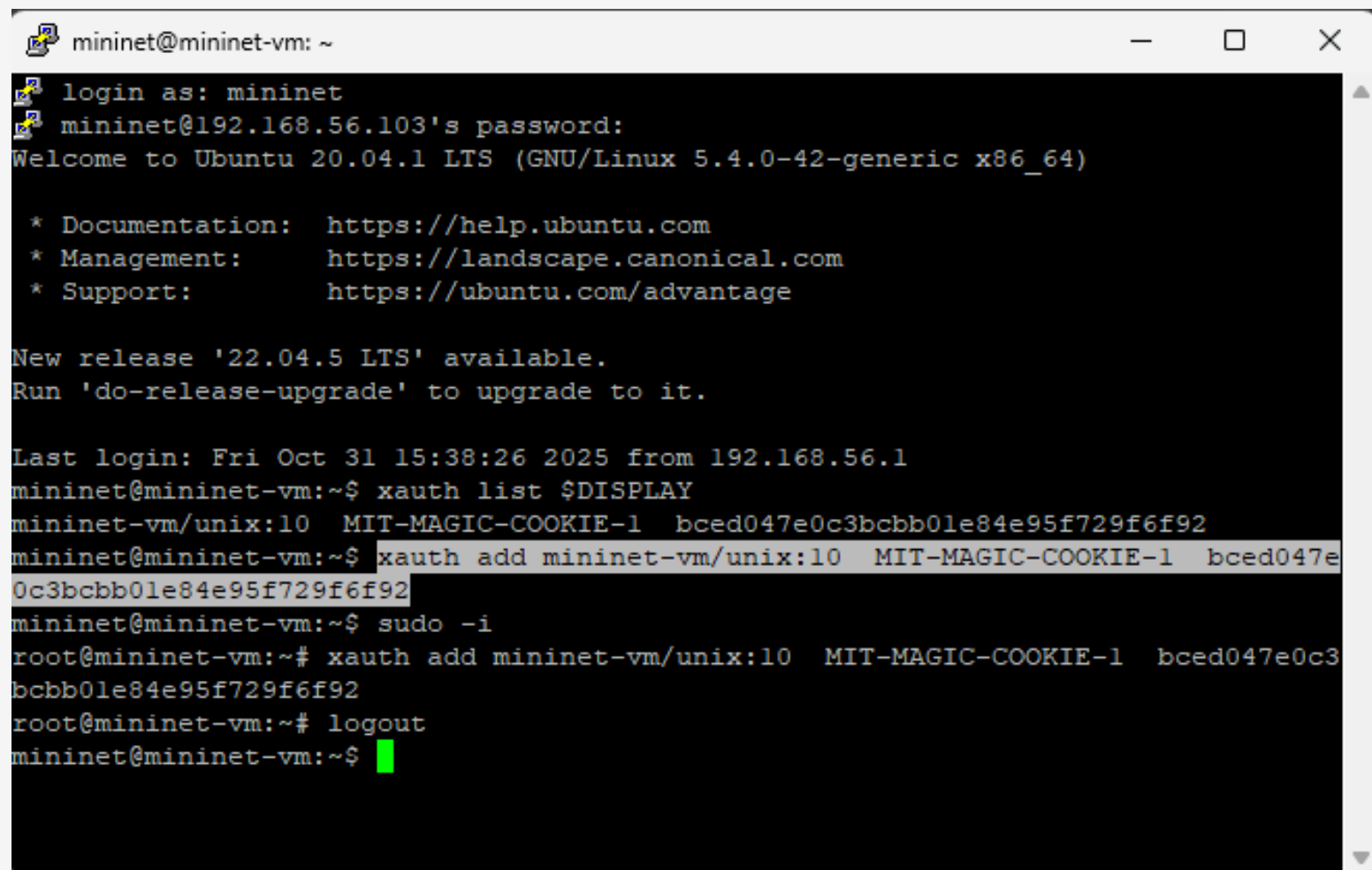# Лабораторная работа №5
Моделирование сетей передачи данных

Исаев Б. А.

2025

Российский университет дружбы народов имени Патриса Лумумбы, Москва, Россия
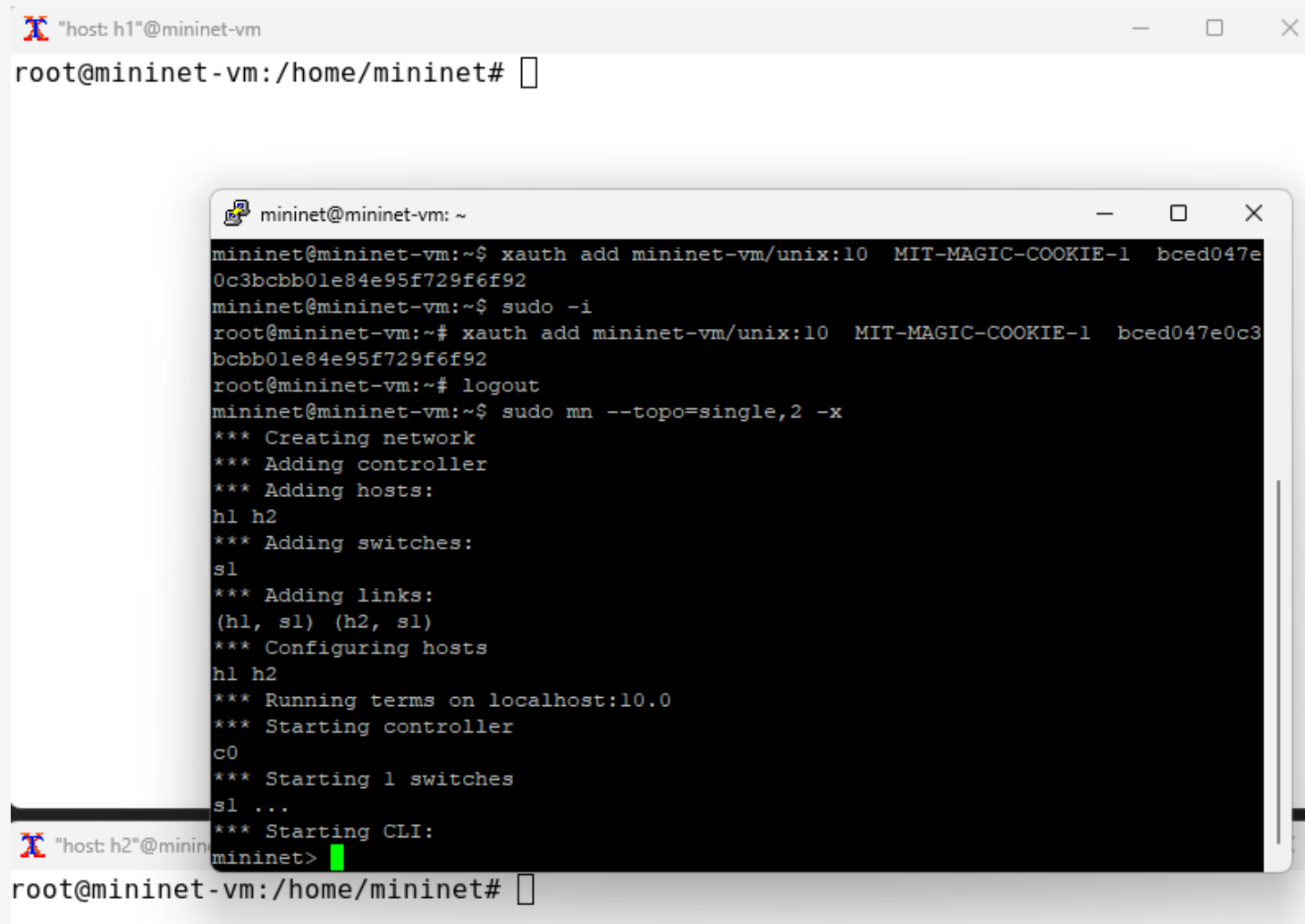
Запуск лабораторной топологии

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

Запуск лабораторной топологии

Рис. 2: Создание простейшей топологии

Запуск лабораторной топологии

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

Запуск лабораторной топологии

Рис. 4: Проверка подключения между хостами h1 и h2

Интерактивные эксперименты

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

Интерактивные эксперименты


```
"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


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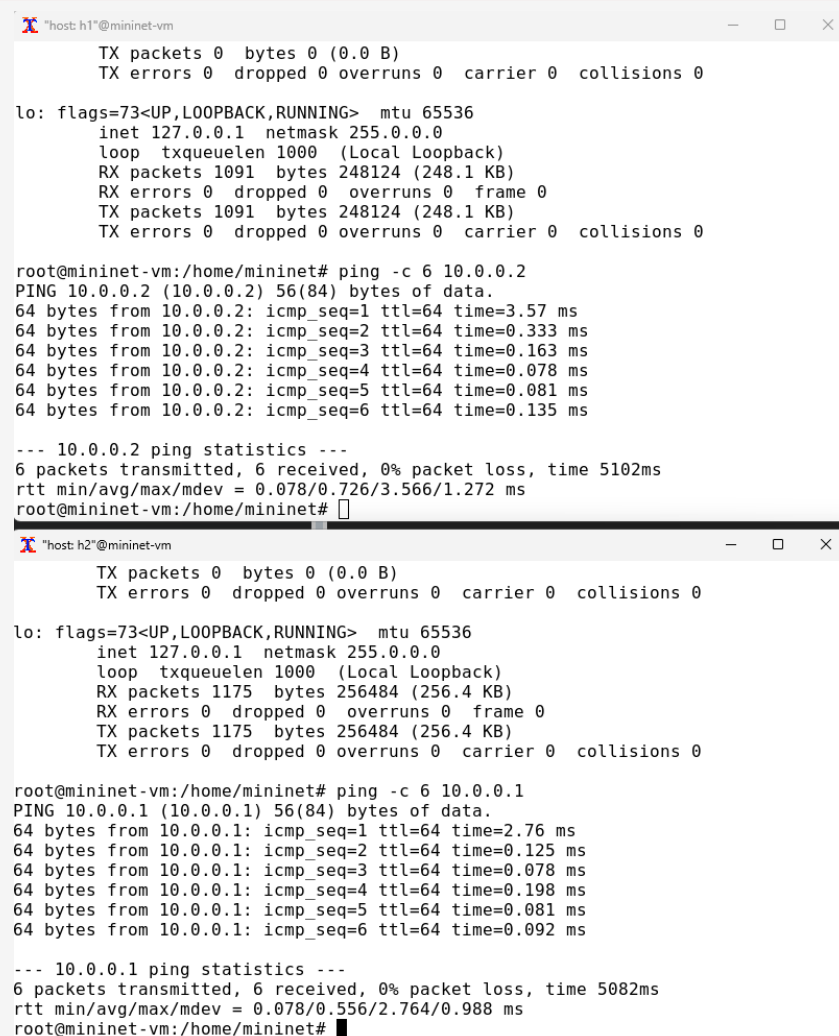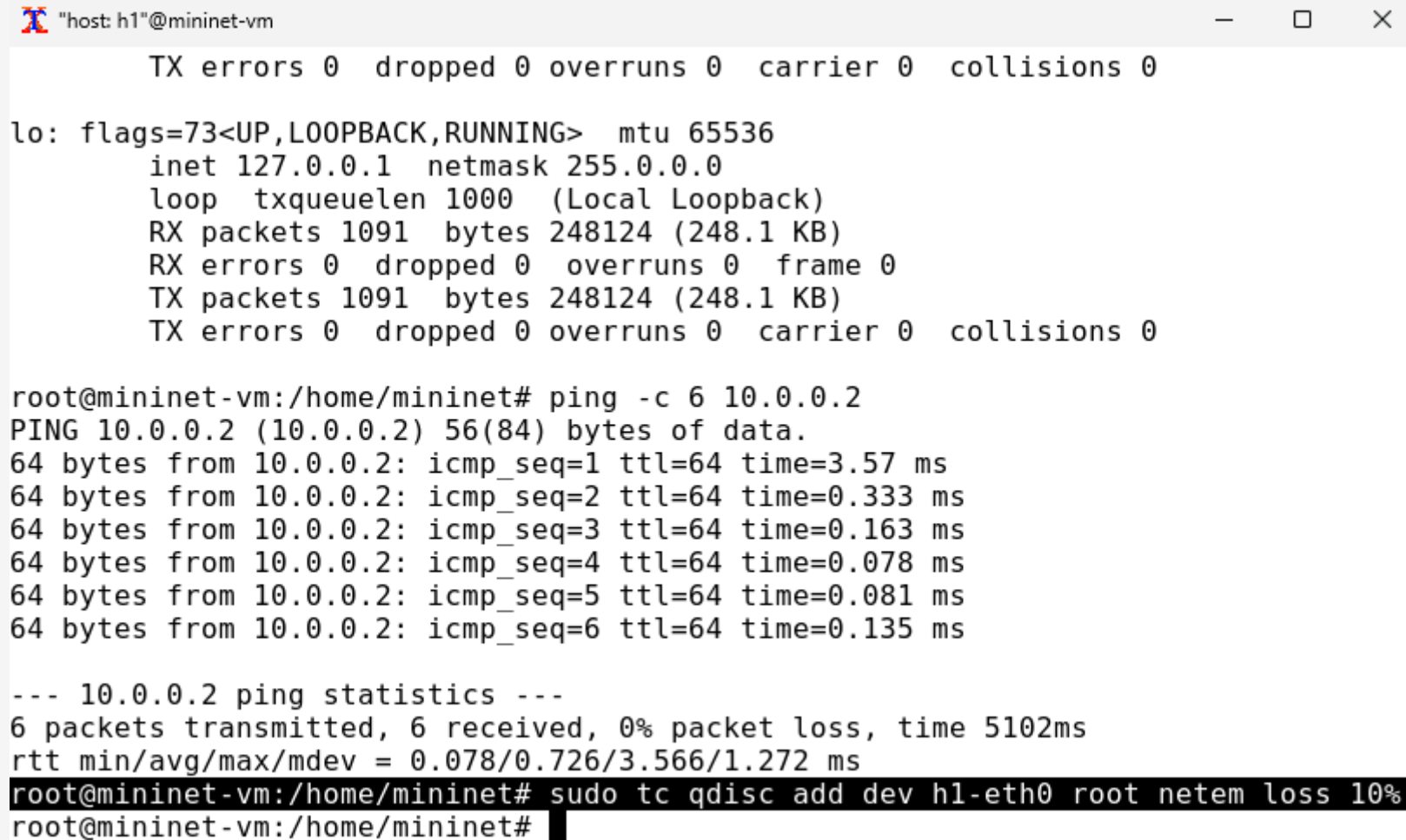
Рис. 7: Добавление 10% потерь пакетов на хосте h2

Интерактивные эксперименты


```
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#
```
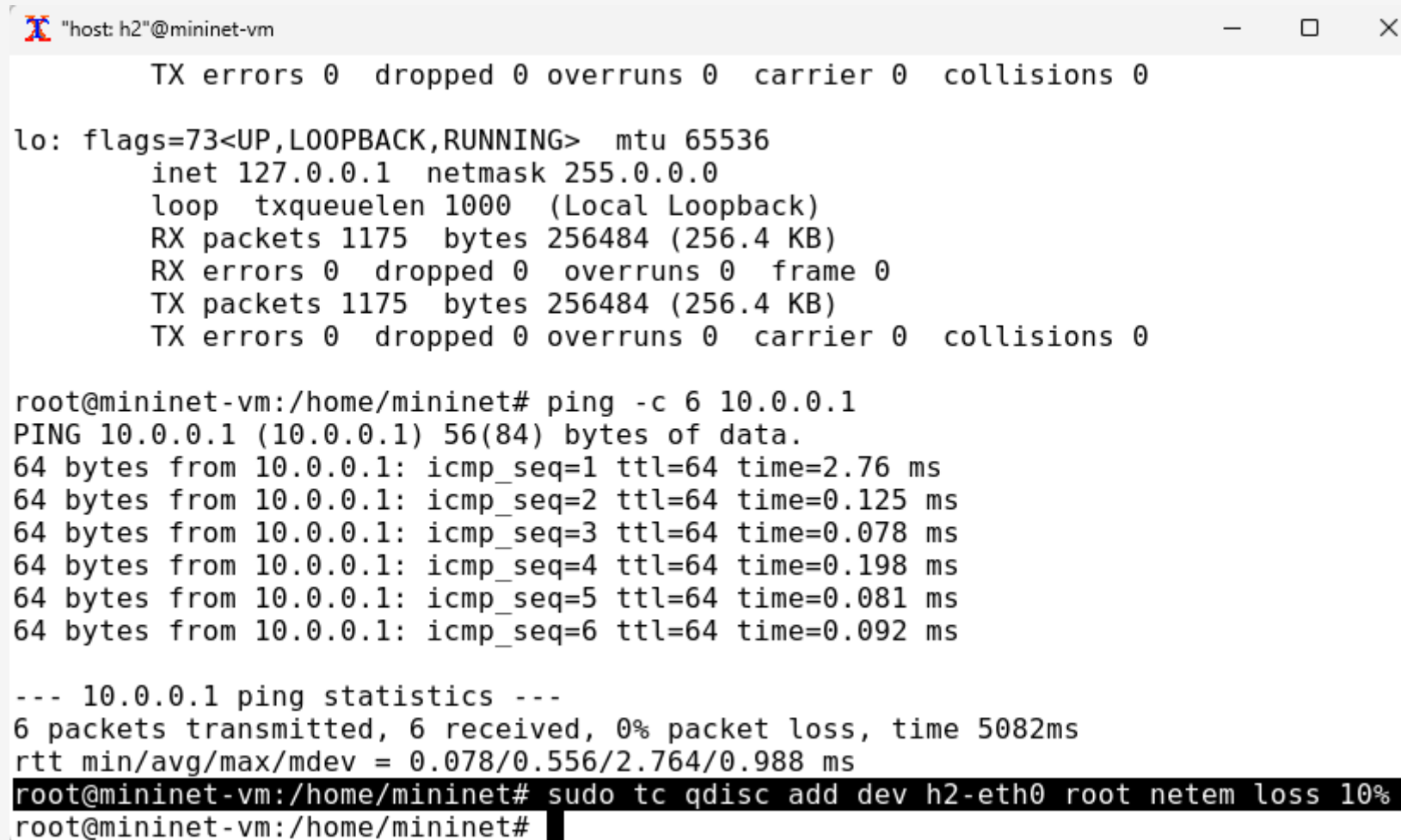
Рис. 8: Проверка

Интерактивные эксперименты

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

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# █
```
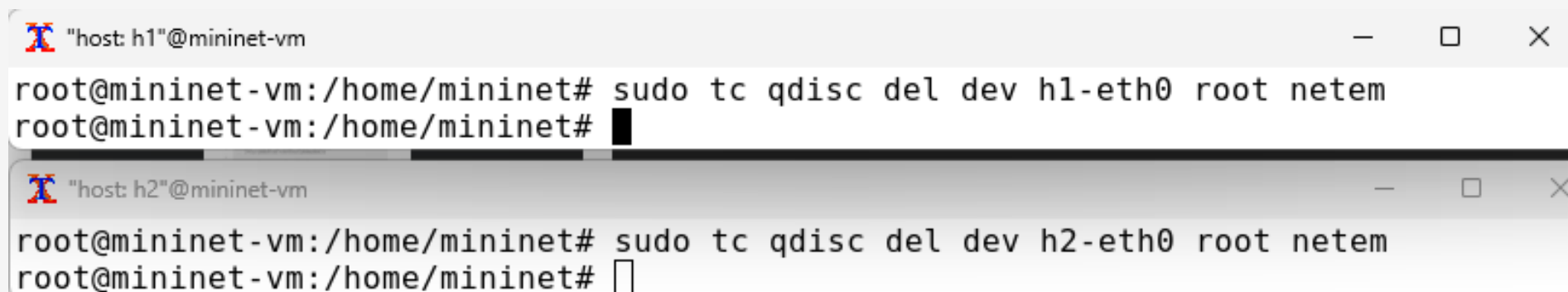
Рис. 10: Проверка
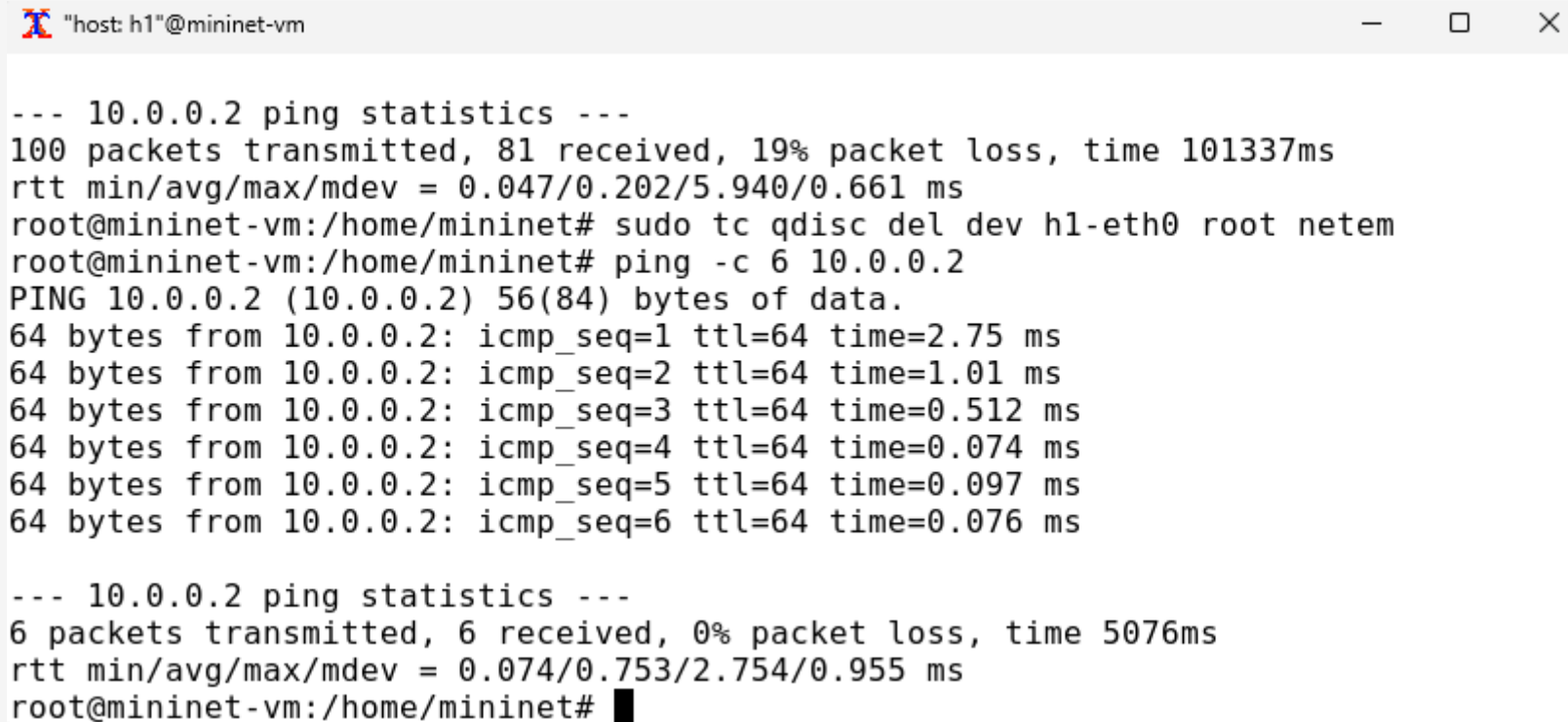
Интерактивные эксперименты


```
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# sudo tc qdisc add dev h1-eth0 root netem loss 50% 50%
root@mininet-vm:/home/mininet#
```
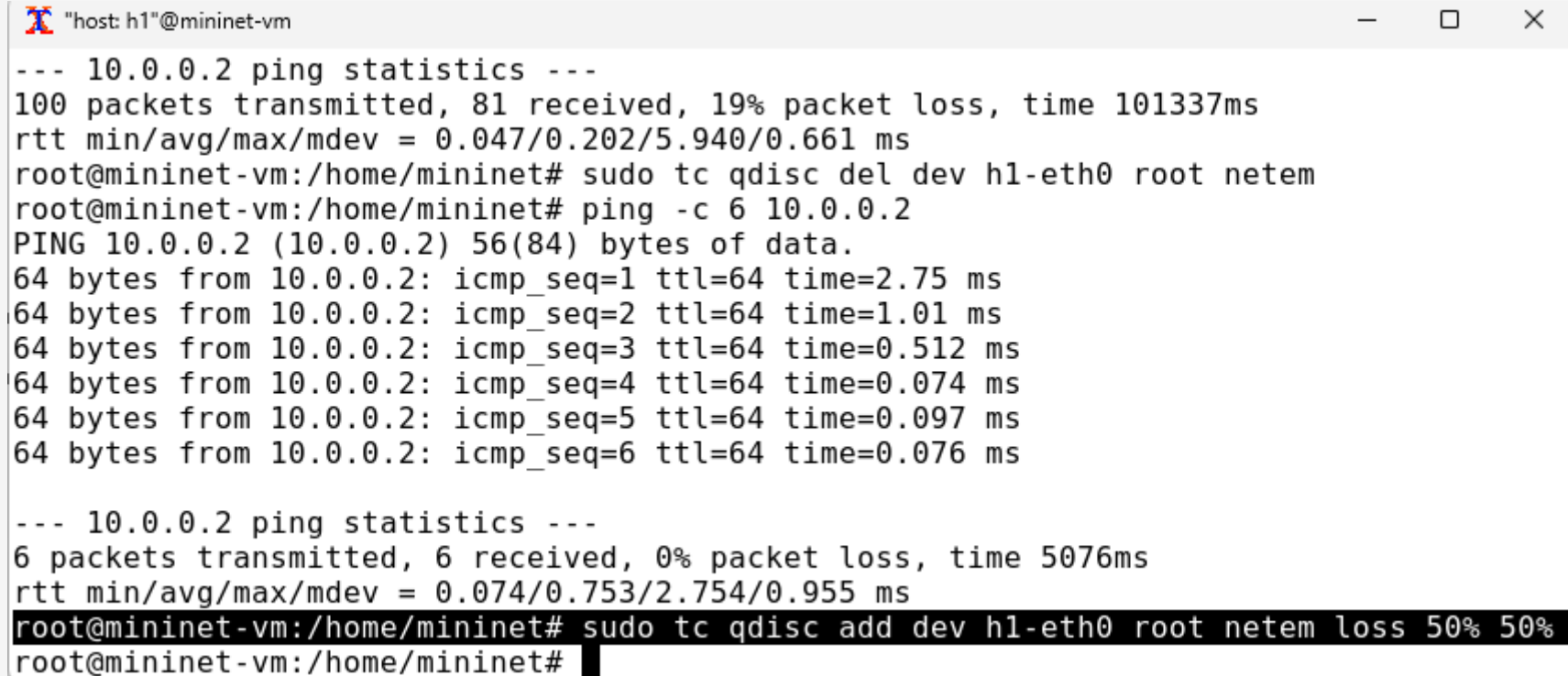
Рис. 11: Добавление на узле h1 коэффициента потери пакетов 50%

Интерактивные эксперименты


```
"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
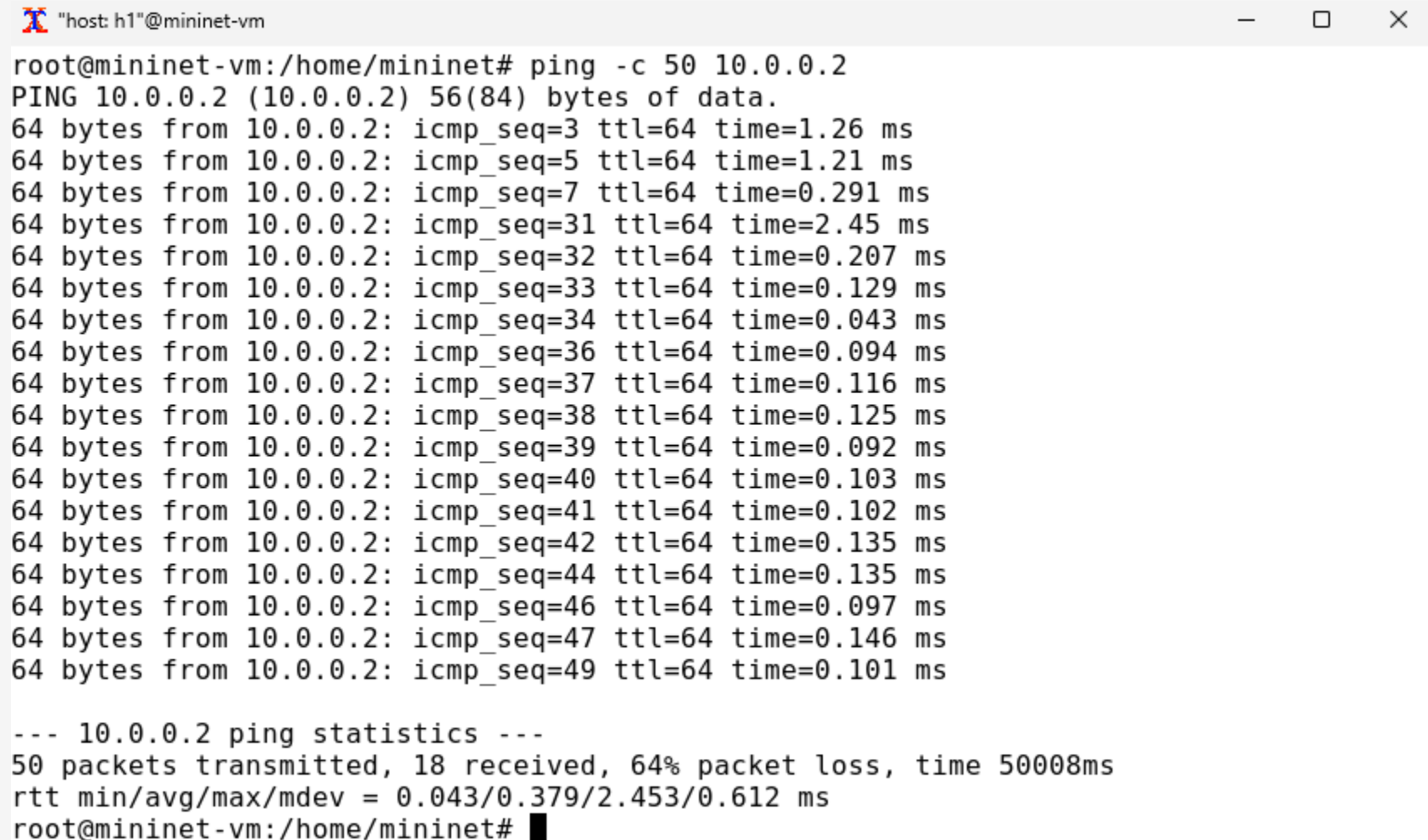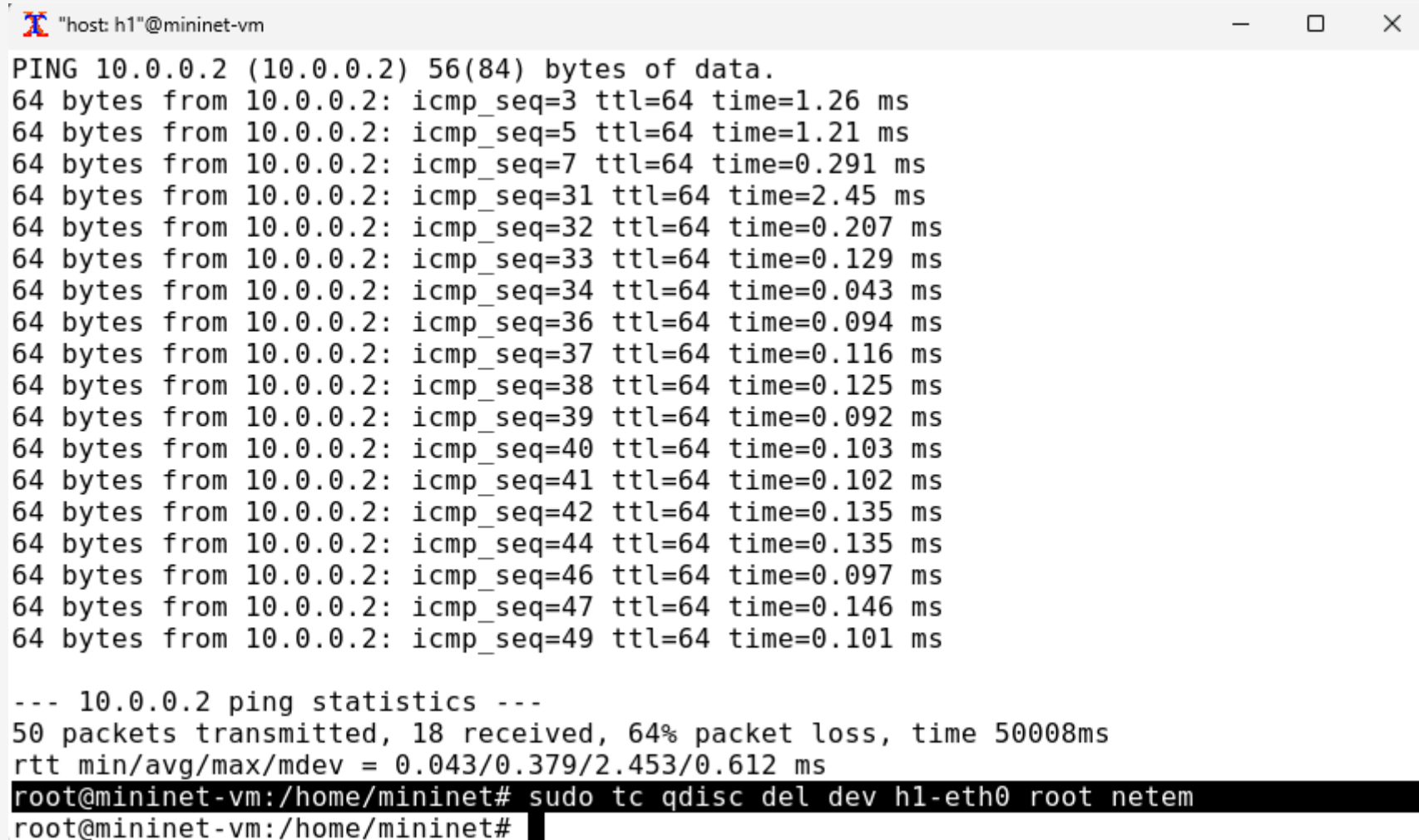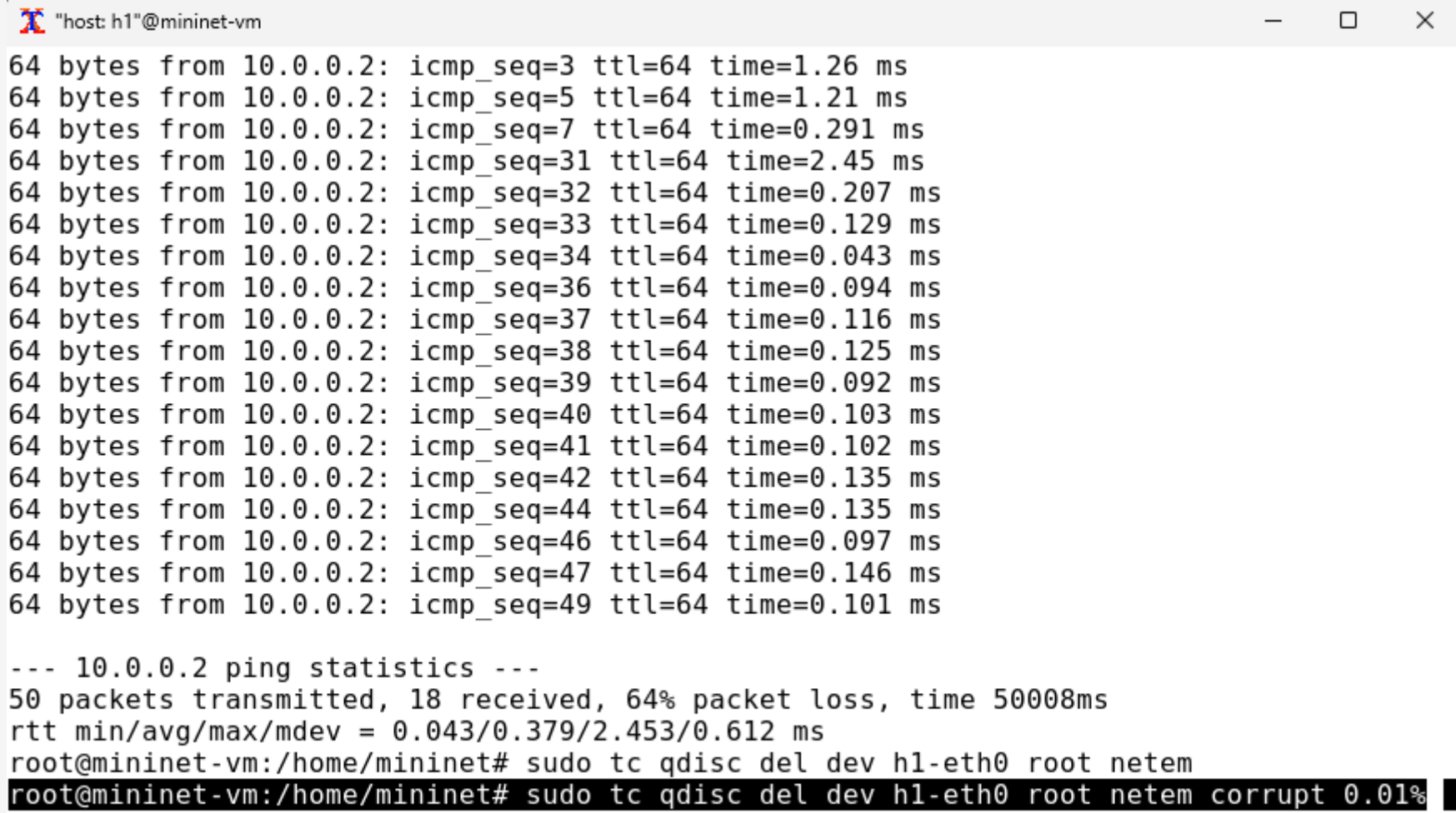
Интерактивные эксперименты


```
"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


```
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


```
"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
- - - - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  7]   0.00-10.00  sec  13.3 GBytes  11.4 Gbits/sec   21             sender
[  7]   0.00-10.01  sec  13.3 GBytes  11.4 Gbits/sec                  receiver

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

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

Интерактивные эксперименты

Рис. 16: Восстановление конфигурации интерфейса по умолчанию
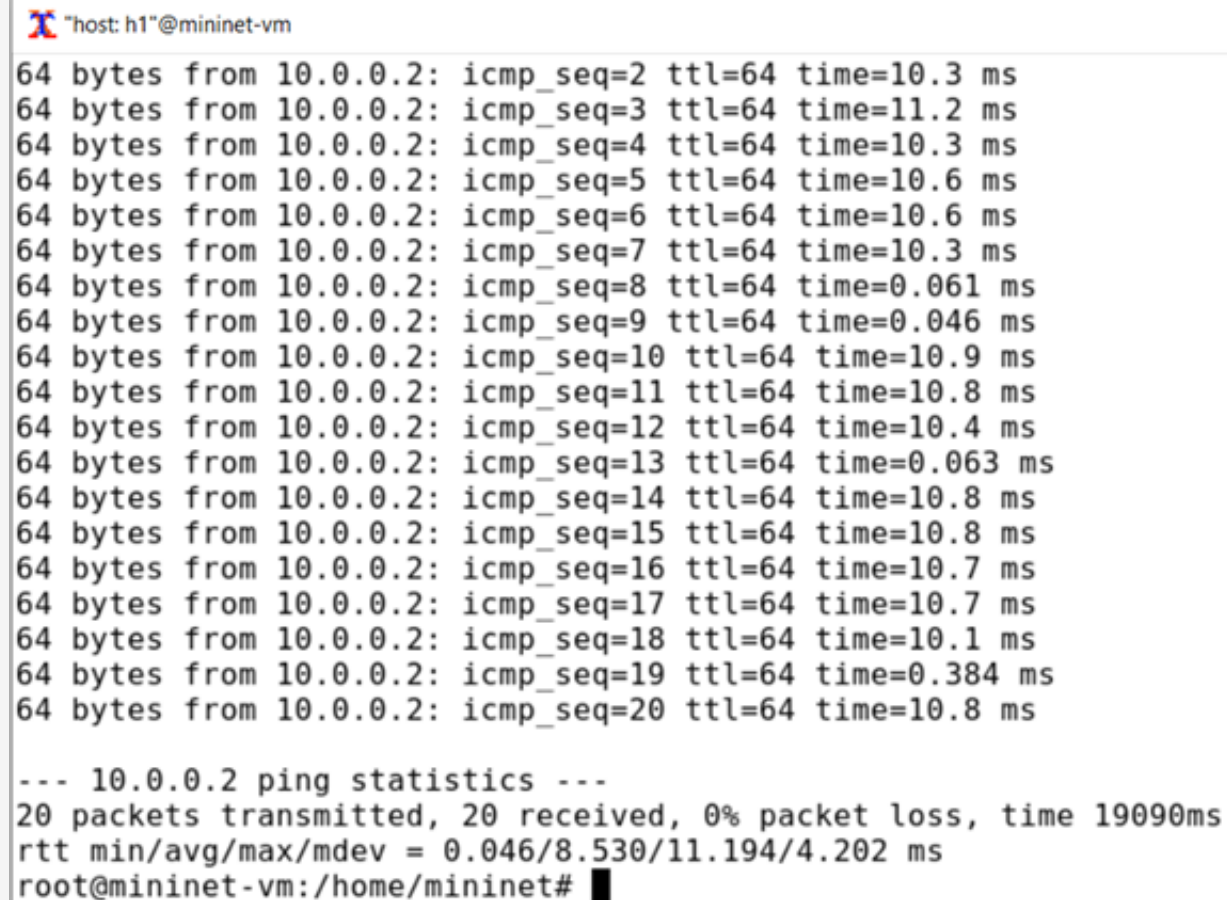
Интерактивные эксперименты

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

Интерактивные эксперименты


```
"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# █
```
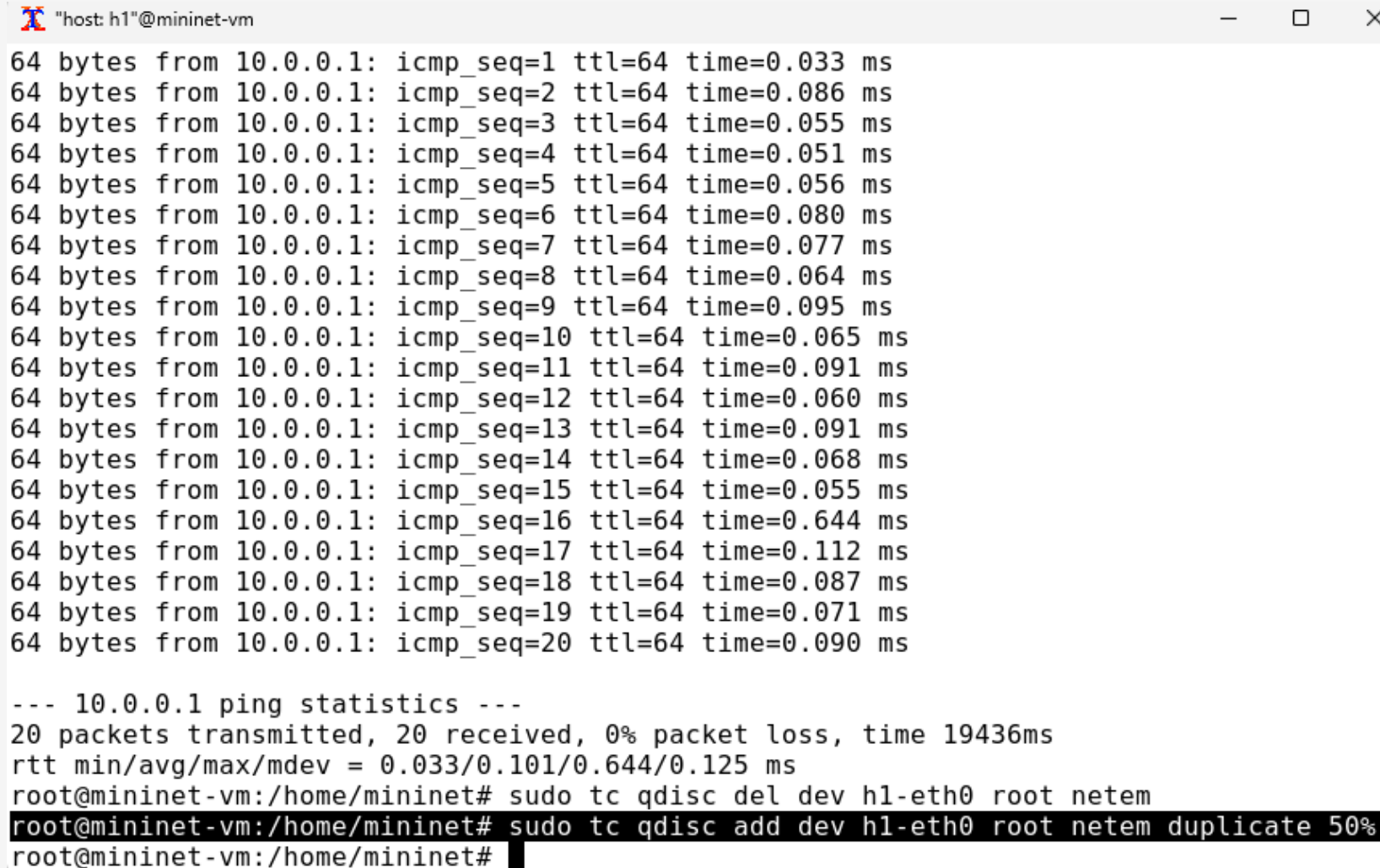
Рис. 18: Проверка

Интерактивные эксперименты

Рис. 19: Восстановление конфигурации интерфейса по умолчанию

Интерактивные эксперименты
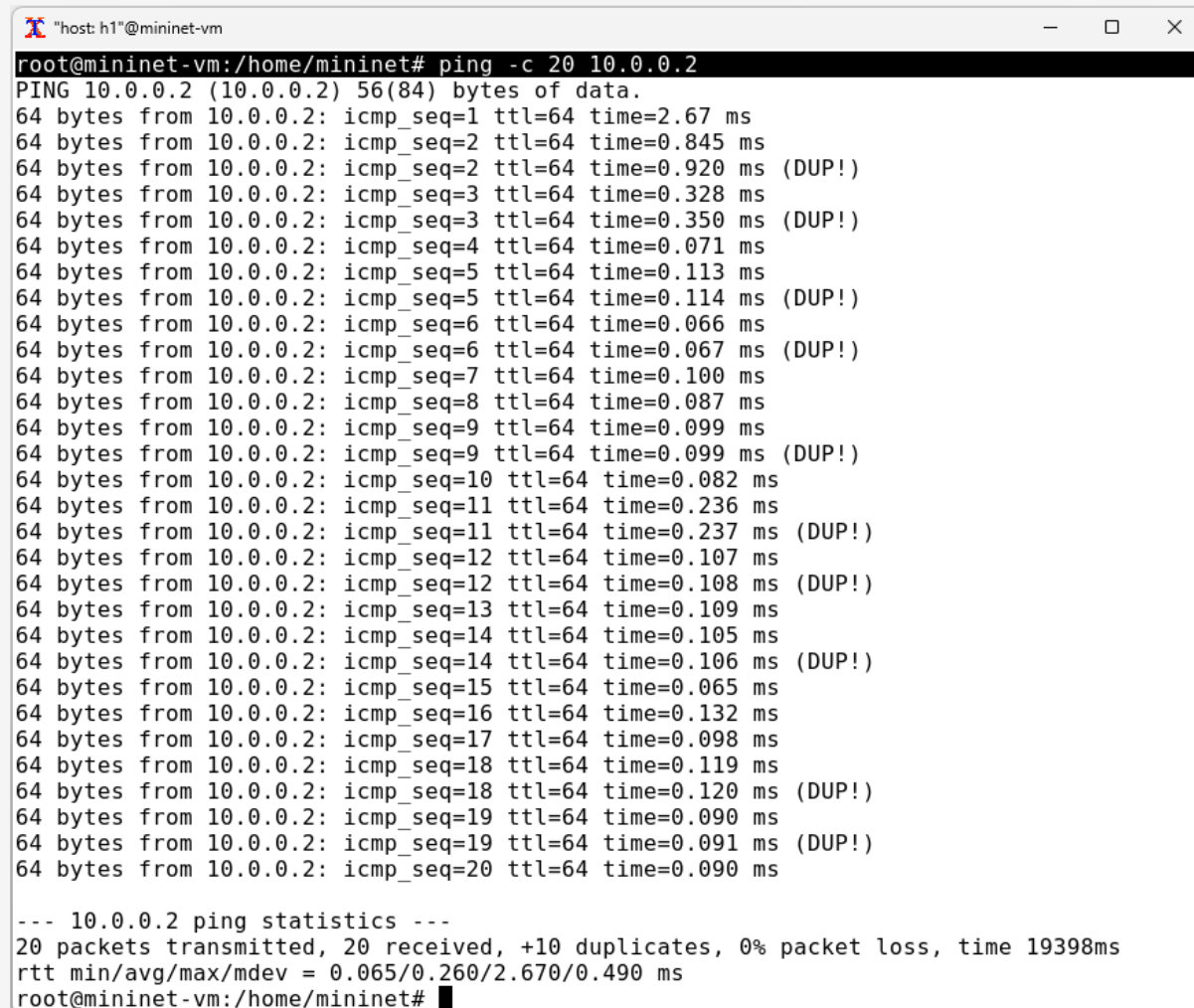


```
"host: h1"@mininet-vm                                          —  □  ×
64 bytes from 10.0.0.1: icmp_seq=1 ttl=64 time=0.033 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=0.086 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=0.055 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=0.051 ms
64 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


```
"host: h1"@mininet-vm                                    —  □  ✕
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


```
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
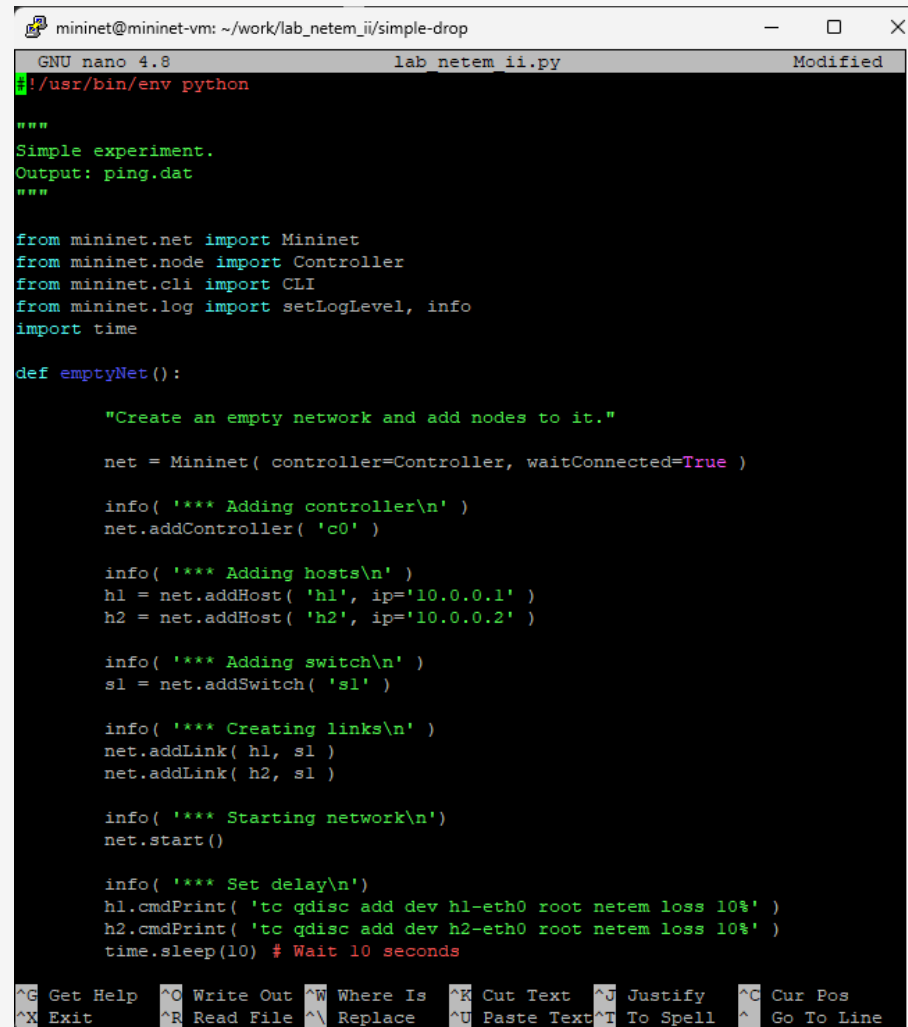
Рис. 23: Создание каталога expname

Воспроизведение экспериментов

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

Воспроизведение экспериментов

Рис. 25: Создание скрипта для эксперимента

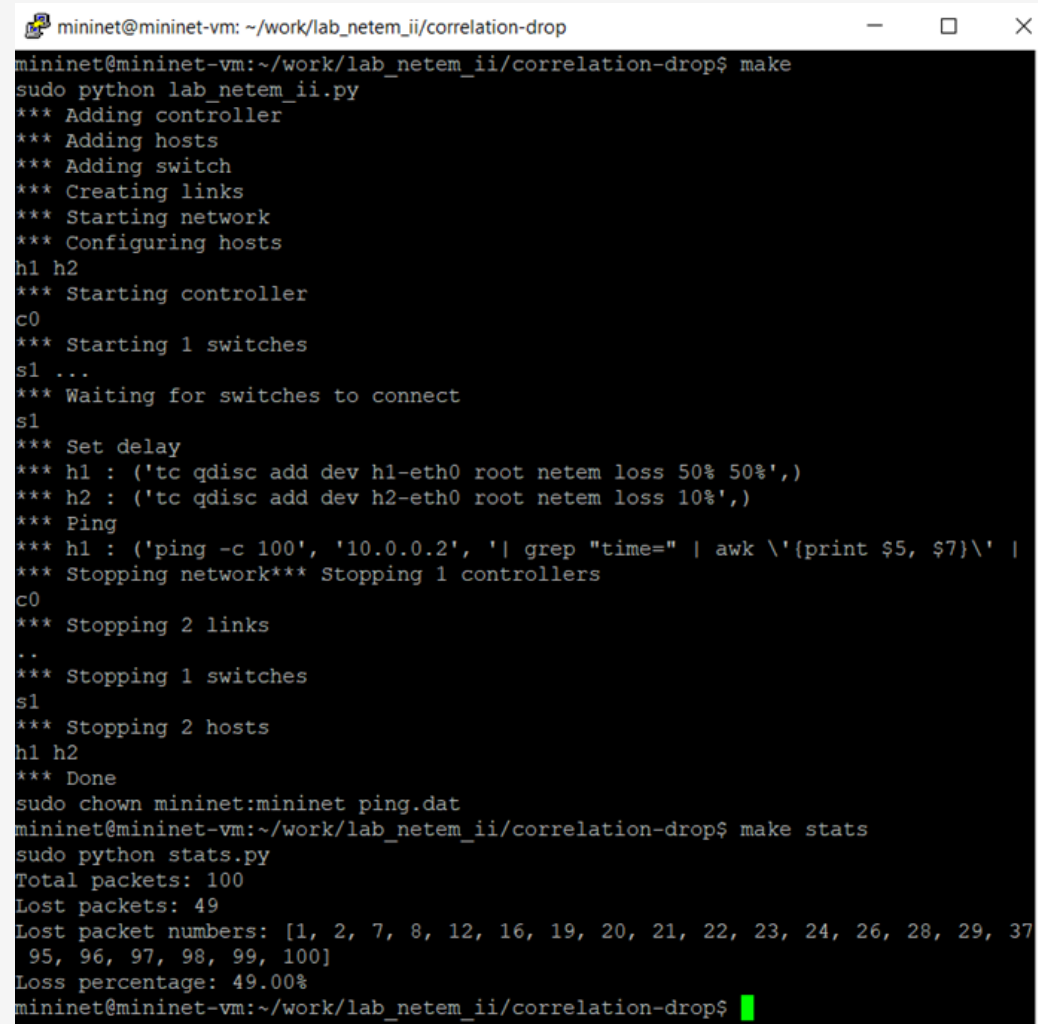# Воспроизведение экспериментов


```
  mininet@mininet-vm: ~/work/lab_netem_ii/simple-drop                                        □  ×

  GNU nano 4.8                                    stats.py                               Modified
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-] 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
```
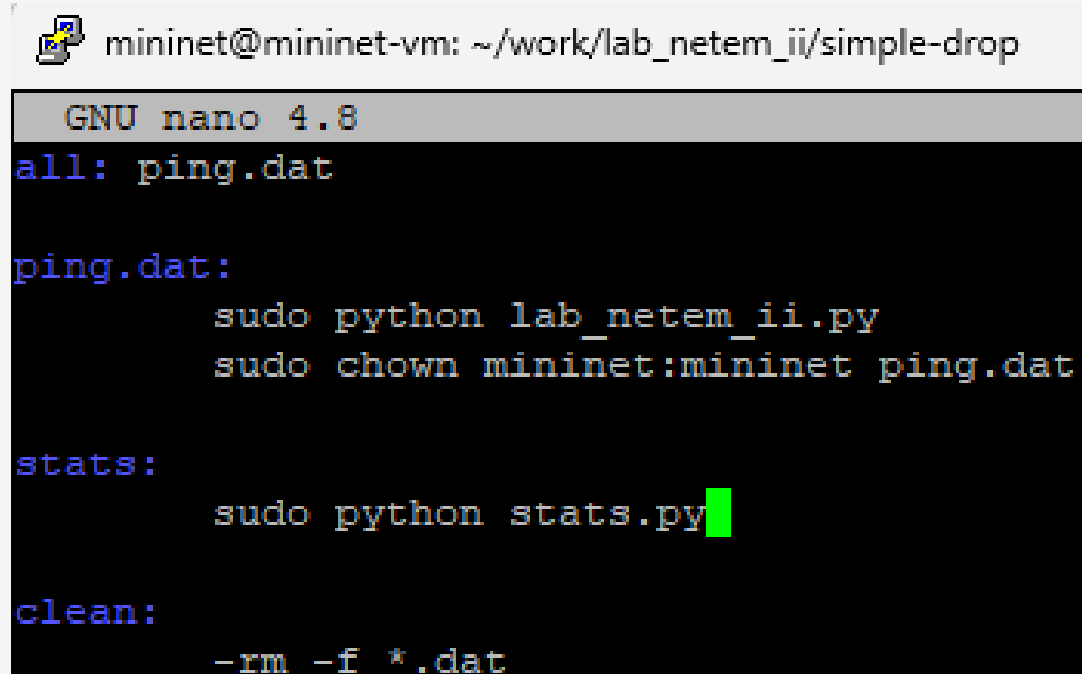
Рис. 26: Создание нового скрипта для вывода информации о потере пакетов

Воспроизведение экспериментов

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

Рис. 29: Реализация воспроизводимого эксперимента по исследованию параметров сети

Воспроизведение экспериментов

Рис. 30: Реализация воспроизводимого эксперимента по исследованию параметров сети

Воспроизведение экспериментов

Рис. 31: Реализация воспроизводимого эксперимента по исследованию параметров сети

Воспроизведение экспериментов

Рис. 32: Реализация воспроизводимого эксперимента по исследованию параметров сети

Вывод

• 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

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