Лабораторная работа № 5

Эмуляция и измерение потерь пакетов в глобальных сетях

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Информация

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Вводная часть

Цели и задачи

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 по исследованию параметров сети, связанных с потерей, дублированием, изменением порядка и повре- ждением пакетов при передаче данных.
3. Реализуйте воспроизводимый эксперимент по добавлению правила отбрасы- вания пакетов в эмулируемой глобальной сети. На экран выведите сводную информацию о потерянных пакетах.
4. Самостоятельно реализуйте воспроизводимые эксперименты по иссле- дованию параметров сети, связанных с потерей, изменением порядка и повреждением пакетов при передаче данных. На экран выведите сводную информацию о потерянных пакетах.

Результаты

Поставленные боевые задачи были выполнены, все цели достигнуты.

Выполнение лабораторной работы

1. Запуск простейшей топологии

```
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:10.0
** Starting controller
c0
** Starting 1 switches
s1 ...
** Starting CLI:
mininet>
mininet>
```

```
root@mininet-vm:/home/mininet# ifconfig
h1-eth0: flags=4163<UP,BROADCAST,RUNNING,MULTIC
ST>  mtu 1500
        inet 10.0.0.1  netmask 255.0.0.0  broad
cast 10.255.255.255
        ether f6:a2:89:50:33:88  txqueuelen 100
  (Ethernet)
        RX packets 0  bytes 0 (0.0 B)
        RX errors 0  dropped 0  overruns 0  fra
me 0
        TX packets 0  bytes 0 (0.0 B)
        TX errors 0  dropped 0 overruns 0  carr
ier 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 848  bytes 261596 (261.5 KB)
        RX errors 0  dropped 0  overruns 0  fra
me 0
        TX packets 848  bytes 261596 (261.5 KB)
        TX errors 0  dropped 0 overruns 0  carr
ier 0  collisions 0

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

```
root@mininet-vm:/home/mininet# ifconfig
h2-eth0: flags=4163<UP,BROADCAST,RUNNING,MULTIC
AST>  mtu 1500
        inet 10.0.0.2  netmask 255.0.0.0  broad
cast 10.255.255.255
        ether d2:4c:f0:f8:3e:3d  txqueuelen 100
0  (Ethernet)
        RX packets 0  bytes 0 (0.0 B)
        RX errors 0  dropped 0  overruns 0  fra
me 0
        TX packets 0  bytes 0 (0.0 B)
        TX errors 0  dropped 0 overruns 0  carr
ier 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 785  bytes 249584 (249.5 KB)
        RX errors 0  dropped 0  overruns 0  fra
me 0
        TX packets 785  bytes 249584 (249.5 KB)
        TX errors 0  dropped 0 overruns 0  carr
ier 0  collisions 0

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

2. Проверка соединения

```
root@mininet-vm:/home/mininet# ifconfig
h1-eth0: flags=4163<UP,BROADCAST,RUNNING,MULTIC
AST>  mtu 1500
        inet 10.0.0.1  netmask 255.0.0.0  broad
cast 10.255.255.255
        ether f6:a2:89:50:33:88  txqueuelen 100
0  (Ethernet)
        RX packets 0  bytes 0 (0.0 B)
        RX errors 0  dropped 0  overruns 0  fra
me 0
        TX packets 0  bytes 0 (0.0 B)
        TX errors 0  dropped 0 overruns 0  carr
ier 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 848  bytes 261596 (261.5 KB)
        RX errors 0  dropped 0  overruns 0  fra
me 0
        TX packets 848  bytes 261596 (261.5 KB)
        TX errors 0  dropped 0 overruns 0  carr
ier 0  collisions 0

root@mininet-vm:/home/mininet# ping 10.0.0.2 c-6
ping: c-6: Temporary failure in name resolution
root@mininet-vm:/home/mininet# ping 10.0.0.2 c -6
ping: socket: Address family not supported by protocol
root@mininet-vm:/home/mininet# ping -c 6 10.0.0.2
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=0.659 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.099 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.034 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.022 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.023 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.027 ms

--- 10.0.0.2 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5105ms
rtt min/avg/max/mdev = 0.022/0.144/0.659/0.231 ms
root@mininet-vm:/home/mininet#
```

```
root@mininet-vm:/home/mininet# ifconfig
h2-eth0: flags=4163<UP,BROADCAST,RUNNING,MULTIC
AST>  mtu 1500
        inet 10.0.0.2  netmask 255.0.0.0  broad
cast 10.255.255.255
        ether d2:4c:f0:f8:3e:3d  txqueuelen 100
0  (Ethernet)
        RX packets 0  bytes 0 (0.0 B)
        RX errors 0  dropped 0  overruns 0  fra
me 0
        TX packets 0  bytes 0 (0.0 B)
        TX errors 0  dropped 0 overruns 0  carr
ier 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 785  bytes 249584 (249.5 KB)
        RX errors 0  dropped 0  overruns 0  fra
me 0
        TX packets 785  bytes 249584 (249.5 KB)
        TX errors 0  dropped 0 overruns 0  carr
ier 0  collisions 0

root@mininet-vm:/home/mininet# ping -c 6  10.0.0.1
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=0.382 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=0.029 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=0.032 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=0.041 ms
64 bytes from 10.0.0.1: icmp_seq=5 ttl=64 time=0.041 ms
64 bytes from 10.0.0.1: icmp_seq=6 ttl=64 time=0.038 ms

--- 10.0.0.1 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5121ms
rtt min/avg/max/mdev = 0.029/0.093/0.382/0.128 ms
root@mininet-vm:/home/mininet#
```

3. Потеря пакетов

```
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root netem loss 10%
root@mininet-vm:/home/mininet# ping -c 6 10.0.0.2
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.239 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.164 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.039 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.036 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.033 ms

--- 10.0.0.2 ping statistics ---
6 packets transmitted, 5 received, 16.6667% packet loss, time 5105ms
rtt min/avg/max/mdev = 0.033/0.102/0.239/0.084 ms
root@mininet-vm:/home/mininet#
```

4. 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 -c 50 10.0.0.2
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.373 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.209 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.103 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.034 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=0.036 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=0.034 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=0.042 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=0.041 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=0.042 ms
64 bytes from 10.0.0.2: icmp_seq=21 ttl=64 time=0.041 ms
64 bytes from 10.0.0.2: icmp_seq=22 ttl=64 time=0.035 ms
64 bytes from 10.0.0.2: icmp_seq=23 ttl=64 time=0.024 ms
64 bytes from 10.0.0.2: icmp_seq=24 ttl=64 time=0.044 ms
64 bytes from 10.0.0.2: icmp_seq=25 ttl=64 time=0.022 ms
64 bytes from 10.0.0.2: icmp_seq=26 ttl=64 time=0.040 ms
64 bytes from 10.0.0.2: icmp_seq=34 ttl=64 time=0.034 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=37 ttl=64 time=0.047 ms
64 bytes from 10.0.0.2: icmp_seq=38 ttl=64 time=0.041 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=0.045 ms
64 bytes from 10.0.0.2: icmp_seq=48 ttl=64 time=0.041 ms
64 bytes from 10.0.0.2: icmp_seq=49 ttl=64 time=0.280 ms
64 bytes from 10.0.0.2: icmp_seq=50 ttl=64 time=0.049 ms

--- 10.0.0.2 ping statistics ---
50 packets transmitted, 24 received, 52% packet loss, time 50158ms
rtt min/avg/max/mdev = 0.022/0.072/0.373/0.085 ms
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root netem
root@mininet-vm:/home/mininet#
```

5. Повреждение пакетов

```
Warning: this system does not seem to support IPv6 - trying IPv4
-----------------------------------------------------------
Server listening on 5201
-----------------------------------------------------------
Accepted connection from 10.0.0.1, port 51688
[  5] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 51690
[ ID] Interval           Transfer     Bitrate
[  5]   0.00-1.00   sec  6.38 GBytes  54.8 Gbits/sec
[  5]   1.00-2.00   sec  6.35 GBytes  54.5 Gbits/sec
[  5]   2.00-3.00   sec  6.30 GBytes  54.2 Gbits/sec
[  5]   3.00-4.00   sec  6.32 GBytes  54.3 Gbits/sec
[  5]   4.00-5.00   sec  6.35 GBytes  54.5 Gbits/sec
[  5]   5.00-6.00   sec  6.61 GBytes  56.8 Gbits/sec
[  5]   6.00-7.00   sec  6.89 GBytes  59.2 Gbits/sec
[  5]   7.00-8.00   sec  7.82 GBytes  67.1 Gbits/sec
[  5]   8.00-9.00   sec  8.07 GBytes  69.3 Gbits/sec
[  5]   9.00-10.00  sec  7.37 GBytes  63.3 Gbits/sec
[  5]  10.00-10.00  sec   192 KBytes   447 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate
[  5]   0.00-10.00  sec  68.5 GBytes  58.8 Gbits/sec                receiver
-----------------------------------------------------------
Server listening on 5201
-----------------------------------------------------------
```

```
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
iperf3: error - unable to connect to server: Connection refused
root@mininet-vm:/home/mininet# iperf3 -c 10.0.0.2
iperf3: error - unable to connect to server: Connection refused
root@mininet-vm:/home/mininet# sudo iperf3 -c 10.0.0.2
iperf3: error - unable to connect to server: Connection refused
root@mininet-vm:/home/mininet# iperf3 -c 10.0.0.2
iperf3: error - unable to connect to server: Connection refused
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 51690 connected to 10.0.0.2 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  7]   0.00-1.00   sec  6.40 GBytes  54.9 Gbits/sec   19   1.02 MBytes
[  7]   1.00-2.00   sec  6.35 GBytes  54.5 Gbits/sec   17    677 KBytes
[  7]   2.00-3.00   sec  6.30 GBytes  54.1 Gbits/sec   15   1.15 MBytes
[  7]   3.00-4.00   sec  6.32 GBytes  54.3 Gbits/sec   13   1.68 MBytes
[  7]   4.00-5.00   sec  6.34 GBytes  54.5 Gbits/sec   13   2.04 MBytes
[  7]   5.00-6.00   sec  6.61 GBytes  56.8 Gbits/sec   12   1.93 MBytes
[  7]   6.00-7.00   sec  6.90 GBytes  59.3 Gbits/sec   17   2.15 MBytes
[  7]   7.00-8.00   sec  7.82 GBytes  67.1 Gbits/sec   20   2.74 MBytes
[  7]   8.00-9.00   sec  8.07 GBytes  69.3 Gbits/sec   14   2.68 MBytes
[  7]   9.00-10.00  sec  7.36 GBytes  63.3 Gbits/sec   21   1.81 MBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  7]   0.00-10.00  sec  68.5 GBytes  58.8 Gbits/sec  161             sender
[  7]   0.00-10.00  sec  68.5 GBytes  58.8 Gbits/sec                  receiver

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

```
root@mininet-vm:/home/mininet# iperf -s
-----------------------------------------------------------
Server listening on TCP port 5001
TCP window size: 85.3 KByte (default)
-----------------------------------------------------------
^Croot@mininet-vm:/home/mininet# iperf -s
-----------------------------------------------------------
Server listening on TCP port 5001
TCP window size: 85.3 KByte (default)
-----------------------------------------------------------
^Croot@mininet-vm:/home/mininet# sudo iperf -s
-----------------------------------------------------------
Server listening on TCP port 5001
TCP window size: 85.3 KByte (default)
-----------------------------------------------------------
^Croot@mininet-vm:/home/mininet#
```

6. Переупорядочивание пакетов

```
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root netem delay 10ms reorder 25
 50%
root@mininet-vm:/home/mininet#
root@mininet-vm:/home/mininet# ping -c 20 10.0.0.2
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=10.3 ms

64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=10.1 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=10.5 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=10.5 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=10.5 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=10.5 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=10.3 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=10.5 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=10.6 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=10.5 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=10.5 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=0.041 ms
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=10.5 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=10.5 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=0.041 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=10.5 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 19115ms
rtt min/avg/max/mdev = 0.041/9.446/10.669/3.136 ms
root@mininet-vm:/home/mininet#
root@mininet-vm:/home/mininet# 
```

7. Дублирование пакетов

```
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root netem duplicate 50%
root@mininet-vm:/home/mininet# ping -c 20 10.0.0.2
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=0.110 ms

64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.043 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.043 ms (DUP!)
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=3 ttl=64 time=0.038 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.038 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.038 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.046 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.046 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.049 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=0.042 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=0.043 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=0.046 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=0.046 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=0.039 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=0.039 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=0.032 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.049 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=0.045 ms
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=0.047 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=0.034 ms
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=0.044 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=0.047 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=0.047 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=0.047 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=0.044 ms
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=0.043 ms
64 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=0.041 ms

--- 10.0.0.2 ping statistics ---
20 packets transmitted, 20 received, +8 duplicates, 0% packet loss, time 19466ms
rtt min/avg/max/mdev = 0.032/0.045/0.110/0.013 ms
root@mininet-vm:/home/mininet#
root@mininet-vm:/home/mininet# █
```

8. Выполнение автоматизированного эксперимента

```
mininet@mininet-vm:~/work/lab_netem_ii/simple-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 loss',)
Command line is not complete. Try option "help"
*** h2 : ('tc qdisc add dev h2-eth0 root netem loss%',)
What is "loss%"?
Usage: ... netem           [ limit PACKETS ]
                           [ delay TIME [ JITTER [CORRELATION]]]
                           [ distribution {uniform|normal|pareto|paretonormal} ]
                           [ corrupt PERCENT [CORRELATION]]
                           [ duplicate PERCENT [CORRELATION]]
                           [ loss random PERCENT [CORRELATION]]
                           [ loss state P13 [P31 [P32 [P23 P14]]]
                           [ loss gemodel PERCENT [R [1-H [1-K]]]
                           [ ecn ]
                           [ reorder PERCENT [CORRELATION] [ gap DISTANCE ]]
                           [ rate RATE [PACKETOVERHEAD] [CELLSIZE] [CELLOVERHEAD]]
                           [ slot MIN_DELAY [MAX_DELAY] [packets MAX_PACKETS] [bytes MAX_BYTES]]
               [ slot distribution {uniform|normal|pareto|paretonormal|custom} DELAY JITTER [packets MAX_
PACKETS] [bytes MAX_BYTES]]
*** Ping
*** h1 : ('ping -c 100', '10.0.0.2', '| grep "time=" | awk \'{print $5, $7}\' | sed -e \'s/time=//g\' -e \
's/icmp_seq=//g\' > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 2 links
.
.
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
mininet@mininet-vm:~/work/lab_netem_ii/simple-drop$
```

9. lab_netem_ii.py

```python
#!/usr/bin/env python
"""
Simple experiment.
Output: ping.dat
"""

from mininet.net import Mininet
from mininet.node import Controller
from mininet.cli import CLI
from mininet.log import setLogLevel, info
import time

def emptyNet():
    "Create an empty network and add nodes to it."
    net = Mininet( controller=Controller, waitConnected=True )
    info( '*** Adding controller\n' )
    net.addController( 'c0' )

    info( '*** Adding hosts\n' )
    h1 = net.addHost( 'h1', ip='10.0.0.1' )
    h2 = net.addHost( 'h2', ip='10.0.0.2' )

    info( '*** Adding switch\n' )
    s1 = net.addSwitch( 's1' )

    info( '*** Creating links\n' )
    net.addLink( h1, s1 )
    net.addLink( h2, s1 )

    info( '*** Starting network\n')
    net.start()

    info( '*** Set delay\n')
    h1.cmdPrint( 'tc qdisc add dev h1-eth0 root netem loss' )
    h2.cmdPrint( 'tc qdisc add dev h2-eth0 root netem loss%' )

    time.sleep(10) # Wait 10 seconds

    info( '*** Ping\n')

    h1.cmdPrint( 'ping -c 100', h2.IP(), '| grep "time=" | awk \'{print $5, $7}\' | sed -e \'s/time=//g\'
-e \'s/icmp_seq=//g\' > ping.dat')

    info( '*** Stopping network' )
    net.stop()

if __name__ == '__main__':
    setLogLevel( 'info' )
    emptyNet()
```

lab_netem_ii.py   1,1   All

10. Makefile

```makefile
all: ping.dat
ping.dat:
        sudo python lab_netem_ii.py
        sudo chown mininet:mininet ping.dat


clean:
        -rm -f *.dat
```

Выводы

Я получил навыки проведения интер- активных экспериментов в среде Mininet по исследованию параметров сети, связанных с потерей, дублированием, изменением порядка и повреждением пакетов при передаче данных.