

## Лабораторная работа №5

### Моделирование сетей передачи данных

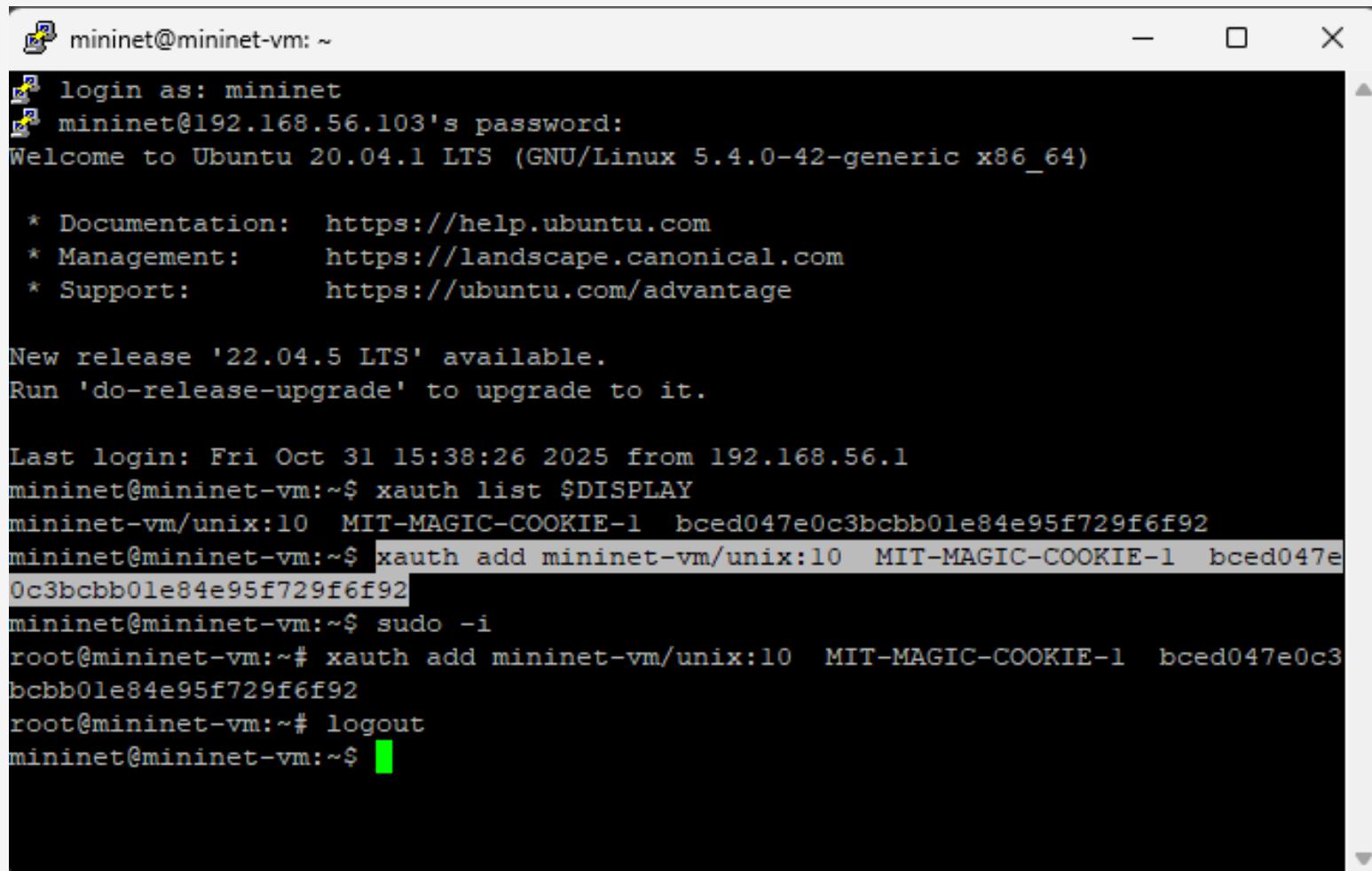
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## Запуск лабораторной топологии



mininet@mininet-vm: ~

login as: mininet

mininet@192.168.56.103's password:

Welcome to Ubuntu 20.04.1 LTS (GNU/Linux 5.4.0-42-generic x86\_64)

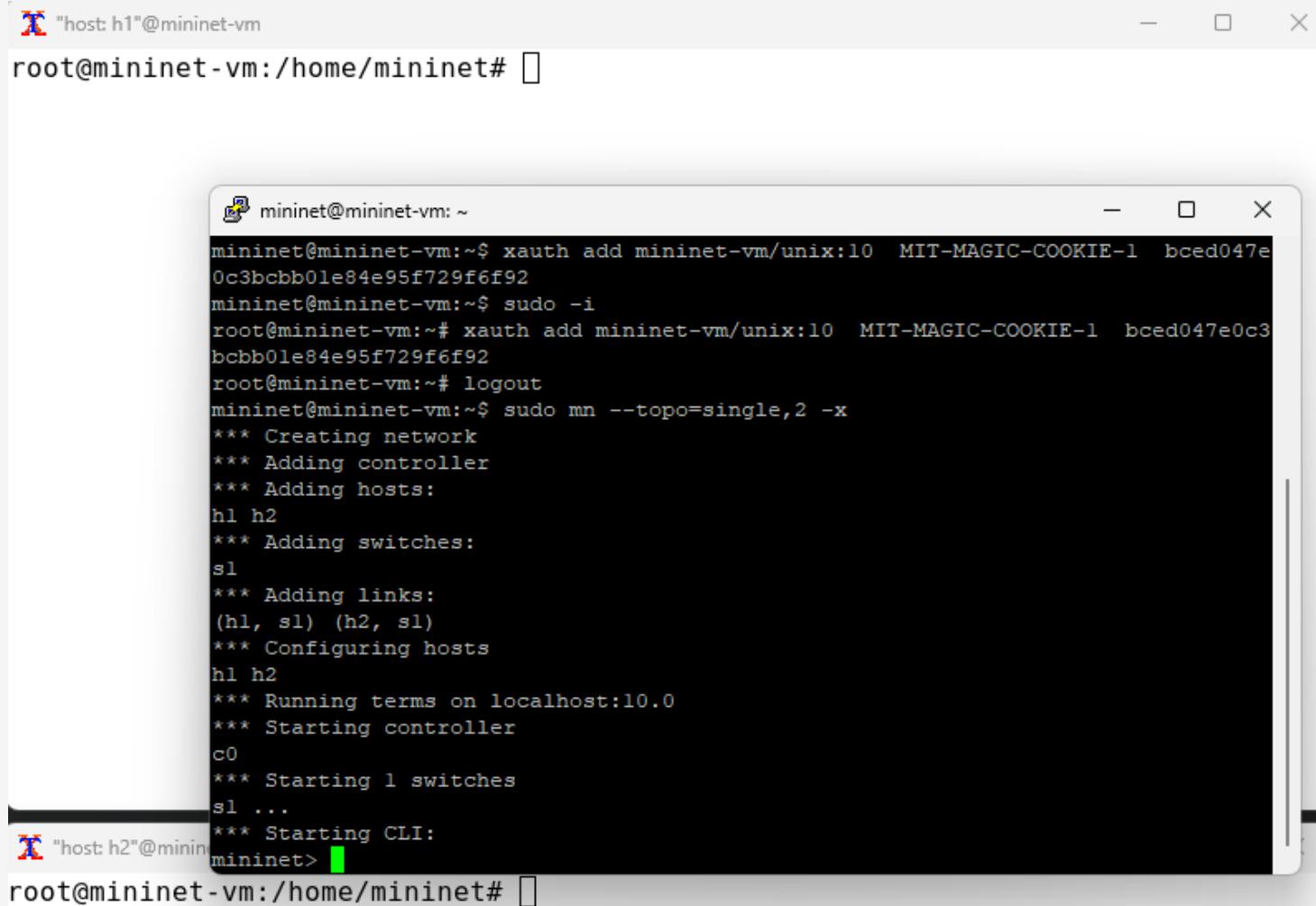
\* Documentation: <https://help.ubuntu.com>  
\* Management: <https://landscape.canonical.com>  
\* Support: <https://ubuntu.com/advantage>

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

Last login: Fri Oct 31 15:38:26 2025 from 192.168.56.1  
mininet@mininet-vm:~\$ xauth list \$DISPLAY  
mininet-vm/unix:10 MIT-MAGIC-COOKIE-1 bced047e0c3bcbb01e84e95f729f6f92  
mininet@mininet-vm:~\$ xauth add mininet-vm/unix:10 MIT-MAGIC-COOKIE-1 bced047e0c3bcbb01e84e95f729f6f92  
mininet@mininet-vm:~\$ sudo -i  
root@mininet-vm:~# xauth add mininet-vm/unix:10 MIT-MAGIC-COOKIE-1 bced047e0c3bcbb01e84e95f729f6f92  
root@mininet-vm:~# logout  
mininet@mininet-vm:~\$

Рис. 1: Исправление прав запуска X-соединения в виртуальной машине mininet

## Запуск лабораторной топологии



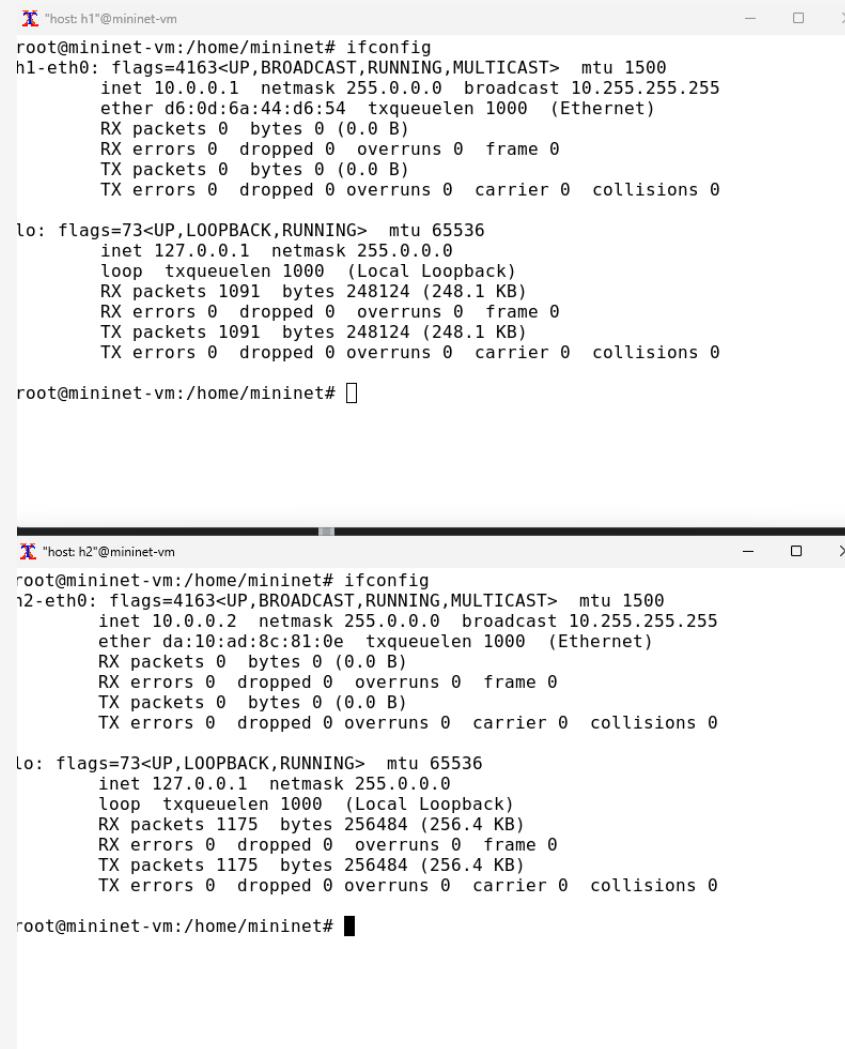
The screenshot shows a terminal window with two tabs. The top tab, titled "host: h1" @ mininet-vm, has a root prompt: "root@mininet-vm:/home/mininet#". The bottom tab, titled "mininet" @ mininet-vm, has a mininet prompt: "mininet>". The main window displays the command-line interface for creating a network topology:

```
mininet@mininet-vm:~$ xauth add mininet-vm/unix:10 MIT-MAGIC-COOKIE-1 bced047e0c3b3bcbb01e84e95f729f6f92
mininet@mininet-vm:~$ sudo -i
root@mininet-vm:~# xauth add mininet-vm/unix:10 MIT-MAGIC-COOKIE-1 bced047e0c3b3bcbb01e84e95f729f6f92
root@mininet-vm:~# logout
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>
```

The terminal window has a dark background with light-colored text. The tabs are white with black text. The main window has a black background with white text.

Рис. 2: Создание простейшей топологии

## Запуск лабораторной топологии



The image displays two separate terminal windows, each showing the output of the 'ifconfig' command on a host machine running a Mininet virtual machine. The top window is titled "host h1" and the bottom window is titled "host h2". Both windows show the configuration for their respective hosts.

**Host h1 Configuration:**

```
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 d6:0d:6a:44:d6:54 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 1091 bytes 248124 (248.1 KB)
        RX errors 0 dropped 0 overruns 0 frame 0
        TX packets 1091 bytes 248124 (248.1 KB)
        TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

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

**Host h2 Configuration:**

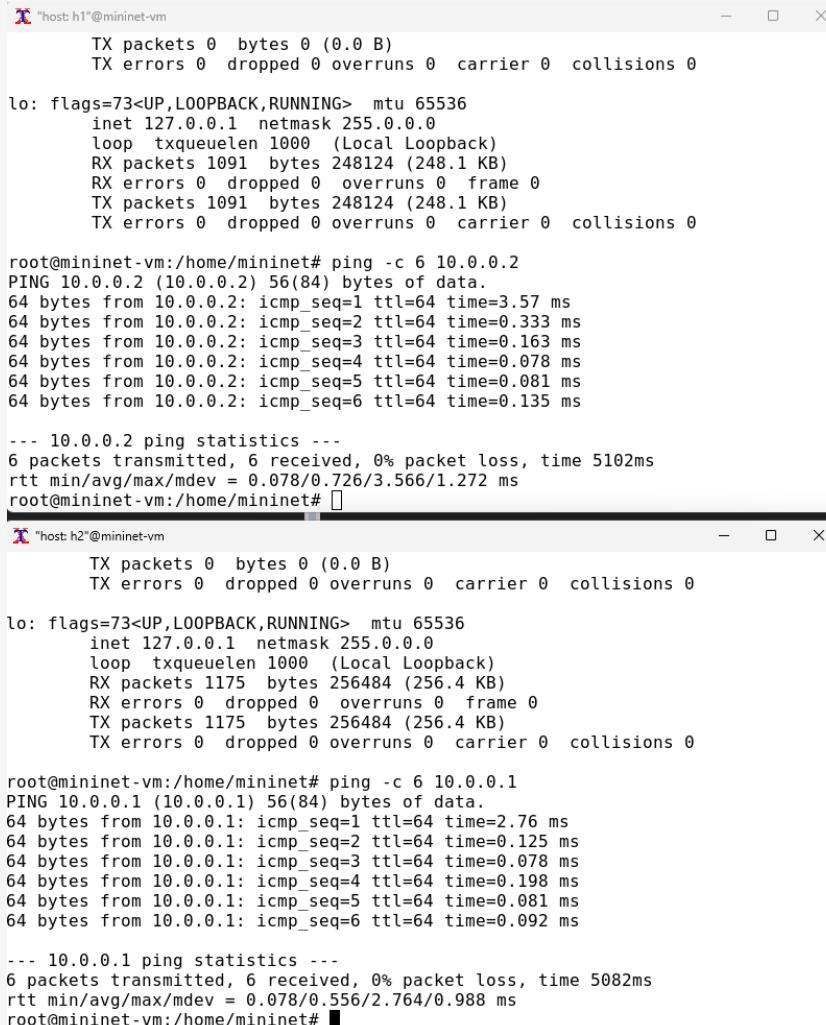
```
root@mininet-vm:/home/mininet# ifconfig
h2-eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 10.0.0.2 netmask 255.0.0.0 broadcast 10.255.255.255
        ether da:10:ad:8c:81:0e txqueuelen 1000 (Ethernet)
        RX packets 0 bytes 0 (0.0 B)
        RX errors 0 dropped 0 overruns 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 1175 bytes 256484 (256.4 KB)
        RX errors 0 dropped 0 overruns 0 frame 0
        TX packets 1175 bytes 256484 (256.4 KB)
        TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

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

Рис. 3: Отображение информации их сетевых интерфейсов и IP-адресов

## Запуск лабораторной топологии



The image shows two terminal windows side-by-side. Both windows are titled with their host names: "host h1" and "host h2". Each window displays network interface statistics and the results of a ping command between two hosts.

**Host h1 Statistics:**

```
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 1091 bytes 248124 (248.1 KB)
        RX errors 0 dropped 0 overruns 0 frame 0
        TX packets 1091 bytes 248124 (248.1 KB)
        TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

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=3.57 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.333 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.163 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.078 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.081 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.135 ms

--- 10.0.0.2 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5102ms
rtt min/avg/max/mdev = 0.078/0.726/3.566/1.272 ms
root@mininet-vm:/home/mininet#
```

**Host h2 Statistics:**

```
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 1175 bytes 256484 (256.4 KB)
        RX errors 0 dropped 0 overruns 0 frame 0
        TX packets 1175 bytes 256484 (256.4 KB)
        TX errors 0 dropped 0 overruns 0 carrier 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=2.76 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=0.125 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=0.078 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=0.198 ms
64 bytes from 10.0.0.1: icmp_seq=5 ttl=64 time=0.081 ms
64 bytes from 10.0.0.1: icmp_seq=6 ttl=64 time=0.092 ms

--- 10.0.0.1 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5082ms
rtt min/avg/max/mdev = 0.078/0.556/2.764/0.988 ms
root@mininet-vm:/home/mininet#
```

Рис. 4: Проверка подключения между хостами h1 и h2

## Интерактивные эксперименты

```
X "host: h1"@mininet-vm
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 1091  bytes 248124 (248.1 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 1091  bytes 248124 (248.1 KB)
        TX errors 0  dropped 0  overruns 0  carrier 0  collisions 0

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=3.57 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.333 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.163 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.078 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.081 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.135 ms

--- 10.0.0.2 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5102ms
rtt min/avg/max/mdev = 0.078/0.726/3.566/1.272 ms
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root netem loss 10%
root@mininet-vm:/home/mininet#
```

Рис. 5: Добавление 10% потерь пакетов на хосте h1

## Интерактивные эксперименты

```
X "host: h1"@mininet-vm
64 bytes from 10.0.0.2: icmp_seq=81 ttl=64 time=0.102 ms
64 bytes from 10.0.0.2: icmp_seq=82 ttl=64 time=0.081 ms
64 bytes from 10.0.0.2: icmp_seq=83 ttl=64 time=0.088 ms
64 bytes from 10.0.0.2: icmp_seq=84 ttl=64 time=0.105 ms
64 bytes from 10.0.0.2: icmp_seq=86 ttl=64 time=0.115 ms
64 bytes from 10.0.0.2: icmp_seq=87 ttl=64 time=0.075 ms
64 bytes from 10.0.0.2: icmp_seq=88 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=89 ttl=64 time=0.081 ms
64 bytes from 10.0.0.2: icmp_seq=90 ttl=64 time=0.084 ms
64 bytes from 10.0.0.2: icmp_seq=91 ttl=64 time=0.095 ms
64 bytes from 10.0.0.2: icmp_seq=92 ttl=64 time=0.070 ms
64 bytes from 10.0.0.2: icmp_seq=93 ttl=64 time=0.219 ms
64 bytes from 10.0.0.2: icmp_seq=94 ttl=64 time=0.070 ms
64 bytes from 10.0.0.2: icmp_seq=95 ttl=64 time=0.071 ms
64 bytes from 10.0.0.2: icmp_seq=96 ttl=64 time=0.078 ms
64 bytes from 10.0.0.2: icmp_seq=97 ttl=64 time=0.072 ms
64 bytes from 10.0.0.2: icmp_seq=98 ttl=64 time=0.085 ms
64 bytes from 10.0.0.2: icmp_seq=99 ttl=64 time=0.086 ms
64 bytes from 10.0.0.2: icmp_seq=100 ttl=64 time=0.119 ms

--- 10.0.0.2 ping statistics ---
100 packets transmitted, 90 received, 10% packet loss, time 101342ms
rtt min/avg/max/mdev = 0.047/0.098/0.298/0.041 ms
root@mininet-vm:/home/mininet# █
```

Рис. 6: Проверка

## Интерактивные эксперименты

```
X "host h2"@mininet-vm
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 1175 bytes 256484 (256.4 KB)
        RX errors 0 dropped 0 overruns 0 frame 0
        TX packets 1175 bytes 256484 (256.4 KB)
        TX errors 0 dropped 0 overruns 0 carrier 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=2.76 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=0.125 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=0.078 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=0.198 ms
64 bytes from 10.0.0.1: icmp_seq=5 ttl=64 time=0.081 ms
64 bytes from 10.0.0.1: icmp_seq=6 ttl=64 time=0.092 ms

--- 10.0.0.1 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5082ms
rtt min/avg/max/mdev = 0.078/0.556/2.764/0.988 ms
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h2-eth0 root netem loss 10%
root@mininet-vm:/home/mininet#
```

Рис. 7: Добавление 10% потерь пакетов на хосте h2

## Интерактивные эксперименты

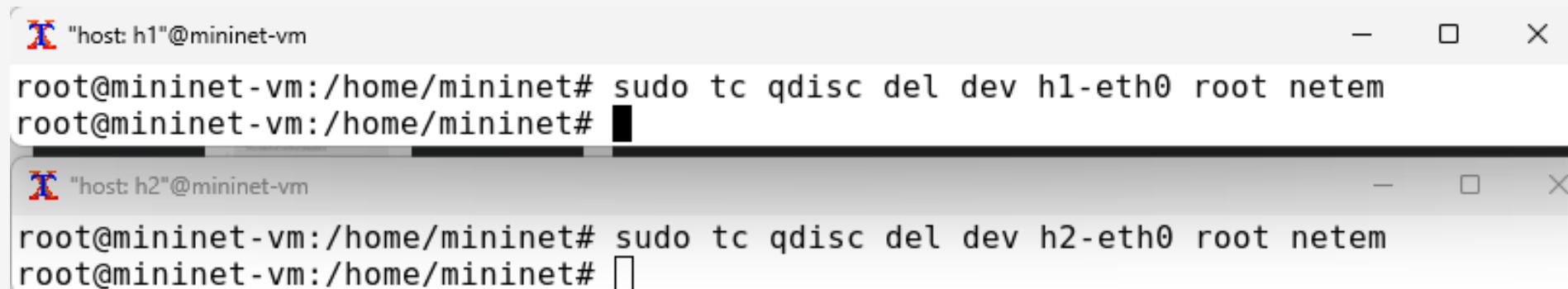
```
X "host h1"@mininet-vm
64 bytes from 10.0.0.2: icmp_seq=76 ttl=64 time=0.212 ms
64 bytes from 10.0.0.2: icmp_seq=77 ttl=64 time=0.080 ms
64 bytes from 10.0.0.2: icmp_seq=78 ttl=64 time=0.132 ms
64 bytes from 10.0.0.2: icmp_seq=81 ttl=64 time=0.826 ms
64 bytes from 10.0.0.2: icmp_seq=82 ttl=64 time=0.139 ms
64 bytes from 10.0.0.2: icmp_seq=84 ttl=64 time=0.081 ms
64 bytes from 10.0.0.2: icmp_seq=85 ttl=64 time=0.101 ms
64 bytes from 10.0.0.2: icmp_seq=87 ttl=64 time=0.077 ms
64 bytes from 10.0.0.2: icmp_seq=88 ttl=64 time=0.093 ms
64 bytes from 10.0.0.2: icmp_seq=90 ttl=64 time=0.123 ms
64 bytes from 10.0.0.2: icmp_seq=91 ttl=64 time=0.113 ms
64 bytes from 10.0.0.2: icmp_seq=92 ttl=64 time=0.637 ms
64 bytes from 10.0.0.2: icmp_seq=93 ttl=64 time=0.077 ms
64 bytes from 10.0.0.2: icmp_seq=94 ttl=64 time=0.078 ms
64 bytes from 10.0.0.2: icmp_seq=95 ttl=64 time=0.060 ms
64 bytes from 10.0.0.2: icmp_seq=96 ttl=64 time=0.102 ms
64 bytes from 10.0.0.2: icmp_seq=97 ttl=64 time=0.076 ms
64 bytes from 10.0.0.2: icmp_seq=98 ttl=64 time=0.115 ms
64 bytes from 10.0.0.2: icmp_seq=100 ttl=64 time=0.082 ms

--- 10.0.0.2 ping statistics ---
100 packets transmitted, 81 received, 19% packet loss, time 101337ms
rtt min/avg/max/mdev = 0.047/0.202/5.940/0.661 ms
root@mininet-vm:/home/mininet# █
```

Рис. 8: Проверка

## Интерактивные эксперименты

---



The image shows two terminal windows side-by-side. Both windows have a red 'X' icon in the top-left corner and standard window control buttons (minimize, maximize, close) in the top-right corner.

The left terminal window is titled "host: h1"@"mininet-vm". It contains the following command:

```
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root netem
```

The right terminal window is titled "host: h2"@"mininet-vm". It also contains the same command:

```
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h2-eth0 root netem
```

Рис. 9: Восстановление конфигурации по умолчанию для хоста h1 и хоста h2

## Интерактивные эксперименты

---

```
X "host h1"@mininet-vm - □ ×

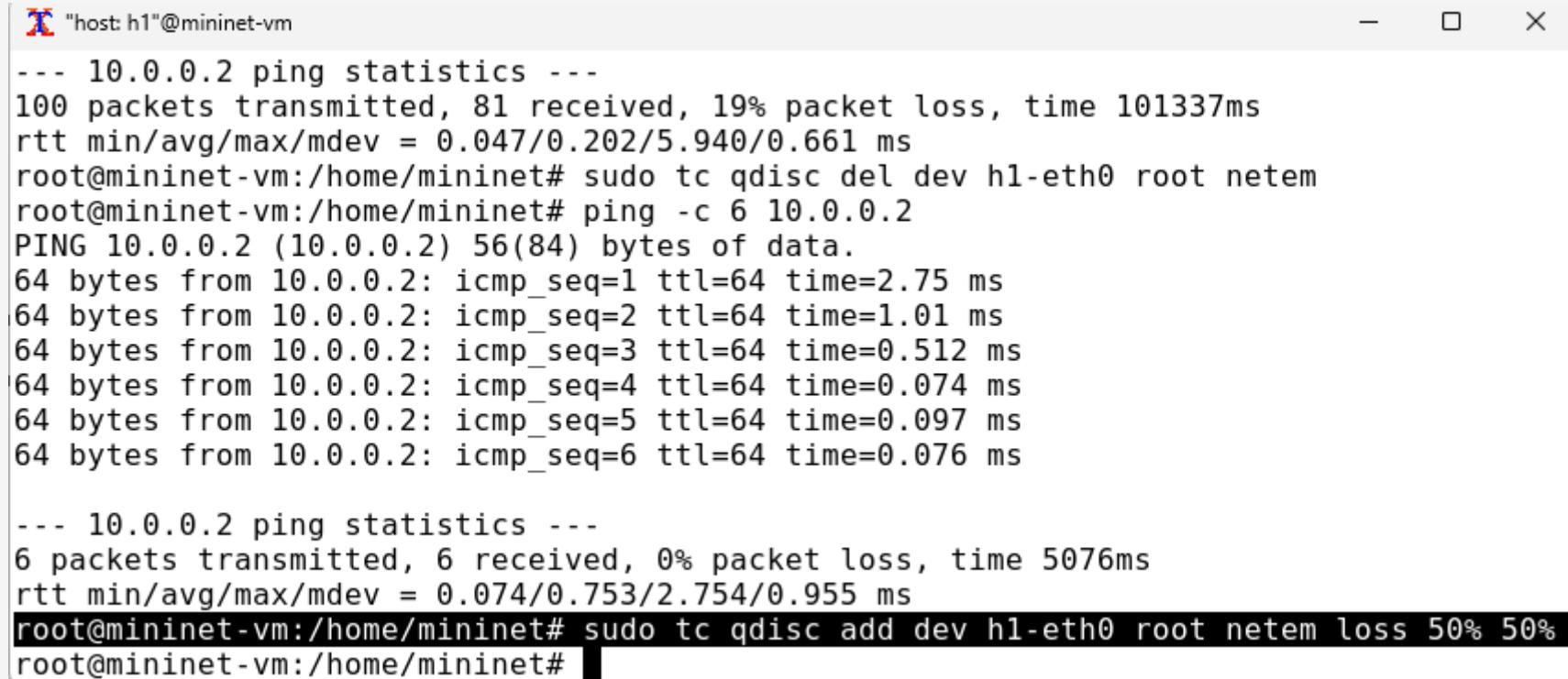
--- 10.0.0.2 ping statistics ---
100 packets transmitted, 81 received, 19% packet loss, time 101337ms
rtt min/avg/max/mdev = 0.047/0.202/5.940/0.661 ms
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root netem
root@mininet-vm:/home/mininet# ping -c 6 10.0.0.2
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=2.75 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=1.01 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.512 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.074 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.097 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.076 ms

--- 10.0.0.2 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5076ms
rtt min/avg/max/mdev = 0.074/0.753/2.754/0.955 ms
root@mininet-vm:/home/mininet# █
```

Рис. 10: Проверка

## Интерактивные эксперименты

---



"host h1"@\mininet-vm

```
--- 10.0.0.2 ping statistics ---
100 packets transmitted, 81 received, 19% packet loss, time 101337ms
rtt min/avg/max/mdev = 0.047/0.202/5.940/0.661 ms
root@\mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root netem
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=2.75 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=1.01 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.512 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.074 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.097 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.076 ms

--- 10.0.0.2 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5076ms
rtt min/avg/max/mdev = 0.074/0.753/2.754/0.955 ms
root@\mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root netem loss 50% 50%
root@\mininet-vm:/home/mininet#
```

Рис. 11: Добавление на узле h1 коэффициента потери пакетов 50%

## Интерактивные эксперименты

```
X "host h1"@mininet-vm
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=3 ttl=64 time=1.26 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=1.21 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=0.291 ms
64 bytes from 10.0.0.2: icmp_seq=31 ttl=64 time=2.45 ms
64 bytes from 10.0.0.2: icmp_seq=32 ttl=64 time=0.207 ms
64 bytes from 10.0.0.2: icmp_seq=33 ttl=64 time=0.129 ms
64 bytes from 10.0.0.2: icmp_seq=34 ttl=64 time=0.043 ms
64 bytes from 10.0.0.2: icmp_seq=36 ttl=64 time=0.094 ms
64 bytes from 10.0.0.2: icmp_seq=37 ttl=64 time=0.116 ms
64 bytes from 10.0.0.2: icmp_seq=38 ttl=64 time=0.125 ms
64 bytes from 10.0.0.2: icmp_seq=39 ttl=64 time=0.092 ms
64 bytes from 10.0.0.2: icmp_seq=40 ttl=64 time=0.103 ms
64 bytes from 10.0.0.2: icmp_seq=41 ttl=64 time=0.102 ms
64 bytes from 10.0.0.2: icmp_seq=42 ttl=64 time=0.135 ms
64 bytes from 10.0.0.2: icmp_seq=44 ttl=64 time=0.135 ms
64 bytes from 10.0.0.2: icmp_seq=46 ttl=64 time=0.097 ms
64 bytes from 10.0.0.2: icmp_seq=47 ttl=64 time=0.146 ms
64 bytes from 10.0.0.2: icmp_seq=49 ttl=64 time=0.101 ms

--- 10.0.0.2 ping statistics ---
50 packets transmitted, 18 received, 64% packet loss, time 50008ms
rtt min/avg/max/mdev = 0.043/0.379/2.453/0.612 ms
root@mininet-vm:/home/mininet# █
```

Рис. 12: Проверка

## Интерактивные эксперименты

```
X "host h1"@mininet-vm
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=1.26 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=1.21 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=0.291 ms
64 bytes from 10.0.0.2: icmp_seq=31 ttl=64 time=2.45 ms
64 bytes from 10.0.0.2: icmp_seq=32 ttl=64 time=0.207 ms
64 bytes from 10.0.0.2: icmp_seq=33 ttl=64 time=0.129 ms
64 bytes from 10.0.0.2: icmp_seq=34 ttl=64 time=0.043 ms
64 bytes from 10.0.0.2: icmp_seq=36 ttl=64 time=0.094 ms
64 bytes from 10.0.0.2: icmp_seq=37 ttl=64 time=0.116 ms
64 bytes from 10.0.0.2: icmp_seq=38 ttl=64 time=0.125 ms
64 bytes from 10.0.0.2: icmp_seq=39 ttl=64 time=0.092 ms
64 bytes from 10.0.0.2: icmp_seq=40 ttl=64 time=0.103 ms
64 bytes from 10.0.0.2: icmp_seq=41 ttl=64 time=0.102 ms
64 bytes from 10.0.0.2: icmp_seq=42 ttl=64 time=0.135 ms
64 bytes from 10.0.0.2: icmp_seq=44 ttl=64 time=0.135 ms
64 bytes from 10.0.0.2: icmp_seq=46 ttl=64 time=0.097 ms
64 bytes from 10.0.0.2: icmp_seq=47 ttl=64 time=0.146 ms
64 bytes from 10.0.0.2: icmp_seq=49 ttl=64 time=0.101 ms

--- 10.0.0.2 ping statistics ---
50 packets transmitted, 18 received, 64% packet loss, time 50008ms
rtt min/avg/max/mdev = 0.043/0.379/2.453/0.612 ms
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root netem
root@mininet-vm:/home/mininet#
```

Рис. 13: Восстановление конфигурации интерфейса по умолчанию

## Интерактивные эксперименты

```
X "host: h1"@mininet-vm
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=1.26 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=1.21 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=0.291 ms
64 bytes from 10.0.0.2: icmp_seq=31 ttl=64 time=2.45 ms
64 bytes from 10.0.0.2: icmp_seq=32 ttl=64 time=0.207 ms
64 bytes from 10.0.0.2: icmp_seq=33 ttl=64 time=0.129 ms
64 bytes from 10.0.0.2: icmp_seq=34 ttl=64 time=0.043 ms
64 bytes from 10.0.0.2: icmp_seq=36 ttl=64 time=0.094 ms
64 bytes from 10.0.0.2: icmp_seq=37 ttl=64 time=0.116 ms
64 bytes from 10.0.0.2: icmp_seq=38 ttl=64 time=0.125 ms
64 bytes from 10.0.0.2: icmp_seq=39 ttl=64 time=0.092 ms
64 bytes from 10.0.0.2: icmp_seq=40 ttl=64 time=0.103 ms
64 bytes from 10.0.0.2: icmp_seq=41 ttl=64 time=0.102 ms
64 bytes from 10.0.0.2: icmp_seq=42 ttl=64 time=0.135 ms
64 bytes from 10.0.0.2: icmp_seq=44 ttl=64 time=0.135 ms
64 bytes from 10.0.0.2: icmp_seq=46 ttl=64 time=0.097 ms
64 bytes from 10.0.0.2: icmp_seq=47 ttl=64 time=0.146 ms
64 bytes from 10.0.0.2: icmp_seq=49 ttl=64 time=0.101 ms

--- 10.0.0.2 ping statistics ---
50 packets transmitted, 18 received, 64% packet loss, time 50008ms
rtt min/avg/max/mdev = 0.043/0.379/2.453/0.612 ms
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root netem
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root netem corrupt 0.01%
```

Рис. 14: Добавление на узле h1 0.01% повреждения пакетов

## Интерактивные эксперименты

```
X "host: h1"@mininet-vm
Cannot find device "h2-eth0"
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 41988 connected to 10.0.0.2 port 5201
[ ID] Interval           Transfer     Bitrate      Retr  Cwnd
[ 7]  0.00-1.01   sec  1.25 GBytes   10.7 Gbits/sec    1  5.79 MBytes
[ 7]  1.01-2.01   sec  1.33 GBytes   11.4 Gbits/sec    2  2.93 MBytes
[ 7]  2.01-3.00   sec  1.26 GBytes   10.9 Gbits/sec    1  2.32 MBytes
[ 7]  3.00-4.00   sec  1.25 GBytes   10.7 Gbits/sec    1  2.00 MBytes
[ 7]  4.00-5.00   sec  1.40 GBytes   12.1 Gbits/sec    1  1.67 MBytes
[ 7]  5.00-6.00   sec  1.28 GBytes   10.9 Gbits/sec    3  1.09 MBytes
[ 7]  6.00-7.00   sec  1.38 GBytes   11.8 Gbits/sec    2  1.20 MBytes
[ 7]  7.00-8.00   sec  1.23 GBytes   10.6 Gbits/sec    3  2.20 MBytes
[ 7]  8.00-9.01   sec  1.40 GBytes   11.9 Gbits/sec    5  894 KBytes
[ 7]  9.01-10.00  sec  1.54 GBytes   13.3 Gbits/sec    2  1.44 MBytes
[ 7]  0.00-10.00  sec  13.3 GBytes   11.4 Gbits/sec   21
[ 7]  0.00-10.01  sec  13.3 GBytes   11.4 Gbits/sec
sender
receiver

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

Рис. 15: Проверка конфигурации с помощью инструмента iPerf3 для проверки повторных передач

## Интерактивные эксперименты

```
X "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 41988 connected to 10.0.0.2 port 5201
[ ID] Interval          Transfer     Bitrate      Retr  Cwnd
[ 7]  0.00-1.01    sec   1.25 GBytes   10.7 Gbits/sec   1  5.79 MBytes
[ 7]  1.01-2.01    sec   1.33 GBytes   11.4 Gbits/sec   2  2.93 MBytes
[ 7]  2.01-3.00    sec   1.26 GBytes   10.9 Gbits/sec   1  2.32 MBytes
[ 7]  3.00-4.00    sec   1.25 GBytes   10.7 Gbits/sec   1  2.00 MBytes
[ 7]  4.00-5.00    sec   1.40 GBytes   12.1 Gbits/sec   1  1.67 MBytes
[ 7]  5.00-6.00    sec   1.28 GBytes   10.9 Gbits/sec   3  1.09 MBytes
[ 7]  6.00-7.00    sec   1.38 GBytes   11.8 Gbits/sec   2  1.20 MBytes
[ 7]  7.00-8.00    sec   1.23 GBytes   10.6 Gbits/sec   3  2.20 MBytes
[ 7]  8.00-9.01    sec   1.40 GBytes   11.9 Gbits/sec   5  894 KBytes
[ 7]  9.01-10.00   sec   1.54 GBytes   13.3 Gbits/sec   2  1.44 MBytes
-
[ ID] Interval          Transfer     Bitrate      Retr
[ 7]  0.00-10.00   sec   13.3 GBytes   11.4 Gbits/sec  21
[ 7]  0.00-10.01   sec   13.3 GBytes   11.4 Gbits/sec
                                         sender
                                         receiver

iperf Done.
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root netem
root@mininet-vm:/home/mininet#
```

Рис. 16: Восстановление конфигурации интерфейса по умолчанию

## Интерактивные эксперименты

---



A screenshot of a terminal window titled "host: h1" @ mininet-vm. The window contains the following command and its output:

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

Рис. 17: Добавление на узле h1 правила из лабораторной работы

## Интерактивные эксперименты

```
xi "host: h1"@mininet-vm
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=10.3 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=11.2 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=10.3 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=10.6 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=10.6 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=0.061 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=0.046 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=10.9 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=10.4 ms
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=0.063 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=10.8 ms
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=10.8 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=10.7 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=10.7 ms
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=10.1 ms
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=0.384 ms
64 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=10.8 ms

--- 10.0.0.2 ping statistics ---
20 packets transmitted, 20 received, 0% packet loss, time 19090ms
rtt min/avg/max/mdev = 0.046/8.530/11.194/4.202 ms
root@mininet-vm:/home/mininet#
```

Рис. 18: Проверка

## Интерактивные эксперименты

---



terminal window showing a root shell on host h1@mininet-vm. The user runs the command 'sudo tc qdisc del dev h1-eth0 root netem' to remove a traffic discipline from the interface.

```
"host: h1" @mininet-vm
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root netem
root@mininet-vm:/home/mininet# █
```

Рис. 19: Восстановление конфигурации интерфейса по умолчанию

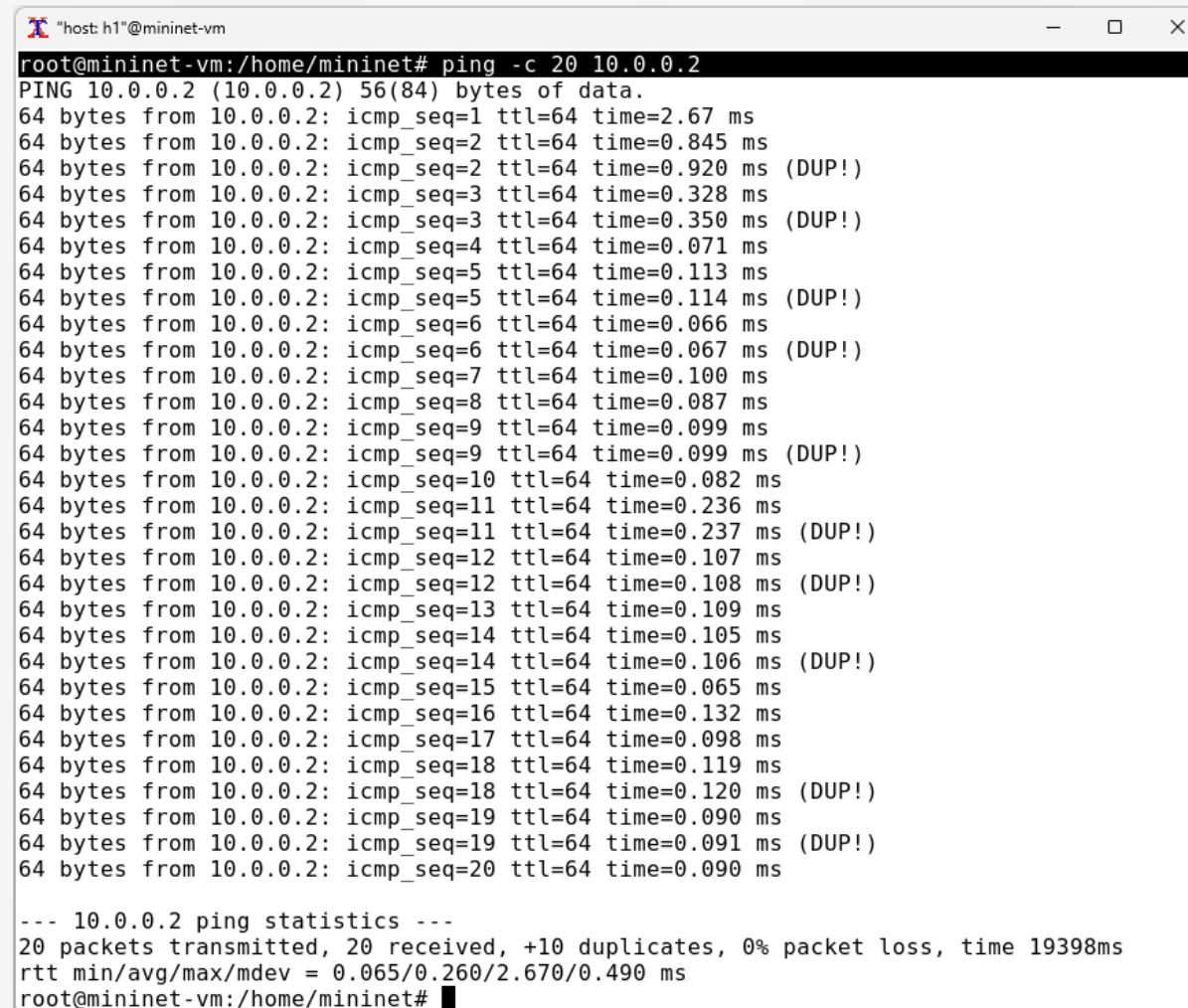
## Интерактивные эксперименты

```
X "host: h1"@mininet-vm
64 bytes from 10.0.0.1: icmp_seq=1 ttl=64 time=0.033 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=0.086 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=0.055 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=0.051 ms
64 bytes from 10.0.0.1: icmp_seq=5 ttl=64 time=0.056 ms
64 bytes from 10.0.0.1: icmp_seq=6 ttl=64 time=0.080 ms
64 bytes from 10.0.0.1: icmp_seq=7 ttl=64 time=0.077 ms
64 bytes from 10.0.0.1: icmp_seq=8 ttl=64 time=0.064 ms
64 bytes from 10.0.0.1: icmp_seq=9 ttl=64 time=0.095 ms
64 bytes from 10.0.0.1: icmp_seq=10 ttl=64 time=0.065 ms
64 bytes from 10.0.0.1: icmp_seq=11 ttl=64 time=0.091 ms
64 bytes from 10.0.0.1: icmp_seq=12 ttl=64 time=0.060 ms
64 bytes from 10.0.0.1: icmp_seq=13 ttl=64 time=0.091 ms
64 bytes from 10.0.0.1: icmp_seq=14 ttl=64 time=0.068 ms
64 bytes from 10.0.0.1: icmp_seq=15 ttl=64 time=0.055 ms
64 bytes from 10.0.0.1: icmp_seq=16 ttl=64 time=0.644 ms
64 bytes from 10.0.0.1: icmp_seq=17 ttl=64 time=0.112 ms
64 bytes from 10.0.0.1: icmp_seq=18 ttl=64 time=0.087 ms
64 bytes from 10.0.0.1: icmp_seq=19 ttl=64 time=0.071 ms
64 bytes from 10.0.0.1: icmp_seq=20 ttl=64 time=0.090 ms

--- 10.0.0.1 ping statistics ---
20 packets transmitted, 20 received, 0% packet loss, time 19436ms
rtt min/avg/max/mdev = 0.033/0.101/0.644/0.125 ms
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#
```

Рис. 20: Добавление на узле h1 правила с дублированием 50% пакетов

## Интерактивные эксперименты



The screenshot shows a terminal window titled "host h1" running on a Mininet VM. The user has run the command `ping -c 20 10.0.0.2`. The output displays 20 ICMP echo requests sent to the target host at 10.0.0.2. Each request is 64 bytes long, has a TTL of 64, and includes the sequence number (icmp\_seq). The times for each request range from 0.065 ms to 2.67 ms. The output highlights several duplicate responses (DUP!) with sequence numbers 2, 3, 5, 6, 9, 11, 12, 13, 14, 15, 16, 17, 18, 19, and 20. After the ping command, the terminal shows statistics: 20 packets transmitted, 20 received, 10 duplicates, 0% packet loss, and a total time of 19398ms. The round-trip time (RTT) is summarized as min/avg/max/mdev = 0.065/0.260/2.670/0.490 ms.

```
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=2.67 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.845 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.920 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.328 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.350 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.071 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.113 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.114 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.066 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.067 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=0.100 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=0.087 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=0.099 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=0.099 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=0.082 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.236 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.237 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=0.107 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=0.108 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=0.109 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=0.105 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=0.106 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=0.065 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=0.132 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=0.098 ms
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=0.119 ms
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=0.120 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=0.090 ms
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=0.091 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=0.090 ms

--- 10.0.0.2 ping statistics ---
20 packets transmitted, 20 received, +10 duplicates, 0% packet loss, time 19398ms
rtt min/avg/max/mdev = 0.065/0.260/2.670/0.490 ms
root@mininet-vm:/home/mininet#
```

Рис. 21: Проверка

## Интерактивные эксперименты

---



The screenshot shows a terminal window with the title "host: h1" @mininet-vm. The window contains the following text:

```
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root netem
root@mininet-vm:/home/mininet# █
```

Рис. 22: Восстановление конфигурации интерфейса по умолчанию

## Воспроизведение экспериментов

---

```
mininet@mininet-vm:~$ mkdir -p ~/work/lab_netem_i/expname  
mininet@mininet-vm:~$
```

Рис. 23: Создание каталога expname

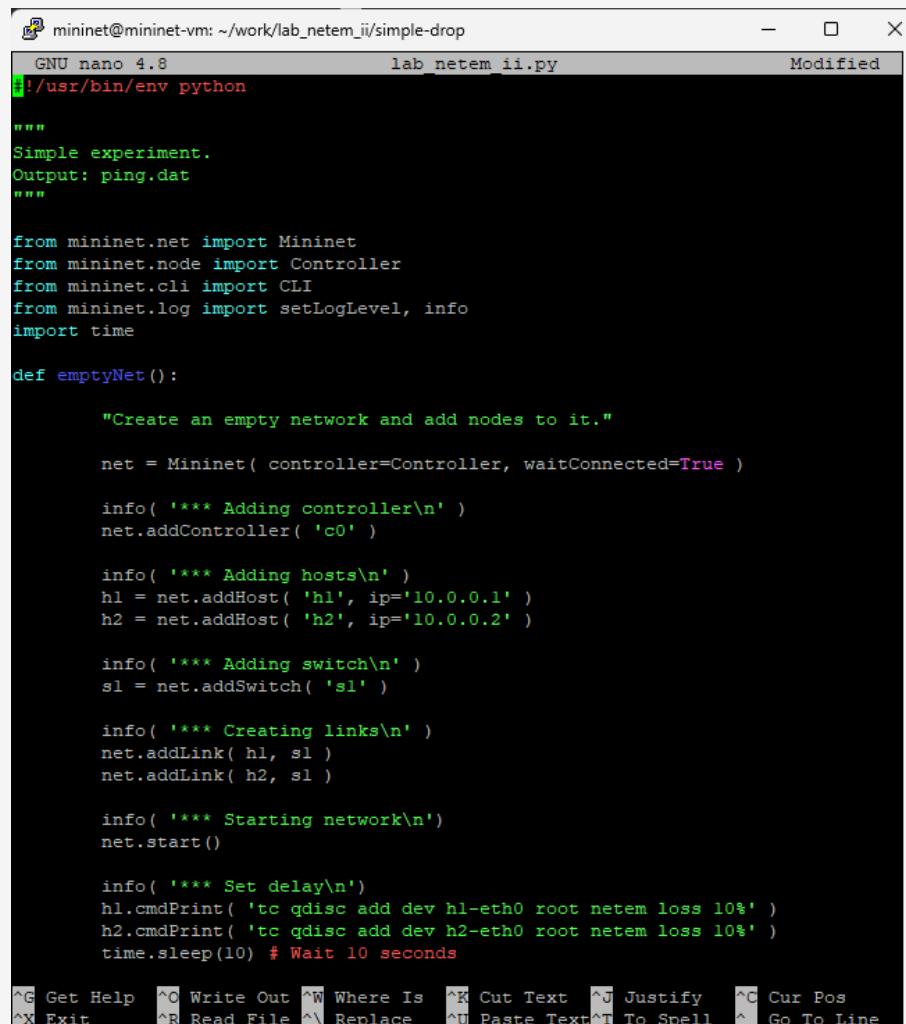
## Воспроизведение экспериментов

---

```
mininet@mininet-vm:~$ mkdir -p ~/work/lab_netem_ii/simple-drop
mininet@mininet-vm:~$ cd ^C
mininet@mininet-vm:~$ cd ~/work/lab_netem_ii/simple-drop
mininet@mininet-vm:~/work/lab_netem_ii/simple-drop$ touch lab_netem_ii.py
mininet@mininet-vm:~/work/lab_netem_ii/simple-drop$ ls
lab_netem_ii.py
mininet@mininet-vm:~/work/lab_netem_ii/simple-drop$ █
```

Рис. 24: Создание каталога simple-drop и дальнейшее его открытие

## Воспроизведение экспериментов



The screenshot shows a terminal window titled "mininet@mininet-vm: ~/work/lab\_neterm\_ii/simple-drop". The window contains a code editor displaying a Python script named "lab\_neterm\_ii.py". The script is used to set up a simple network experiment. It imports necessary modules from mininet and defines a function "emptyNet" which creates two hosts (h1 and h2) and one switch (s1), connects them, starts the network, and configures traffic classes on both hosts to drop 10% of packets. The terminal interface includes standard nano editor key bindings at the bottom.

```
GNU nano 4.8          lab_neterm_ii.py          Modified
#!/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 )

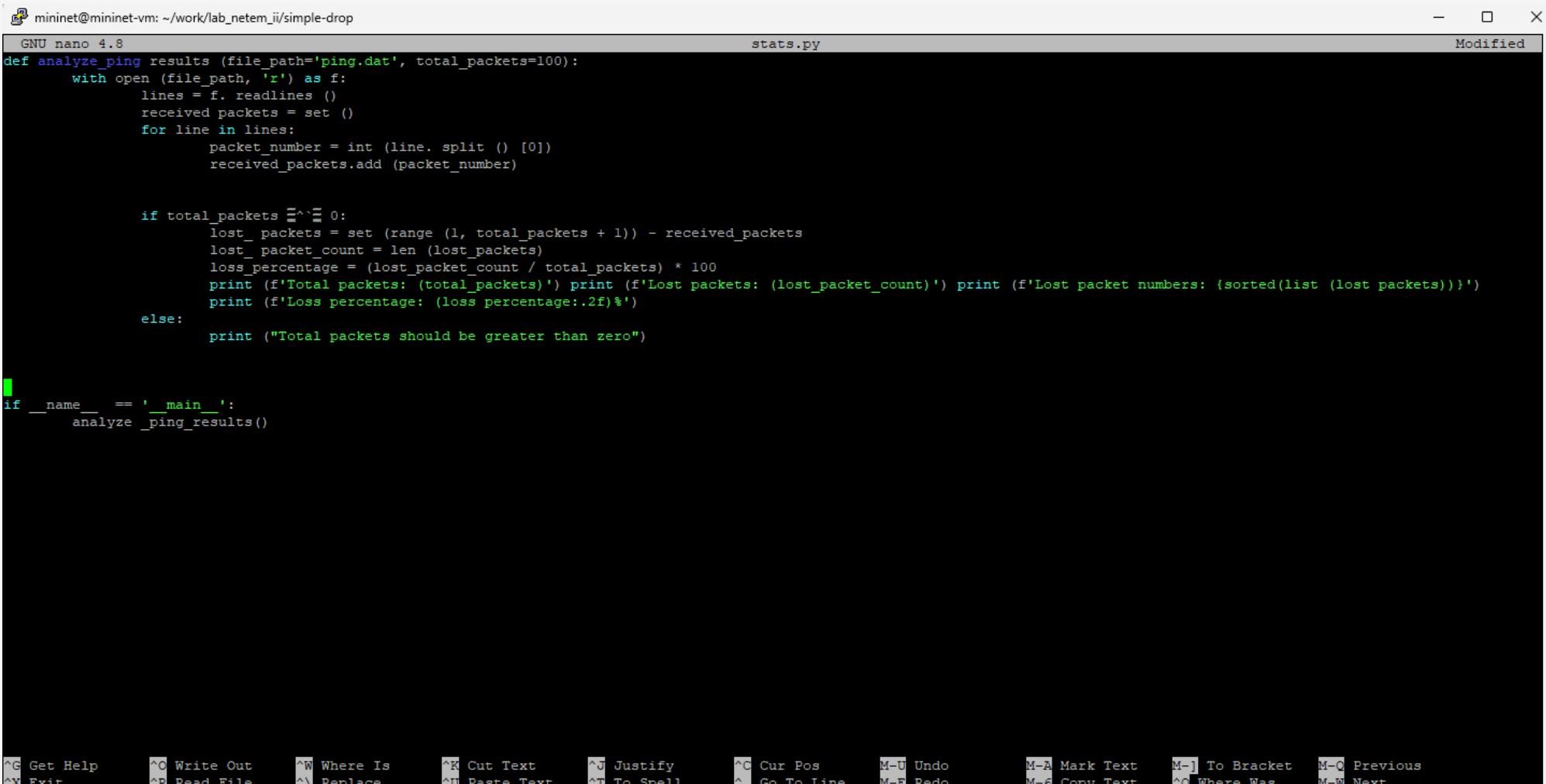
    info( "*** Starting network\n" )
    net.start()

    info( "*** Set delay\n" )
    h1.cmdPrint( 'tc qdisc add dev h1-eth0 root netem loss 10%' )
    h2.cmdPrint( 'tc qdisc add dev h2-eth0 root netem loss 10%' )
    time.sleep(10) # Wait 10 seconds

^G Get Help  ^O Write Out  ^W Where Is  ^K Cut Text  ^J Justify  ^C Cur Pos
^X Exit     ^R Read File  ^\ Replace   ^U Paste Text^T To Spell  ^L Go To Line
```

Рис. 25: Создание скрипта для эксперимента

## Воспроизведение экспериментов



```
mininet@mininet-vm: ~/work/lab_neterm_ii/simple-drop
GNU nano 4.8
def analyze_ping_results(file_path='ping.dat', total_packets=100):
    with open(file_path, 'r') as f:
        lines = f.readlines()
        received_packets = set()
        for line in lines:
            packet_number = int(line.split()[0])
            received_packets.add(packet_number)

    if total_packets == 0:
        lost_packets = set(range(1, total_packets + 1)) - received_packets
        lost_packet_count = len(lost_packets)
        loss_percentage = (lost_packet_count / total_packets) * 100
        print(f'Total packets: {total_packets}')
        print(f'Lost packets: {lost_packet_count}')
        print(f'Lost packet numbers: {sorted(list(lost_packets))}')
        print(f'Loss percentage: {loss_percentage:.2f}%')
    else:
        print("Total packets should be greater than zero")

if __name__ == '__main__':
    analyze_ping_results()
```

^G Get Help ^O Write Out ^W Where Is ^K Cut Text ^J Justify ^C Cur Pos M-U Undo M-A Mark Text M-J To Bracket M-Q Previous  
^X Exit ^R Read File ^\ Replace ^U Paste Text ^T To Spell ^ Go To Line M-E Redo M-6 Copy Text ^Q Where Was M-W Next

Рис. 26: Создание нового скрипта для вывода информации о потере пакетов

## Воспроизведение экспериментов

---

```
mininet@mininet-vm: ~/work/lab_netem_ii/simple-drop  
GNU nano 4.8  
all: ping.dat  
  
ping.dat:  
        sudo python lab_netem_ii.py  
        sudo chown mininet:mininet ping.dat  
  
stats:  
        sudo python stats.py  
  
clean:  
        -rm -f *.dat
```

Рис. 27: Создание Makefile и помещение в него скрипта

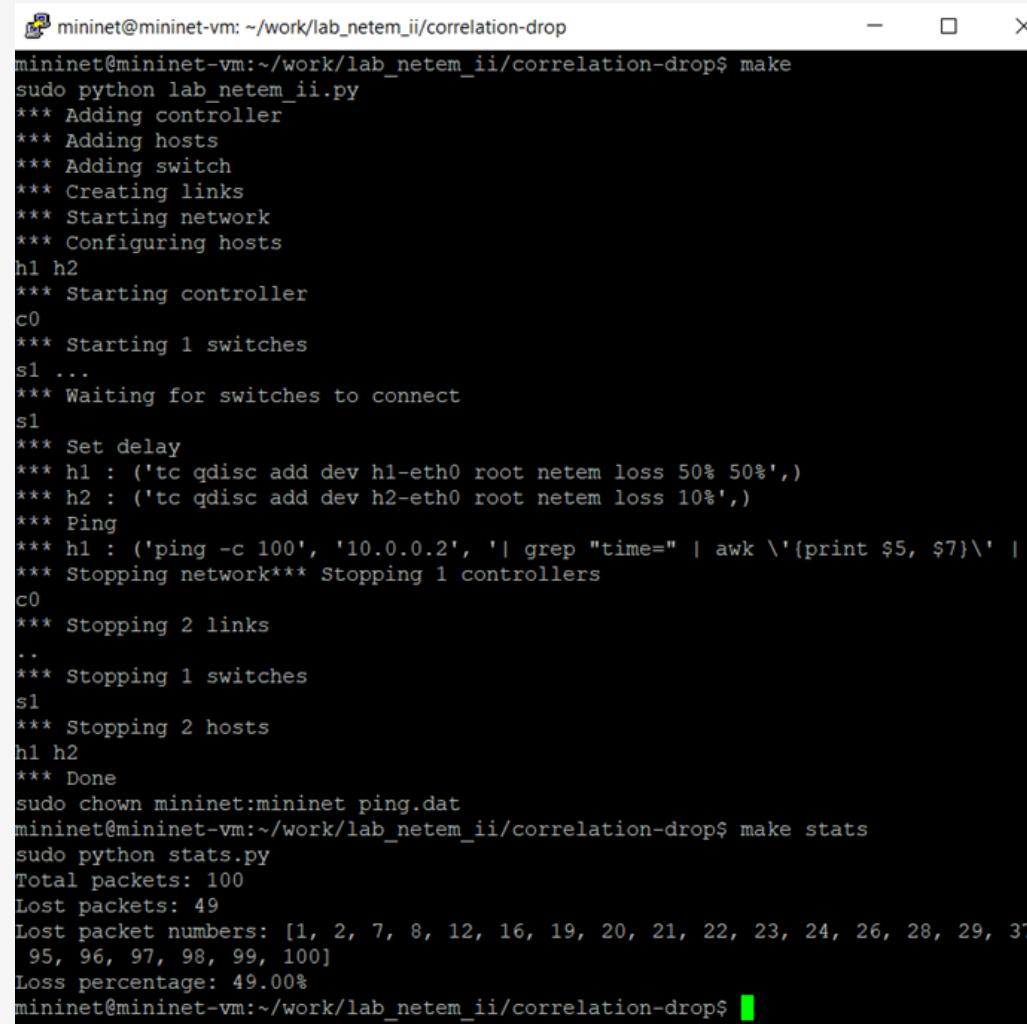
## Воспроизведение экспериментов

---

```
mininet@mininet-vm:~/work/lab_netem_ii/simple-drop$ make
make: Nothing to be done for 'all'.
mininet@mininet-vm:~/work/lab_netem_ii/simple-drop$ make stats
sudo python stats.py
\Total packets: (total_packets)
Lost packets: (lost_packet_count)
Lost packet numbers: [21, 23, 25, 26, 28, 49, 50, 51, 56, 60, 64, 80, 81, 83, 87, 91, 100]
Loss percentage: (loss_percentage:.2f)%
mininet@mininet-vm:~/work/lab_netem_ii/simple-drop$
```

Рис. 28: Выполнение эксперимента и последующая очистка каталога

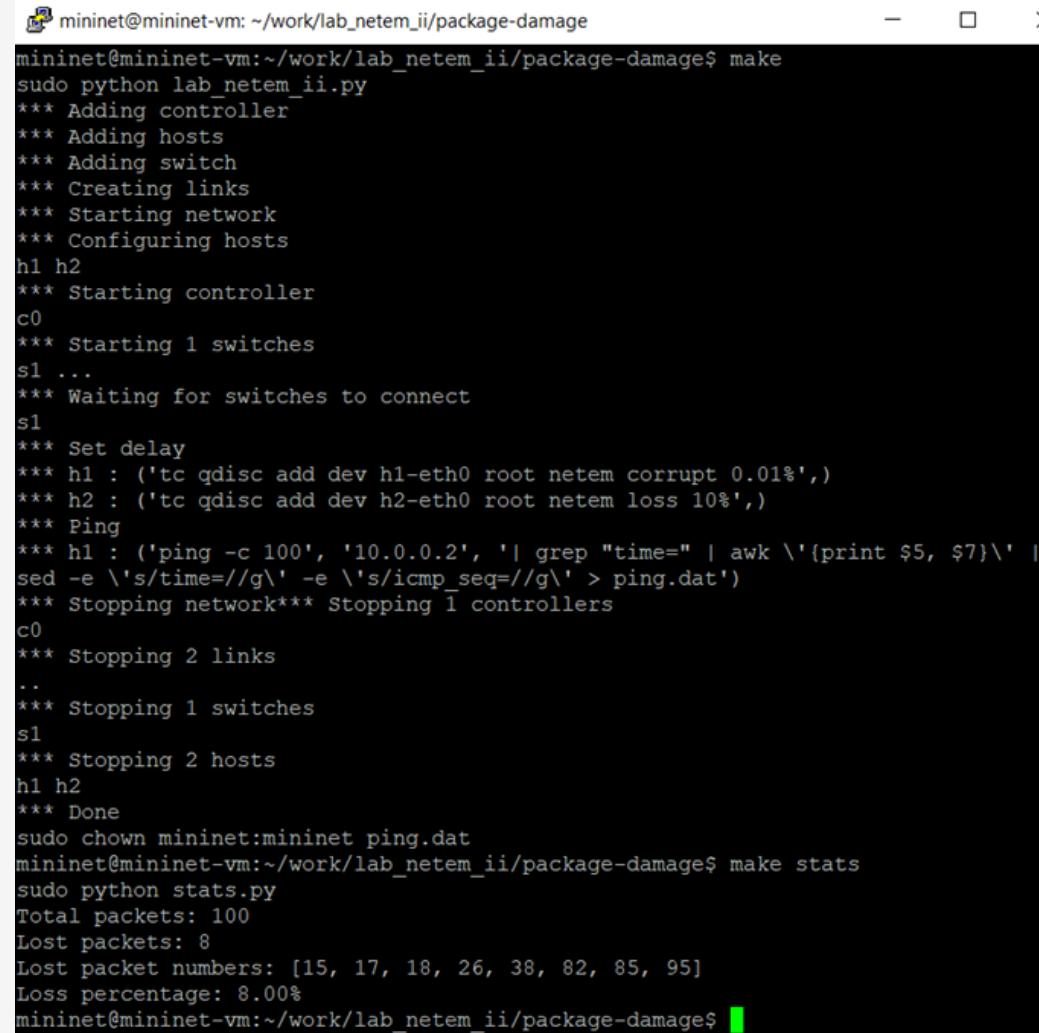
## Воспроизведение экспериментов



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 : ('tc qdisc add dev h1-eth0 root netem loss 50% 50%',)  
\*\*\* 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}\'')  
\*\*\* 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/correlation-drop\$ make stats  
sudo python stats.py  
Total packets: 100  
Lost packets: 49  
Lost packet numbers: [1, 2, 7, 8, 12, 16, 19, 20, 21, 22, 23, 24, 26, 28, 29, 37,  
95, 96, 97, 98, 99, 100]  
Loss percentage: 49.00%  
mininet@mininet-vm:~/work/lab\_netem\_ii/correlation-drop\$

Рис. 29: Реализация воспроизводимого эксперимента по исследованию параметров сети

## Воспроизведение экспериментов

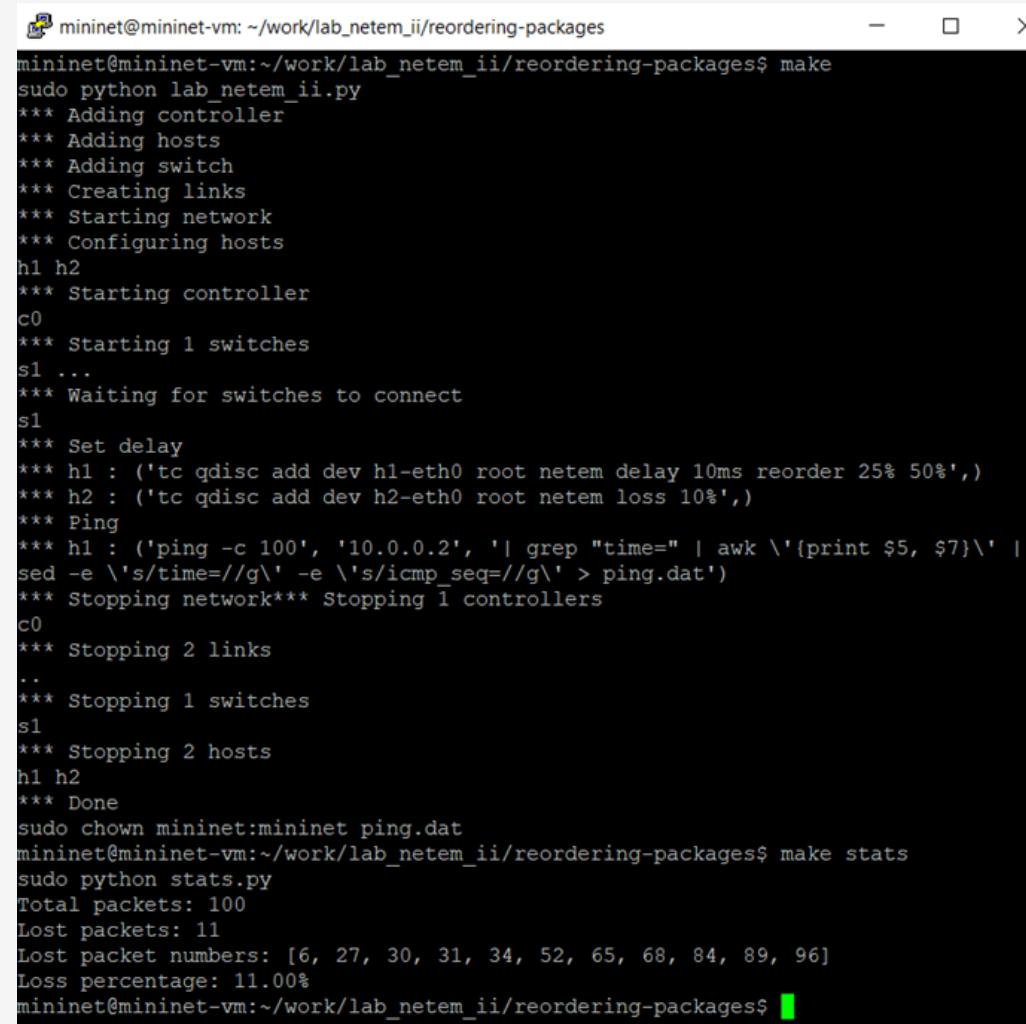


Screenshot of a terminal window titled "mininet@mininet-vm: ~/work/lab\_netem\_ii/package-damage". The window shows the execution of a Python script to set up a network topology and perform a ping test between hosts h1 and h2, while applying network delays and corruption. The terminal also displays the resulting statistics from the experiment.

```
mininet@mininet-vm:~/work/lab_netem_ii/package-damage$ 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%,')
*** 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, $7}\' | sed -e \'s/time=/g\' -e \'s/icmp_seq=/g\' > ping.dat')
*** Stopping network
*** Stopping 1 controllers
c0
*** Stopping 2 links
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
mininet@mininet-vm:~/work/lab_netem_ii/package-damage$ make stats
sudo python stats.py
Total packets: 100
Lost packets: 8
Lost packet numbers: [15, 17, 18, 26, 38, 82, 85, 95]
Loss percentage: 8.00%
mininet@mininet-vm:~/work/lab_netem_ii/package-damage$
```

Рис. 30: Реализация воспроизводимого эксперимента по исследованию параметров сети

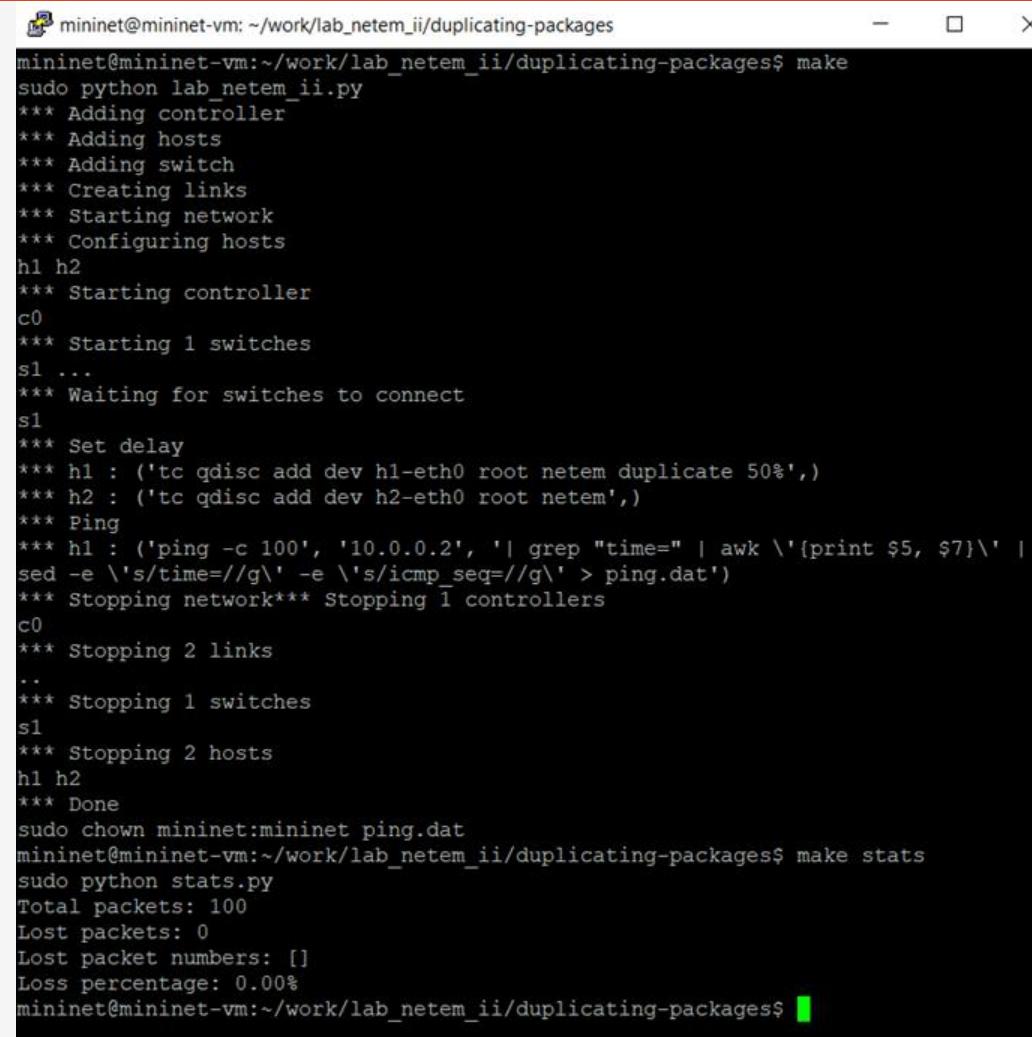
## Воспроизведение экспериментов



mininet@mininet-vm: ~/work/lab\_netem\_ii/reordering-packages\$ 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 delay 10ms reorder 25% 50%',)  
\*\*\* 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  
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/reordering-packages\$ make stats  
sudo python stats.py  
Total packets: 100  
Lost packets: 11  
Lost packet numbers: [6, 27, 30, 31, 34, 52, 65, 68, 84, 89, 96]  
Loss percentage: 11.00%  
mininet@mininet-vm:~/work/lab\_netem\_ii/reordering-packages\$

Рис. 31: Реализация воспроизводимого эксперимента по исследованию параметров сети

## Воспроизведение экспериментов



```
mininet@mininet-vm:~/work/lab_netem_ii/duplicating-packages$ 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%',)
*** h2 : ('tc qdisc add dev h2-eth0 root netem',)
*** Ping
*** h1 : ('ping -c 100', '10.0.0.2', '| grep "time=" | awk \'{print $5, $7}\'' |
sed -e '/s/time=/g' -e '/s/icmp_seq=/g' > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 2 links
...
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
mininet@mininet-vm:~/work/lab_netem_ii/duplicating-packages$ make stats
sudo python stats.py
Total packets: 100
Lost packets: 0
Lost packet numbers: []
Loss percentage: 0.00%
mininet@mininet-vm:~/work/lab_netem_ii/duplicating-packages$
```

Рис. 32: Реализация воспроизводимого эксперимента по исследованию параметров сети

## Вывод

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

## Список литературы. Библиография

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[1] Mininet: <https://mininet.org/>