

Лабораторная работа № 5

Эмуляция и измерение потерь пакетов в глобальных сетях

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Информация

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Цель 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.

Выполнение лабораторной работы

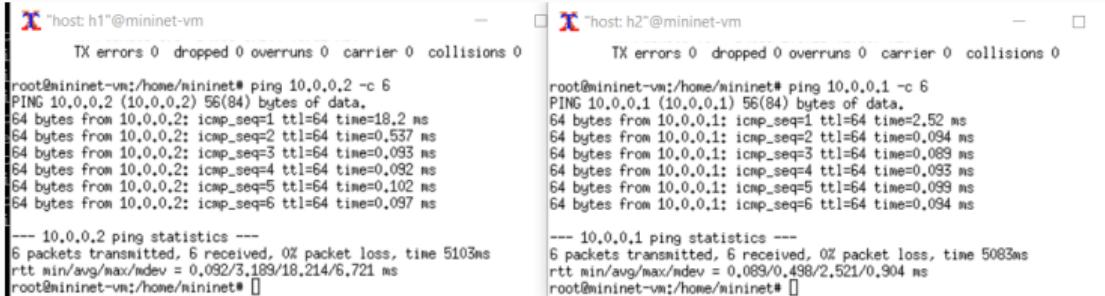
The image shows two separate terminal windows side-by-side. Both windows have a red 'X' icon at the top left and a close button at the top right. The window on the left is titled "host: h1" and the window on the right is titled "host: h2". Both windows display the command "root@mininet-vm:/home/mininet# ifconfig" followed by the output of the ifconfig command for their respective hosts.

```
host: h1"@"mininet-vm
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# 

host: h2"@"mininet-vm
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:9c: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

Выполнение лабораторной работы



The image shows two terminal windows side-by-side. Both windows have a title bar with a red 'X' icon and the text "host: h1" or "host: h2" followed by "@mininet-vm". The left window (h1) displays the following command and its output:

```
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#
```

The right window (h2) displays the following command and its output:

```
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

Выполнение лабораторной работы

```
X "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=9 ttl=64 time=0.099 ms
```

Рис. 3: Добавление потери пакетов

Выполнение лабораторной работы

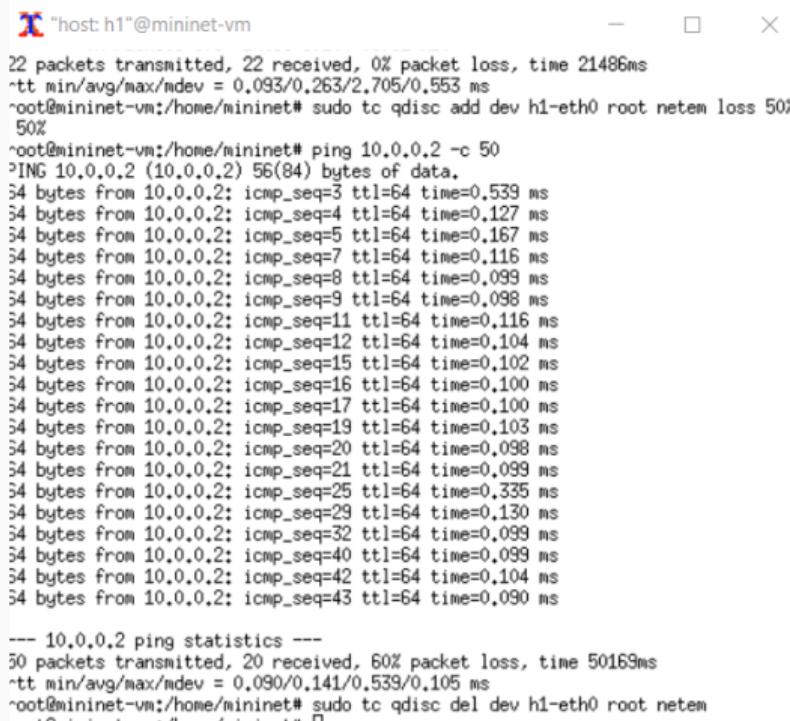
The screenshot shows two terminal windows side-by-side. The left window, titled "host: h2" @ mininet-vm, has a root prompt. It runs the command `sudo tc qdisc add dev h2-eth0 root netem loss 10%`. The right window, titled "host: h1" @ mininet-vm, also has a root prompt. It runs a `ping` command to host 10.0.0.2, showing detailed statistics for each of 26 transmitted packets. The right window then runs another `ping` command, showing 30 transmitted packets with 30% packet loss.

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

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



```
"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.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=0.539 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.127 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.167 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.116 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.099 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=0.116 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=0.099 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=0.098 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=0.116 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.104 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=0.102 ms
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=0.100 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=0.100 ms
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=0.100 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=0.100 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=0.100 ms
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=0.103 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=0.099 ms
64 bytes from 10.0.0.2: icmp_seq=21 ttl=64 time=0.335 ms
64 bytes from 10.0.0.2: icmp_seq=22 ttl=64 time=0.130 ms
64 bytes from 10.0.0.2: icmp_seq=23 ttl=64 time=0.099 ms
64 bytes from 10.0.0.2: icmp_seq=24 ttl=64 time=0.099 ms
64 bytes from 10.0.0.2: icmp_seq=25 ttl=64 time=0.104 ms
64 bytes from 10.0.0.2: icmp_seq=26 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=27 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=28 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=29 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=30 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=31 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=32 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=33 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=34 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=35 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=36 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=37 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=38 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=39 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=40 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=41 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=42 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=43 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=44 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=45 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=46 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=47 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=48 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=49 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=50 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
```

Рис. 5: Добавление значения корреляции для потери пакетов

Выполнение лабораторной работы

The screenshot shows two terminal windows from a Mininet VM. The top window is titled "host: h2" and the bottom window is titled "host: h1".

Host h2 Terminal:

```
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 1.39 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
                                         receiver
-----
```

Host h1 Terminal:

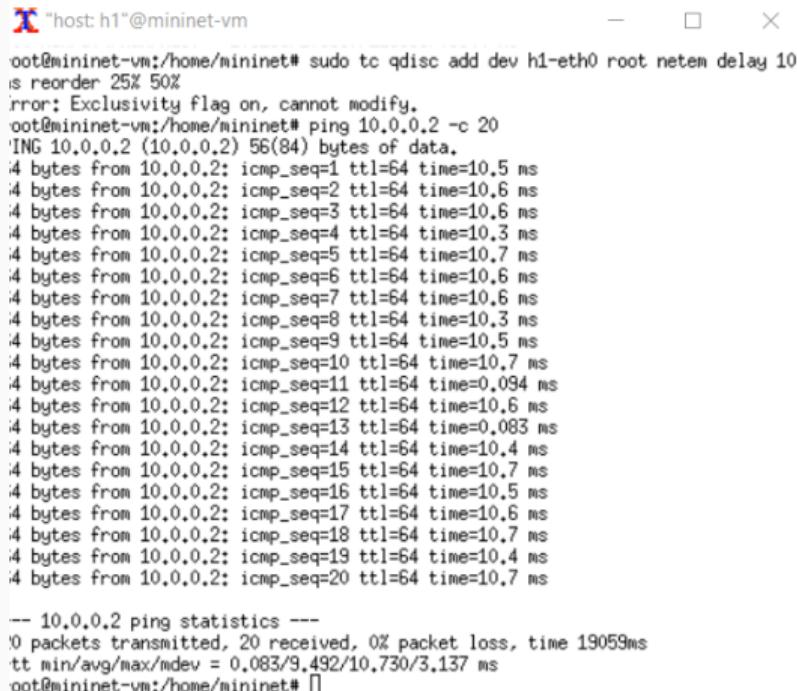
```
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root netem
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root netem corrupt
0.01%
root@mininet-vm:/home/mininet# iperf3 -c 10.0.0.2
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 58766 connected to 10.0.0.2 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
[ 7] 0.00-10.00 sec 14.8 GBytes 12.7 Gbits/sec 27
                                         sender
[ 7] 0.00-10.00 sec 14.8 GBytes 12.7 Gbits/sec
                                         receiver
```

iperf Done.

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

Рис. 6: Добавление повреждения пакетов

Выполнение лабораторной работы

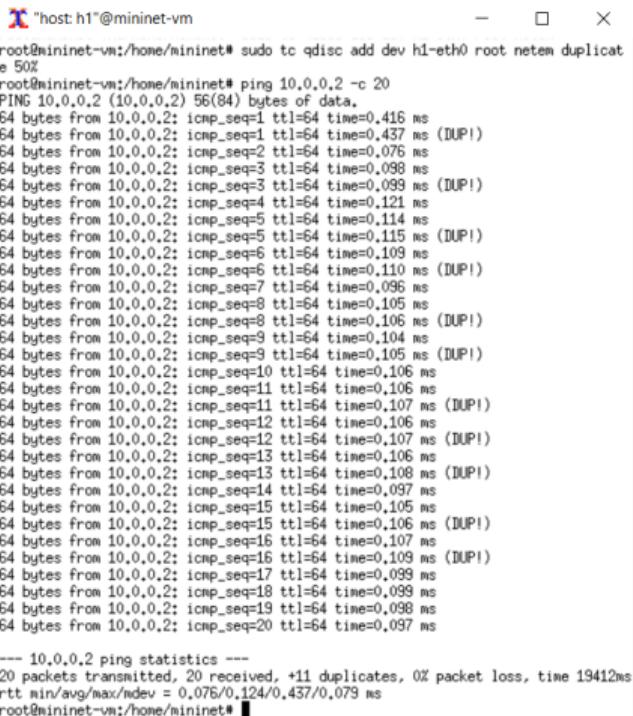


The screenshot shows a terminal window titled "host: h1@mininet-vm". The terminal output is as follows:

```
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root netem delay 10ms reorder 25% 50%
error: Exclusivity flag on, cannot modify.
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.
... (20 ICMP echo requests shown)
... (20 ICMP echo replies shown)
-- 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
root@mininet-vm:/home/mininet#
```

Рис. 7: Добавление переупорядочивания пакетов

Выполнение лабораторной работы



```
"host: h1"@"mininet-vm" - □ ×
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=0.416 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=0.096 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

Выполнение лабораторной работы

```
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

Выполнение лабораторной работы

```
info( '*** Ping\n')
h1.cmdPrint( 'ping -c 100', h2.IP(), '| grep "packet loss:" | awk \'{print $6, $7, $8}\'
```

Рис. 10: Редактирование скрипта

Выполнение лабораторной работы

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

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

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

Рис. 11: Makefile

Выполнение лабораторной работы

```
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, $8}\' > ping.dat')
*** Stopping network
*** Stopping 1 controllers
c0
*** Stopping 2 links
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
mininet@mininet-vm:~/work/lab_netem_ii/simple-drop$ ping.dat
```

Рис. 12: Проведение эксперимента

Выводы

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.

Спасибо за внимание!