

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.

Задачи

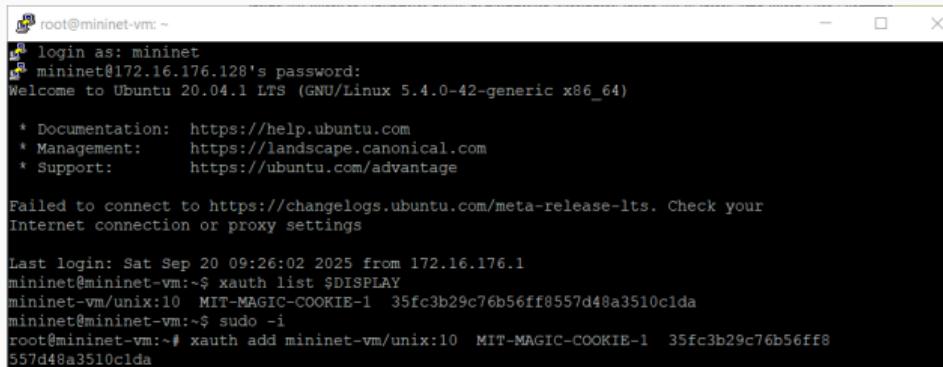
1. Задайте простейшую топологию, состоящую из двух хостов и коммутатора с назначенной по умолчанию mininet сетью 10.0.0.0/8.
2. Проведите интерактивные эксперименты по исследованию параметров сети, связанных с потерей, дублированием, изменением порядка и повреждением пакетов при передаче данных.

Задачи

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

Выполнение лабораторной работы



```
root@mininet-vm: ~
[~] login as: mininet
[~] mininet@172.16.176.128's password:
Welcome to Ubuntu 20.04.1 LTS (GNU/Linux 5.4.0-42-generic x86_64)

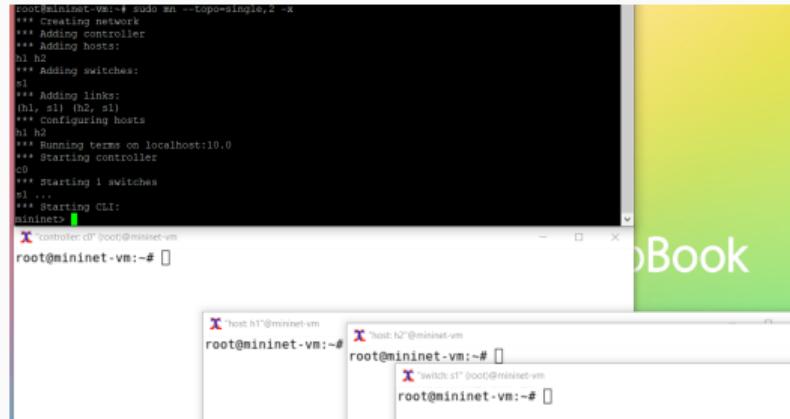
 * Documentation: https://help.ubuntu.com
 * Management: https://landscape.canonical.com
 * Support: https://ubuntu.com/advantage

Failed to connect to https://changelogs.ubuntu.com/meta-release-lts. Check your
Internet connection or proxy settings

Last login: Sat Sep 20 09:26:02 2025 from 172.16.176.1
mininet@mininet-vm:~$ xauth list $DISPLAY
mininet-vm/unix:10 MIT-MAGIC-COOKIE-1 35fc3b29c76b56ff8557d48a3510c1da
mininet@mininet-vm:~$ sudo -i
root@mininet-vm:~# xauth add mininet-vm/unix:10 MIT-MAGIC-COOKIE-1 35fc3b29c76b56ff8
557d48a3510c1da
```

Рис. 1: Исправление MIT magic cookie

Выполнение лабораторной работы



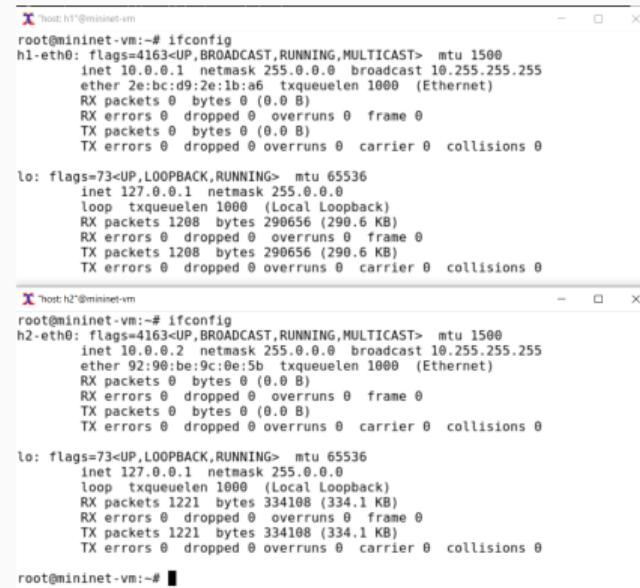
The screenshot shows a terminal window with a yellow gradient background. The terminal output is as follows:

```
root@mininet-vm:~# sudo mn --topo=single,2 -c
*** Creating network
*** adding controller
*** adding hosts
*** Adding switches:
h1 h2
*** 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> 
X "controller:0" (root@mininet-vm
root@mininet-vm:~# 

host:h1@mininet-vm:~# 
root@mininet-vm:~# 
host:h2@mininet-vm:~# 
root@mininet-vm:~# 
switch:s1" (root@mininet-vm
root@mininet-vm:~# 
```

Рис. 2: Простейшая топология

Выполнение лабораторной работы



The image shows two terminal windows side-by-side. Both windows have a title bar 'host: h1@mininet-vm' and 'host: h2@mininet-vm'. The left window (h1) displays the ifconfig command output for host h1. The right window (h2) displays the ifconfig command output for host h2. Both outputs show the configuration for the 'h1-eth0' and 'lo' interfaces on host h1, and the 'h2-eth0' and 'lo' interfaces on host h2.

```
root@mininet-vm:~# 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 2e:bc:d9:2e:1b:a6 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 1208 bytes 290656 (290.6 KB)
        RX errors 0 dropped 0 overruns 0 frame 0
        TX packets 1208 bytes 290656 (290.6 KB)
        TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

root@mininet-vm:~# 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 92:98:be:9c:0e:5b 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 1221 bytes 334108 (334.1 KB)
        RX errors 0 dropped 0 overruns 0 frame 0
        TX packets 1221 bytes 334108 (334.1 KB)
        TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

root@mininet-vm:~#
```

Рис. 3: ifconfig на хостах h1 и h2

Выполнение лабораторной работы

```
root@mininet-vm:~# 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=3.09 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=0.166 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=0.167 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=0.180 ms
64 bytes from 10.0.0.1: icmp_seq=5 ttl=64 time=0.158 ms
64 bytes from 10.0.0.1: icmp_seq=6 ttl=64 time=0.117 ms

... 10.0.0.1 ping statistics ...
6 packets transmitted, 6 received, 0% packet loss, time 5077ms
rtt min/avg/max/mdev = 0.117/0.779/3.894/1.393 ms

root@mininet-vm:~# 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=8.95 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=0.382 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.184 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.122 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.109 ms

... 10.0.0.2 ping statistics ...
6 packets transmitted, 6 received, 0% packet loss, time 5087ms
rtt min/avg/max/mdev = 0.109/1.700/8.950/3.245 ms
```

Рис. 4: Проверка подключения между хостами

Выполнение лабораторной работы

```
root@mininet-vm:~# sudo tc qdisc add dev h1-eth0 root netem loss 10%
root@mininet-vm:~# 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=4.36 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=1.45 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.425 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.242 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.243 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.113 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=0.129 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=0.194 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=0.179 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=0.173 ms
```

Рис. 5: Добавление потери в 10%

Выполнение лабораторной работы

```
64 bytes from 10.0.0.2: icmp_seq=93 ttl=64 time=0.134 ms
64 bytes from 10.0.0.2: icmp_seq=94 ttl=64 time=0.139 ms
64 bytes from 10.0.0.2: icmp_seq=95 ttl=64 time=0.126 ms
64 bytes from 10.0.0.2: icmp_seq=96 ttl=64 time=0.127 ms
64 bytes from 10.0.0.2: icmp_seq=97 ttl=64 time=0.255 ms
64 bytes from 10.0.0.2: icmp_seq=98 ttl=64 time=0.196 ms
64 bytes from 10.0.0.2: icmp_seq=99 ttl=64 time=0.123 ms
64 bytes from 10.0.0.2: icmp_seq=100 ttl=64 time=0.131 ms

--- 10.0.0.2 ping statistics ---
100 packets transmitted, 96 received, 4% packet loss, time 101329ms
rtt min/avg/max/mdev = 0.097/0.245/4.363/0.445 ms
root@mininet-vm:~# █
```

Рис. 6: Просмотр сводного отчета

Выполнение лабораторной работы

```
root@mininet-vm:~# sudo tc qdisc add dev h2-eth0 root netem loss 10%
root@mininet-vm:~# 
X "host h1"@mininet-vm
64 bytes from 10.0.0.2: icmp_seq=74 ttl=64 time=0.236 ms
64 bytes from 10.0.0.2: icmp_seq=75 ttl=64 time=0.308 ms
64 bytes from 10.0.0.2: icmp_seq=76 ttl=64 time=0.189 ms
64 bytes from 10.0.0.2: icmp_seq=77 ttl=64 time=0.232 ms
64 bytes from 10.0.0.2: icmp_seq=78 ttl=64 time=0.227 ms
64 bytes from 10.0.0.2: icmp_seq=79 ttl=64 time=0.118 ms
64 bytes from 10.0.0.2: icmp_seq=81 ttl=64 time=0.137 ms
64 bytes from 10.0.0.2: icmp_seq=83 ttl=64 time=0.161 ms
64 bytes from 10.0.0.2: icmp_seq=85 ttl=64 time=0.174 ms
64 bytes from 10.0.0.2: icmp_seq=88 ttl=64 time=0.224 ms
64 bytes from 10.0.0.2: icmp_seq=90 ttl=64 time=0.154 ms
64 bytes from 10.0.0.2: icmp_seq=91 ttl=64 time=0.324 ms
64 bytes from 10.0.0.2: icmp_seq=92 ttl=64 time=0.318 ms
64 bytes from 10.0.0.2: icmp_seq=93 ttl=64 time=0.356 ms
64 bytes from 10.0.0.2: icmp_seq=94 ttl=64 time=0.382 ms
64 bytes from 10.0.0.2: icmp_seq=96 ttl=64 time=0.153 ms
64 bytes from 10.0.0.2: icmp_seq=97 ttl=64 time=0.330 ms
64 bytes from 10.0.0.2: icmp_seq=98 ttl=64 time=0.327 ms
64 bytes from 10.0.0.2: icmp_seq=99 ttl=64 time=0.229 ms
--- 10.0.0.2 ping statistics ---
100 packets transmitted, 82 received, 18% packet loss, time 101320ms
rtt min/avg/max/mdev = 0.118/0.310/3.676/0.426 ms
```

Рис. 7: Добавление потери в 10% на второй хост

Выполнение лабораторной работы

```
root@mininet-vm:~# sudo tc qdisc del dev h2-eth0 root netem
root@mininet-vm:~# 
root@mininet-vm:~# sudo tc qdisc del dev h1-eth0 root netem
root@mininet-vm:~# ping 10.0.0.2 -c 5
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=3.55 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=1.42 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.663 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=0.198 ms

--- 10.0.0.2 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4039ms
rtt min/avg/max/mdev = 0.116/1.189/3.550/1.267 ms
root@mininet-vm:~# 
```

Рис. 8: Восстановление исходных значений потерь

Выполнение лабораторной работы

```
root@mininet-vm:~# sudo tc qdisc add dev h1-eth0 root netem loss 50% 50%
root@mininet-vm:~# 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=5 ttl=64 time=2.27 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=1.94 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=0.690 ms
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=0.144 ms
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=2.61 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=0.245 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=0.282 ms
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=0.237 ms
64 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=0.139 ms
64 bytes from 10.0.0.2: icmp_seq=21 ttl=64 time=0.194 ms
64 bytes from 10.0.0.2: icmp_seq=24 ttl=64 time=0.296 ms
64 bytes from 10.0.0.2: icmp_seq=25 ttl=64 time=0.236 ms
64 bytes from 10.0.0.2: icmp_seq=28 ttl=64 time=0.246 ms
64 bytes from 10.0.0.2: icmp_seq=30 ttl=64 time=0.112 ms
64 bytes from 10.0.0.2: icmp_seq=32 ttl=64 time=0.114 ms
64 bytes from 10.0.0.2: icmp_seq=33 ttl=64 time=0.296 ms
64 bytes from 10.0.0.2: icmp_seq=34 ttl=64 time=0.136 ms
64 bytes from 10.0.0.2: icmp_seq=36 ttl=64 time=0.127 ms
64 bytes from 10.0.0.2: icmp_seq=37 ttl=64 time=0.180 ms
64 bytes from 10.0.0.2: icmp_seq=38 ttl=64 time=0.249 ms
64 bytes from 10.0.0.2: icmp_seq=40 ttl=64 time=0.284 ms
64 bytes from 10.0.0.2: icmp_seq=41 ttl=64 time=0.112 ms
64 bytes from 10.0.0.2: icmp_seq=42 ttl=64 time=0.099 ms
64 bytes from 10.0.0.2: icmp_seq=46 ttl=64 time=0.131 ms
64 bytes from 10.0.0.2: icmp_seq=47 ttl=64 time=0.282 ms
64 bytes from 10.0.0.2: icmp_seq=48 ttl=64 time=0.191 ms
64 bytes from 10.0.0.2: icmp_seq=50 ttl=64 time=0.140 ms

--- 10.0.0.2 ping statistics ---
50 packets transmitted, 27 received, 46% packet loss, time 50068ms
rtt min/avg/max/mdev = 0.099/0.443/2.606/0.661 ms
root@mininet-vm:~# sudo tc qdisc del dev h1-eth0 root netem
root@mininet-vm:~#
```

Рис. 9: Добавление значения корреляции для потери пакетов

Выполнение лабораторной работы

```
root@mininet-vm:~# 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 34558
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 34560
[ ID] Interval Transfer Bitrate
[ 7] 0.00-1.00 sec 176 MBytes 1.47 Gbits/sec
[ 7] 1.00-2.00 sec 175 MBytes 1.47 Gbits/sec
[ 7] 2.00-3.00 sec 168 MBytes 1.41 Gbits/sec
[ 7] 3.00-4.00 sec 180 MBytes 1.51 Gbits/sec
[ 7] 4.00-5.00 sec 150 MBytes 1.26 Gbits/sec
[ 7] 5.00-6.00 sec 172 MBytes 1.44 Gbits/sec
[ 7] 6.00-7.00 sec 185 MBytes 1.55 Gbits/sec
root@mininet-vm:~# iperf3 -c 10.0.0.2
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 34560 connected to 10.0.0.2 port 5201
[ ID] Interval Transfer Bitrate Retr Cwnd
[ 7] 0.00-1.01 sec 176 MBytes 1.47 Gbits/sec 0 782 KBytes
[ 7] 1.01-2.01 sec 175 MBytes 1.47 Gbits/sec 0 1.18 MBytes
[ 7] 2.01-3.01 sec 169 MBytes 1.41 Gbits/sec 0 1.18 MBytes
[ 7] 3.01-4.00 sec 179 MBytes 1.51 Gbits/sec 1 1.56 MBytes
[ 7] 4.00-5.00 sec 150 MBytes 1.26 Gbits/sec 0 1.56 MBytes
[ 7] 5.00-6.00 sec 171 MBytes 1.44 Gbits/sec 0 1.76 MBytes
[ 7] 6.00-7.00 sec 185 MBytes 1.55 Gbits/sec 0 1.85 MBytes
[ 7] 7.00-8.00 sec 441 MBytes 3.70 Gbits/sec 1 1.38 MBytes
[ 7] 8.00-9.00 sec 466 MBytes 3.91 Gbits/sec 0 1.38 MBytes
[ 7] 9.00-10.00 sec 461 MBytes 3.87 Gbits/sec 1 991 KBytes
[ ID] Interval Transfer Bitrate Retr
[ 7] 0.00-10.00 sec 2.51 GBytes 2.16 Gbits/sec 3 sender
[ 7] 0.00-10.00 sec 2.49 GBytes 2.14 Gbits/sec receiver
iperf Done.
root@mininet-vm:~# sudo tc qdisc del dev h1-eth0 root netem
```

Рис. 10: Добавление повреждения пакетов и проверка

Выполнение лабораторной работы

```
root@mininet-vm:~# sudo tc qdisc add dev h1-eth0 root netem delay 10ms reorder  
25% 50%  
root@mininet-vm:~# 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=13.9 ms  
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=12.6 ms  
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=12.0 ms  
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=11.1 ms  
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=10.8 ms  
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=10.9 ms  
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=10.9 ms  
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=11.4 ms  
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=10.5 ms  
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=11.0 ms  
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.203 ms  
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=10.7 ms  
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=10.9 ms  
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=11.2 ms  
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=11.0 ms  
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=11.3 ms  
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=10.6 ms  
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=10.8 ms  
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=10.7 ms  
64 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=11.3 ms  
  
--- 10.0.0.2 ping statistics ---  
20 packets transmitted, 20 received, 0% packet loss, time 19070ms  
rtt min/avg/max/mdev = 0.203/10.695/13.897/2.528 ms  
root@mininet-vm:~# sudo tc qdisc del dev h1-eth0 root netem
```

Рис. 11: Добавление переупорядочивания пакетов

Выполнение лабораторной работы

```
root@mininet-vm:~# sudo tc qdisc add dev h1-eth0 root netem duplicate 50%
root@mininet-vm:~# 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=3.74 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=2.21 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.966 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.209 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.279 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.289 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.285 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=0.182 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=0.351 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=0.361 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=0.290 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=0.321 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=0.331 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.172 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.182 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=0.458 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=0.486 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=0.299 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=0.341 ms
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=0.308 ms
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=0.318 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=0.428 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=0.457 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=0.224 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=0.234 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=0.237 ms
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=0.267 ms
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=0.277 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=0.269 ms

--- 10.0.0.2 ping statistics ---
20 packets transmitted, 20 received, +9 duplicates, 0% packet loss, time 19418ms
rtt min/avg/max/mdev = 0.172/0.509/3.740/0.715 ms
root@mininet-vm:~# sudo tc qdisc del dev h1-eth0 root netem
```

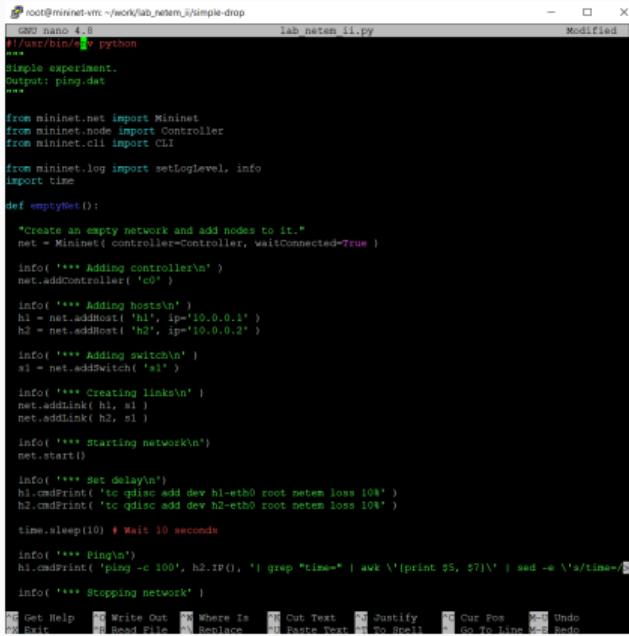
Рис. 12: Добавление дублирования пакетов

Выполнение лабораторной работы

```
root@mininet-vm:~# mkdir -p ~/work/lab_netem_ii/simple-drop
root@mininet-vm:~# cd ~/work/lab_netem_ii/simple-drop
root@mininet-vm:~/work/lab_netem_ii/simple-drop# touch lab_netem_ii.py
root@mininet-vm:~/work/lab_netem_ii/simple-drop# ls
lab_netem_ii.py
root@mininet-vm:~/work/lab netem ii/simple-drop#
```

Рис. 13: Создание рабочего каталога

Выполнение лабораторной работы



The screenshot shows a terminal window titled "lab netem li.py" running on a root shell of a mininet VM. The script is a Python program that sets up a simple network with two hosts (h1, h2) connected to a switch (s1). It then applies queue discipline (qdisc) with loss=10% to both interfaces (h1-eth0, h2-eth0). After a 10-second delay, it performs a ping from h1 to h2. Finally, it stops the network. The terminal window includes standard Linux command-line tools like cmdPrint, grep, awk, and sed.

```
root@mininet-vmc:~/work/lab_netem_0/simple-drop
GNU nano 4.8                               lab netem li.py
#!/usr/bin/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

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

Get Help  Write Out  Where Is  Cut Text  Justify  Cur Pos  Undo
Exit  Read File  Replace  Paste Text  To Spell  Go To Line  Redo
```

Рис. 14: Скрипт на Python для эксперимента

Выполнение лабораторной работы

```
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. 15: Makefile для управления процессом проведения эксперимента

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]\'')
23% packet loss,
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 2 links
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
```

Рис. 16: Запуск эксперимента

Выполнение лабораторной работы

```
GNU nano 4.8           lab_netem_ii.py

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 5% duplicate 50%' )
h2.cmdPrint( 'tc qdisc add dev h2-eth0 root netem loss 5% delay 40ms reorder 40% 10%' )

time.sleep(10) # Wait 10 seconds

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

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

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

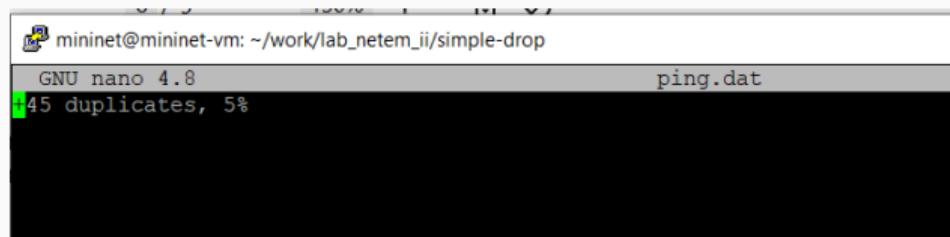
Рис. 17: Изменение файла lab_netem_ii.py

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 5% duplicate 50%',)
*** h2 : ('tc qdisc add dev h2-eth0 root netem loss 5% delay 40ms reorder 40% 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
```

Рис. 18: Запуск эксперимента

Выполнение лабораторной работы



mininet@mininet-vm: ~/work/lab_netem_ii/simple-drop

GNU nano 4.8 ping.dat

45 duplicates, 5%

The terminal window shows the command 'ping' has been run, resulting in 45 duplicates (5%) of the transmitted packets. The file 'ping.dat' is shown to contain this information.

Рис. 19: Просмотр информации

Выводы

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.