GBytes 18.0 Gbits/sec 17   2.15 MBytes
[ 7] 3.00-4.00 sec  2.15 GBytes 18.5 Gbits/sec 11   1.50 MBytes
[ 7] 4.00-5.00 sec  2.20 GBytes 18.9 Gbits/sec 12   1.50 MBytes
[ 7] 5.00-6.00 sec  2.16 GBytes 18.5 Gbits/sec 19   1.05 MBytes
[ 7] 6.00-7.00 sec  2.05 GBytes 17.6 Gbits/sec 16   1.05 MBytes
[ 7] 7.00-8.00 sec  1.74 GBytes 15.0 Gbits/sec 18    754 KBytes
[ 7] 8.00-9.00 sec  1.73 GBytes 14.9 Gbits/sec 19    617 KBytes
[ 7] 9.00-10.00 sec 1.94 GBytes 16.7 Gbits/sec 10    754 KBytes
- - - - -
[ ID] Interval      Transfer    Bitrate      Retr
[ 7] 0.00-10.00 sec 20.4 GBytes 17.5 Gbits/sec 159
Server listening on 5201
receiver
```

Рис. 4: Добавление повреждения пакетов

Добавление переупорядочивания пакетов в интерфейс подключения к эмулируемой глобальной сети

```
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root netem
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root netem delay 10ms reorder 25% 50%
root@mininet-vm:/home/mininet# ping 10.0.0.2 -c 20
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=11.8 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=11.1 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=10.2 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.059 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=10.7 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=10.1 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=10.8 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=10.6 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=10.7 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=10.7 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=10.8 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=10.1 ms
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=10.8 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=10.7 ms
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=10.5 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=10.5 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=10.1 ms
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=10.5 ms
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=10.7 ms
64 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=10.7 ms

--- 10.0.0.2 ping statistics ---
20 packets transmitted, 20 received, 0% packet loss, time 19041ms
rtt min/avg/max/mdev = 0.059/10.108/11.778/2.335 ms
root@mininet-vm:/home/mininet#
```

Рис. 5: Добавление переупорядочивания пакетов

Добавление дублирования пакетов в интерфейс подключения к эмулируемой глобальной сети

```
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root netem
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root netem duplicate 50%
root@mininet-vm:/home/mininet# ping 10.0.0.2 -c 20
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data:
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=0.839 ms
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=0.869 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.537 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.143 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.442 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.050 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.043 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.055 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=0.043 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=0.073 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=0.049 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=0.045 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=0.045 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.098 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.098 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=0.076 ms
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=0.049 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=0.057 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=0.057 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=0.083 ms
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=0.083 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=0.042 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=0.046 ms
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=0.060 ms
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=0.061 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=0.042 ms
64 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=0.066 ms

--- 10.0.0.2 ping statistics ---
20 packets transmitted, 20 received, +7 duplicates, 0% packet loss, time 19441ms
rtt min/avg/max/mdev = 0.042/0.153/0.869/0.228 ms
root@mininet-vm:/home/mininet#
```

Рис. 6: Добавление дублирования пакетов

Воспроизведение экспериментов

```
mininet@mininet-wm1:~/work/lab_netem_ii/simple-drop0 make
sudo python lab_netem_ii.py
*** Adding controller
*** Adding hosts
*** Adding switch
*** Creating links
*** Starting network
*** Configuring hosts
h1 h2
*** Starting controller
s0
*** Starting 1 switches
s1 ...
*** Waiting for switches to connect
s1
*** Set delay
*** h1 : ('tc qdisc add dev h1-eth0 root netem loss 10%,)
*** h2 : ('tc qdisc add dev h2-eth0 root netem loss 10%,)
*** Ping
*** h1 : ('ping -c 100', '10.0.0.2', '| grep "time=" | awk \'{print $5, $7}\\' | sed -e \'s/time=//g\' -e \'s/icmp_seq=//g\' > ping.dat')
*** Stopping network*** Stopping 1 controllers
s0
*** Stopping 2 links
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
sudo python ping.py > ping.txt
cat ping.txt
Total packets: 100
Lost packets: 23
Lost packet numbers: [3, 7, 13, 18, 23, 26, 31, 37, 48, 49, 52, 53, 59, 62, 63, 66, 68, 70, 85, 86, 88, 93, 95]
Loss percentage: 23.00%
```

Рис. 7: Выполните эксперимент

Воспроизведение экспериментов - добавление значения корреляции

```
mininet@mininet-vm:~/work/lab_netem_ii/correlation-drop$ make
sudo python lab_netem_ii.py
*** Adding controller
*** Adding hosts
*** Adding switch
*** Creating links
*** Starting network
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ...
*** Waiting for switches to connect
s1
*** Set delay
*** h1 : ('to qdisc add dev hl-eth0 root netem loss 50% 50%',)
*** Ping
*** h1 : ('ping -c 100', '10.0.0.2', '| grep "time=" | awk '{(print $5, $7)}' | sed -e \"s/time=//g\" -e \"s/icmp_seq=//g\" > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 2 links
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
./ping_plot
sudo python ping.py > ping.txt
cat ping.txt
Total packets: 100
Lost packets: 50
Lost packet numbers: [2, 3, 4, 5, 6, 7, 9, 10, 11, 14, 15, 18, 20, 22, 23, 24, 26, 27, 28, 30, 33, 35, 36, 37, 38, 39, 41, 43, 44, 46, 48, 52, 53,
40, 61, 66, 67, 68, 73, 75, 77, 78, 80, 81, 88, 89, 90, 91, 96, 100]
Loss percentage: 50.00%
Total packets: 100
Lost packets: 50
Lost packet numbers: [2, 3, 4, 5, 6, 7, 9, 10, 11, 14, 15, 18, 20, 22, 23, 24, 26, 27, 28, 30, 33, 35, 36, 37, 38, 39, 41, 43, 44, 46, 48, 52, 53,
40, 61, 66, 67, 68, 73, 75, 77, 78, 80, 81, 88, 89, 90, 91, 96, 100]
Duplicated packets: 0
Duplicated packet numbers: []
Loss percentage: 50.00%
mininet@mininet-vm:~/work/lab_netem_ii/correlation-drop$
```

Рис. 8: Выполнение эксперимент

Воспроизведение экспериментов - добавление повреждения пакетов

```
mininet@mininet-vm:~/work/lab_netem_ii/corruption-drop$ make
sudo python lab_netem_ii.py
*** Adding controller
*** Adding hosts
*** Adding switch
*** Creating links
*** Starting network
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ...
*** Waiting for switches to connect
s1
*** Set delay
*** h1 : ('tc qdisc add dev h1-eth0 root netem corrupt 0.01%')
*** Traffic generation
*** h2 : ('iperf3 -s -D -l',)
*** h1 : ('iperf3 -c', '10.0.0.2', '-J > iperf_result.json')
*** Ping
*** h1 : ('ping -c 100', '10.0.0.2', '| grep "time=" | awk '{print $5, $7}' | sed -e 's/time=//g' -e 's/icmp_seq=//g' > ping.dat')
```

Рис. 9: Выполнение эксперимент

Воспроизведение экспериментов - добавление переупорядочивания пакетов

```
mininet@mininet-vm:~/work/lab_netem_i1/reorder-drop$ make
sudo python lab_netem_i1.py
*** Adding controller
*** Adding hosts
*** Adding switch
*** Creating links
*** Starting network
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ...
*** Waiting for switches to connect
s1
*** Set delay
*** h1 : ('tc qdisc add dev h1-eth0 root netem delay 10ms reorder 25% 25%')
*** Ping
*** h1 : ('ping -c 100', '10.0.0.2', '| grep "time=" | awk '{print $5, $7}' | sed -e 's/time=//g\' -e 's/icmp_seq=//g\' > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 2 links
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
./ping_plot
sudo python ping.py > ping.txt
cat ping.txt
Total packets: 100
Lost packets: 0
Lost packet numbers: []
Loss percentage: 0.00%
Total packets: 100
Lost packets: 0
Lost packet numbers: []
Duplicated packets: 0
Duplicated packet numbers: []
Loss percentage: 0.00%
```

Рис. 10: Выполнение эксперимент

Воспроизведение экспериментов - добавление дублирования пакетов

```
mininet@mininet-vml:/work/lab_netem_ii/duplicate-drop$ make
sudo python lab_netem_ii.py
*** Adding controller
*** Adding hosts
*** Adding switch
*** Creating links
*** Starting network
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ...
*** Waiting for switches to connect
s1
*** Set delay
*** h1 : ('tc qdisc add dev h1-eth0 root netem duplicate 50%'.)
*** Ping
*** h1 : ('ping -c 100', '10.0.0.2', '| grep "time=" | awk '{print $5, $7}' | sed -e \"s/time=//g\" -e \"s/icmp_seq=//g\" > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 2 links
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
./ping_plot
sudo python ping.py > ping.txt
cat ping.txt
Total packets: 100
Lost packets: 0
Lost packet numbers: []
Loss percentage: 0.00%
Total packets: 100
Lost packets: 0
Lost packet numbers: []
Duplicated packets: 50
Duplicated packet numbers: [2, 5, 9, 12, 14, 17, 18, 20, 22, 23, 24, 25, 27, 28, 29, 31, 33, 36, 40, 41, 43, 44, 50, 51, 52, 54, 56, 57, 60, 61, 63, 64, 65, 66, 69, 70, 72, 77, 78, 81, 84, 88, 89, 92, 93, 95, 96, 97, 98, 99]
Loss percentage: 0.00%
```

Рис. 11: Выполнение эксперимент

Выводы по проделанной работе

Получила навыков проведения интерактивных экспериментов в среде Mininet по исследованию параметров сети, связанных с потерей, дублированием, изменением порядка и повреждением пакетов при передаче данных. Эти параметры влияют на производительность протоколов и сетей.