

Лабораторная работа № 5

Эмуляция и измерение потерь пакетов в глобальных сетях

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Информация

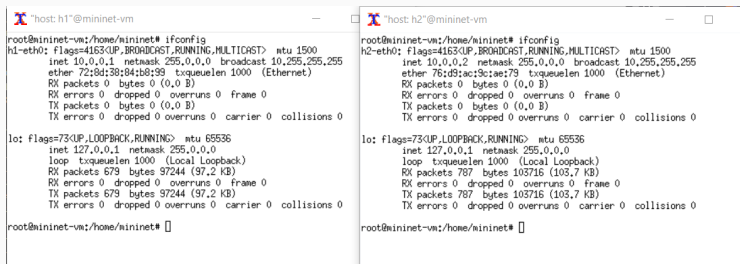
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Основной целью работы является получение навыков проведения интерактивных экспериментов в среде Mininet по исследованию параметров сети, связанных с потерей, дублированием, изменением порядка и повреждением пакетов при передаче данных. Эти параметры 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. На экран выведите сводную информацию о потерянных пакетах.

Выполнение лабораторной работы



The image shows two terminal windows side-by-side, both titled "host: h1" and "host: h2" respectively, indicating they are running in a Mininet virtual environment. Both windows show the output of the 'ifconfig' command for the root user at the mininet-vm prompt. The left window (h1) shows interface h1-eth0 with IP 10.0.0.1 and loopback interface lo with IP 127.0.0.1. The right window (h2) shows interface h2-eth0 with IP 10.0.0.2 and loopback interface lo with IP 127.0.0.1. Both interfaces are up and running, and the statistics for RX and TX packets, bytes, errors, and collisions are all zero.

```
root@mininet-vm:/home/mininet# ifconfig
h1-eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 10.0.0.1 netmask 255.0.0.0 broadcast 10.255.255.255
    ether 72:8d:38:84:b8:99 txqueuelen 1000 (Ethernet)
    RX packets 0 bytes 0 (0.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 0 bytes 0 (0.0 B)
    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 679 bytes 97244 (97.2 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 679 bytes 97244 (97.2 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

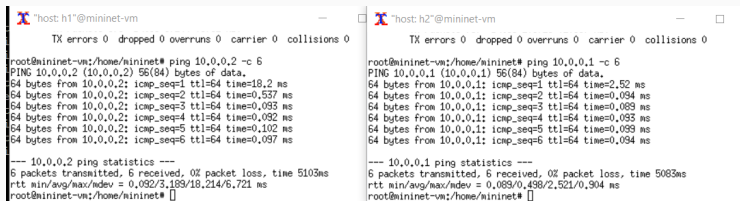
root@mininet-vm:/home/mininet#
```

```
root@mininet-vm:/home/mininet# ifconfig
h2-eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 10.0.0.2 netmask 255.0.0.0 broadcast 10.255.255.255
    ether 76:d9:ac:3c:ae:79 txqueuelen 1000 (Ethernet)
    RX packets 0 bytes 0 (0.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 0 bytes 0 (0.0 B)
    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 787 bytes 103716 (103.7 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 787 bytes 103716 (103.7 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

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

Рис. 1: Информацию о сетевых интерфейсах и IP-адресах хостов



The image shows two terminal windows side-by-side. The left window is titled "host: h1"@mininet-vm and shows a ping command being executed from root@mininet-vm:/home/mininet# to 10.0.0.2 with 6 packets. The output shows successful pings with times ranging from 18.2 ms to 102 ms. The right window is titled "host: h2"@mininet-vm and shows a ping command being executed from root@mininet-vm:/home/mininet# to 10.0.0.1 with 6 packets. The output shows successful pings with times ranging from 2.52 ms to 9.904 ms. Both windows also display network statistics at the top: TX errors 0, dropped 0, overruns 0, carrier 0, collisions 0.

```
host: h1"@mininet-vm
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

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=18.2 ms
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=0.093 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.092 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.102 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.097 ms

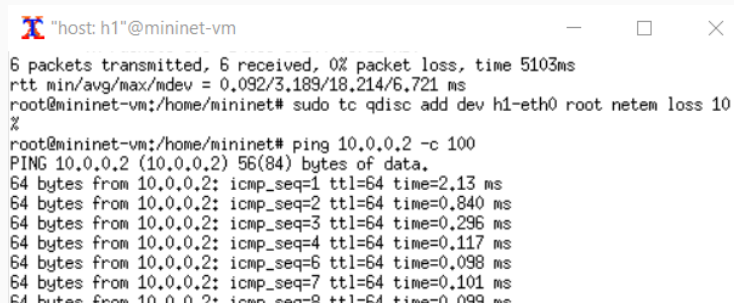
--- 10.0.0.2 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5103ms
rtt min/avg/max/mdev = 0.092/3.189/18.214/6.721 ms
root@mininet-vm:/home/mininet#
```

```
host: h2"@mininet-vm
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

root@mininet-vm:/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=2.52 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=0.094 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=0.089 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=0.093 ms
64 bytes from 10.0.0.1: icmp_seq=5 ttl=64 time=0.099 ms
64 bytes from 10.0.0.1: icmp_seq=6 ttl=64 time=0.094 ms

--- 10.0.0.1 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5083ms
rtt min/avg/max/mdev = 0.089/0.498/2.521/0.904 ms
root@mininet-vm:/home/mininet#
```

Рис. 2: Проверка соединения между хостами

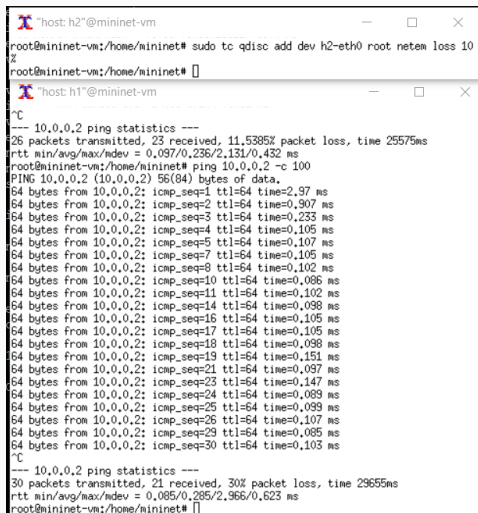


A terminal window titled "host: h1" @mininet-vm. The window shows the output of a series of commands. First, a ping command is run, showing 6 packets transmitted and received with 0% loss. Then, the 'tc' command is used to add a queue discipline to the h1-eth0 interface, setting a 10% packet loss. Finally, another ping command is run to 10.0.0.2, showing a series of successful pings with varying response times.

```
"host: h1" @mininet-vm
6 packets transmitted, 6 received, 0% packet loss, time 5103ms
rtt min/avg/max/mdev = 0.092/3.189/18.214/6.721 ms
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root netem loss 10%
root@mininet-vm:/home/mininet# ping 10.0.0.2 -c 100
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=2.13 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.840 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.296 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.117 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.098 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=0.101 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=0.099 ms
```

Рис. 3: Добавление потери пакетов

Выполнение лабораторной работы



```
"host: h2"@mininet-vm
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h2-eth0 root netem loss 10
%
root@mininet-vm:/home/mininet#

"host: h1"@mininet-vm
^C
--- 10.0.0.2 ping statistics ---
26 packets transmitted, 23 received, 11,5385% packet loss, time 25575ms
rtt min/avg/max/mdev = 0,097/0,236/2,131/0,432 ms
root@mininet-vm:/home/mininet# ping 10.0.0.2 -c 100
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=2,97 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0,907 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0,233 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0,105 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0,107 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=0,105 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=0,102 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=0,086 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0,102 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=0,098 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=0,105 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=0,105 ms
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=0,098 ms
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=0,151 ms
64 bytes from 10.0.0.2: icmp_seq=21 ttl=64 time=0,097 ms
64 bytes from 10.0.0.2: icmp_seq=23 ttl=64 time=0,147 ms
64 bytes from 10.0.0.2: icmp_seq=24 ttl=64 time=0,089 ms
64 bytes from 10.0.0.2: icmp_seq=25 ttl=64 time=0,099 ms
64 bytes from 10.0.0.2: icmp_seq=26 ttl=64 time=0,107 ms
64 bytes from 10.0.0.2: icmp_seq=29 ttl=64 time=0,085 ms
64 bytes from 10.0.0.2: icmp_seq=30 ttl=64 time=0,103 ms
^C
--- 10.0.0.2 ping statistics ---
30 packets transmitted, 21 received, 30% packet loss, time 29655ms
rtt min/avg/max/mdev = 0,085/0,285/2,966/0,623 ms
root@mininet-vm:/home/mininet#
```

Рис. 4: Добавление потери пакетов

Выполнение лабораторной работы

```
root@mininet-vm:~# "host: h1" @mininet-vm
22 packets transmitted, 22 received, 0% packet loss, time 21486ms
rtt min/avg/max/mdev = 0.093/0.263/2.705/0.553 ms
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:
54 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.539 ms
54 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.127 ms
54 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.167 ms
54 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=0.116 ms
54 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=0.099 ms
54 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=0.098 ms
54 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.116 ms
54 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=0.104 ms
54 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=0.102 ms
54 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=0.100 ms
54 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=0.100 ms
54 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=0.103 ms
54 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=0.098 ms
54 bytes from 10.0.0.2: icmp_seq=21 ttl=64 time=0.099 ms
54 bytes from 10.0.0.2: icmp_seq=25 ttl=64 time=0.335 ms
54 bytes from 10.0.0.2: icmp_seq=29 ttl=64 time=0.130 ms
54 bytes from 10.0.0.2: icmp_seq=32 ttl=64 time=0.099 ms
54 bytes from 10.0.0.2: icmp_seq=40 ttl=64 time=0.099 ms
54 bytes from 10.0.0.2: icmp_seq=42 ttl=64 time=0.104 ms
54 bytes from 10.0.0.2: icmp_seq=43 ttl=64 time=0.090 ms

--- 10.0.0.2 ping statistics ---
50 packets transmitted, 20 received, 60% packet loss, time 50169ms
rtt min/avg/max/mdev = 0.090/0.141/0.539/0.105 ms
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root netem
root@mininet-vm:/home/mininet#
```

Рис. 5: Добавление значения корреляции для потери пакетов

Выполнение лабораторной работы

```
host: h2" @mininet-vm
root@mininet-vm:/home/mininet# iperf3 -s
warning: this system does not seem to support IPv6 - trying IPv4

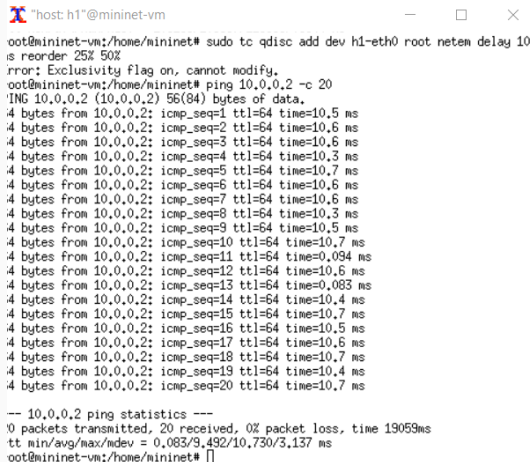
Server listening on 5201

Accepted connection from 10.0.0.1, port 58764
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 58766
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-1.00 sec  1.33 GBytes  11.5 Gbits/sec
[ 7] 1.00-2.00 sec  1.53 GBytes  13.1 Gbits/sec
[ 7] 2.00-3.00 sec  1.60 GBytes  13.8 Gbits/sec
[ 7] 3.00-4.00 sec  1.35 GBytes  11.6 Gbits/sec
[ 7] 4.00-5.00 sec  1.44 GBytes  12.3 Gbits/sec
[ 7] 5.00-6.00 sec  1.55 GBytes  13.3 Gbits/sec
[ 7] 6.00-7.00 sec  1.39 GBytes  11.9 Gbits/sec
[ 7] 7.00-8.00 sec  1.57 GBytes  13.4 Gbits/sec
[ 7] 8.00-9.00 sec  1.43 GBytes  12.3 Gbits/sec
[ 7] 9.00-10.00 sec 1.63 GBytes  14.0 Gbits/sec
[ 7] 10.00-10.00 sec 320 KBytes   3.65 Gbits/sec
-----
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-10.00 sec 14.8 GBytes  12.7 Gbits/sec
-----
Server listening on 5201

host: h1" @mininet-vm
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 58766 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  3         506 KBytes
[ 7] 1.00-2.00 sec  1.53 GBytes  13.1 Gbits/sec  2         395 KBytes
[ 7] 2.00-3.00 sec  1.60 GBytes  13.8 Gbits/sec  2         402 KBytes
[ 7] 3.00-4.00 sec  1.35 GBytes  11.6 Gbits/sec  2         549 KBytes
[ 7] 4.00-5.00 sec  1.44 GBytes  12.4 Gbits/sec  4         1.43 MBytes
[ 7] 5.00-6.00 sec  1.55 GBytes  13.3 Gbits/sec  3         591 KBytes
[ 7] 6.00-7.00 sec  1.39 GBytes  11.9 Gbits/sec  2         871 KBytes
[ 7] 7.00-8.00 sec  1.56 GBytes  13.4 Gbits/sec  1         618 KBytes
[ 7] 8.00-9.00 sec  1.43 GBytes  12.3 Gbits/sec  4         535 KBytes
[ 7] 9.00-10.00 sec 1.63 GBytes  14.0 Gbits/sec  4         132 KBytes
-----
[ ID] Interval      Transfer      Bitrate      Retr      sender
[ 7] 0.00-10.00 sec 14.8 GBytes  12.7 Gbits/sec  27
[ 7] 0.00-10.00 sec 14.8 GBytes  12.7 Gbits/sec
-----
iperf Done.
root@mininet-vm:/home/mininet#
```

Рис. 6: Добавление повреждения пакетов

Выполнение лабораторной работы

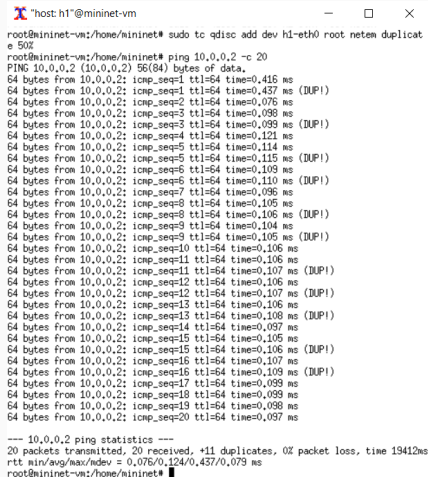


```
"host: h1"@mininet-vm
oot@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root netem delay 10
is reorder 25% 50%
rror: Exclusivity flag on, cannot modify.
oot@mininet-vm:/home/mininet# ping 10.0.0.2 -c 20
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data:
 4 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=10.5 ms
 4 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=10.6 ms
 4 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=10.6 ms
 4 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=10.3 ms
 4 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=10.7 ms
 4 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=10.6 ms
 4 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=10.6 ms
 4 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=10.3 ms
 4 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=10.5 ms
 4 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=10.7 ms
 4 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.094 ms
 4 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=10.6 ms
 4 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=0.083 ms
 4 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=10.4 ms
 4 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=10.7 ms
 4 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=10.5 ms
 4 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=10.6 ms
 4 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=10.7 ms
 4 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=10.4 ms
 4 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=10.7 ms

-- 10.0.0.2 ping statistics --
 0 packets transmitted, 20 received, 0% packet loss, time 19059ms
rtt min/avg/max/mdev = 0.083/9.492/10.730/3.137 ms
oot@mininet-vm:/home/mininet#
```

Рис. 7: Добавление переупорядочивания пакетов

Выполнение лабораторной работы



```
root@mininet-vm: /home/mininet# sudo tc qdisc add dev h1-eth0 root netem duplicat
e 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=0.416 ms
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=0.437 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.076 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.098 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.099 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.121 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.114 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.115 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.109 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.110 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=0.096 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=0.105 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=0.106 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=0.104 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=0.105 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=0.106 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.106 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.107 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=0.106 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=0.107 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=0.106 ms
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=0.108 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=0.097 ms
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=0.105 ms
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=0.106 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=0.107 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=0.109 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=0.099 ms
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=0.099 ms
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=0.098 ms
64 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=0.097 ms

--- 10.0.0.2 ping statistics ---
20 packets transmitted, 20 received, +11 duplicates, 0% packet loss, time 19412ms
rtt min/avg/max/mdev = 0.076/0.124/0.437/0.079 ms
root@mininet-vm: /home/mininet#
```

Рис. 8: Добавление дублирования пакетов

```
GNU nano 4.8 lab netem ii.py Modified
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 10%' )
    h2.cmdPrint( 'tc qdisc add dev h2-eth0 root netem loss 10%' )

    time.sleep(10) # Wait 10 seconds

    info( '*** Ping\n' )
    h1.cmdPrint( 'ping -c 100', h2.IP(), '| grep "time=" | awk \'{print $5, $7}\'' | sed

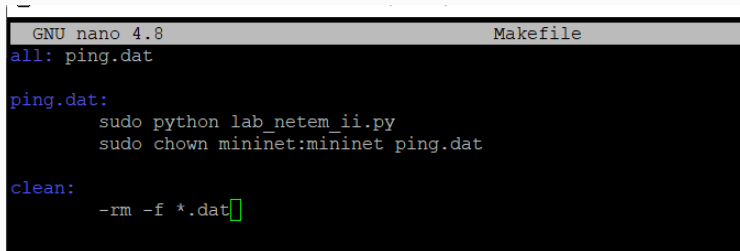
    info( '*** Stopping network' )
    net.stop()

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

Рис. 9: Создание скрипта для эксперимента lab_netem_ii.py

```
info( '*** Ping\n')  
h1.cmdPrint( 'ping -c 100', h2.IP(), '| grep "packet loss:" | awk \'{print $6, $7, $>
```

Рис. 10: Редактирование скрипта



```
GNU nano 4.8 Makefile
all: ping.dat

ping.dat:
    sudo python lab_netem_ii.py
    sudo chown mininet:mininet ping.dat

clean:
    rm -f *.dat
```

Рис. 11: Makefile


```
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 10%,)
*** h2 : ('tc qdisc add dev h2-eth0 root netem loss 10%,)
*** Ping
*** h1 : ('ping -c 100', '10.0.0.2', '| grep "packet loss:" | awk \'{print $6, $7, $8}\\' > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 2 links
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
mininet@mininet-vm:~/work/lab_netem_ii/simple-drop$ cat ping.dat
```

Рис. 12: Проведение эксперимента

В результате выполнения данной лабораторной работы я получила навыки проведения интерактивных экспериментов в среде Mininet по исследованию параметров сети, связанных с потерей, дублированием, изменением порядка и повреждением пакетов при передаче данных.

1. Mininet [Электронный ресурс]. Mininet Project Contributors. URL: <http://mininet.org/> (дата обращения: 17.11.2024).