

Презентация по лабораторной работе №5

Дисциплина: Моделирование сетей передачи данных

Лобанова П.И.

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Российский университет дружбы народов, Москва, Россия

Информация

- Лобанова Полина Иннокентьевна
- Учащаяся на направлении “Фундаментальная информатика и информационные технологии”
- Студентка группы НФИбд-02-22
- polla-2004@mail.ru

Цель

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.

Задание

1. Задайте простейшую топологию, состоящую из двух хостов и коммутатора с назначенной по умолчанию mininet сетью 10.0.0.0/8.
2. Проведите интерактивные эксперименты по исследованию параметров сети, связанных с потерей, дублированием, изменением порядка и повреждением пакетов при передаче данных.
3. Реализуйте воспроизводимый эксперимент по добавлению правила отбрасывания пакетов в эмулируемой глобальной сети. На экран выведите сводную информацию о потерянных пакетах.
4. Самостоятельно реализуйте воспроизводимые эксперименты по исследованию параметров сети, связанных с потерей, изменением порядка и повреждением пакетов при передаче данных. На экран выведите сводную информацию о потерянных пакетах.

Выполнение

```
[pilobanova@fedora ~]$ ssh -Y mininet@192.168.56.103
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

Last login: Sat Sep 13 06:29:15 2025 from 192.168.56.1
mininet@mininet-vm:~$ xauth list $DISPLAY
mininet-vm/unix:10  MIT-MAGIC-COOKIE-1  ecb597e678aeec4f6fed2fa4a884b3d2
mininet@mininet-vm:~$ sudo -i
root@mininet-vm:~# xauth add mininet-vm/unix:10  MIT-MAGIC-COOKIE-1  ecb597e678a
eec4f6fed2fa4a884b3d2
root@mininet-vm:~# xauth add mininet-vm/unix:10  MIT-MAGIC-COOKIE-1  ecb597e678a
eec4f6fed2fa4a884b3d2
root@mininet-vm:~# logout
mininet@mininet-vm:~$
```

Рис. 1: Изменение прав запуска X-соединения.

```
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> 
```

Рис. 2: Создание топологии

```
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 6a:3e:bf:e0:29:6e 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 1248 bytes 337844 (337.8 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 1248 bytes 337844 (337.8 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

Рис. 3: Команда *ifconfig* на хосте *h1*

```
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 46:11:1c:e7:71:5e 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 1176 bytes 331036 (331.0 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 1176 bytes 331036 (331.0 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

Рис. 4: Команда *ifconfig* на хосте *h2*

```
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=1.37 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.248 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.031 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.086 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.047 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.035 ms
```

Рис. 5: Пингование

```
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root netem loss 10%
root@mininet-vm:/home/mininet# █
```

Рис. 6: Добавление процента потерь

```
--- 10.0.0.2 ping statistics ---  
100 packets transmitted, 93 received, 7% packet loss, time 101385ms  
rtt min/avg/max/mdev = 0.026/0.056/0.723/0.079 ms  
root@mininet-vm:/home/mininet# █
```

Рис. 7: Пингование

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

Рис. 8: *Добавление процента потерь*


```
64 bytes from 10.0.0.2: icmp_seq=55 ttl=64 time=0.044 ms
64 bytes from 10.0.0.2: icmp_seq=56 ttl=64 time=0.037 ms
64 bytes from 10.0.0.2: icmp_seq=57 ttl=64 time=0.044 ms
64 bytes from 10.0.0.2: icmp_seq=58 ttl=64 time=0.038 ms
64 bytes from 10.0.0.2: icmp_seq=60 ttl=64 time=0.037 ms
64 bytes from 10.0.0.2: icmp_seq=62 ttl=64 time=0.040 ms
64 bytes from 10.0.0.2: icmp_seq=63 ttl=64 time=0.038 ms
64 bytes from 10.0.0.2: icmp_seq=64 ttl=64 time=0.036 ms
64 bytes from 10.0.0.2: icmp_seq=66 ttl=64 time=0.039 ms
64 bytes from 10.0.0.2: icmp_seq=69 ttl=64 time=0.039 ms
64 bytes from 10.0.0.2: icmp_seq=70 ttl=64 time=0.040 ms
64 bytes from 10.0.0.2: icmp_seq=71 ttl=64 time=0.040 ms
64 bytes from 10.0.0.2: icmp_seq=73 ttl=64 time=0.038 ms
64 bytes from 10.0.0.2: icmp_seq=78 ttl=64 time=0.038 ms
64 bytes from 10.0.0.2: icmp_seq=79 ttl=64 time=0.042 ms
64 bytes from 10.0.0.2: icmp_seq=80 ttl=64 time=0.040 ms
64 bytes from 10.0.0.2: icmp_seq=82 ttl=64 time=0.046 ms
64 bytes from 10.0.0.2: icmp_seq=83 ttl=64 time=0.040 ms
64 bytes from 10.0.0.2: icmp_seq=84 ttl=64 time=0.037 ms
64 bytes from 10.0.0.2: icmp_seq=85 ttl=64 time=0.041 ms
64 bytes from 10.0.0.2: icmp_seq=88 ttl=64 time=0.036 ms
64 bytes from 10.0.0.2: icmp_seq=89 ttl=64 time=0.039 ms
64 bytes from 10.0.0.2: icmp_seq=90 ttl=64 time=0.038 ms
64 bytes from 10.0.0.2: icmp_seq=91 ttl=64 time=0.041 ms
64 bytes from 10.0.0.2: icmp_seq=92 ttl=64 time=0.049 ms
64 bytes from 10.0.0.2: icmp_seq=93 ttl=64 time=0.033 ms
64 bytes from 10.0.0.2: icmp_seq=94 ttl=64 time=0.038 ms
64 bytes from 10.0.0.2: icmp_seq=95 ttl=64 time=0.046 ms
64 bytes from 10.0.0.2: icmp_seq=96 ttl=64 time=0.039 ms
64 bytes from 10.0.0.2: icmp_seq=97 ttl=64 time=0.039 ms
64 bytes from 10.0.0.2: icmp_seq=98 ttl=64 time=0.037 ms
64 bytes from 10.0.0.2: icmp_seq=100 ttl=64 time=0.042 ms

--- 10.0.0.2 ping statistics ---
100 packets transmitted, 74 received, 26% packet loss, time 1013
rtt min/avg/max/mdev = 0.033/0.050/0.399/0.051 ms
```

Рис. 9: Пингование

```
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root netem
root@mininet-vm:/home/mininet# █
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h2-eth0 root netem
root@mininet-vm:/home/mininet# █
```

Рис. 10: Восстановление конфигурации

```
root@mininet-vm:/home/mininet# ping 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=0.639 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.309 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.137 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.037 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.038 ms
^C
--- 10.0.0.2 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4077ms
rtt min/avg/max/mdev = 0.037/0.232/0.639/0.226 ms
```

Рис. 11: Пингование

```
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root netem loss 50% 50%  
root@mininet-vm:/home/mininet# █
```

Рис. 12: Добавление коэффициента потерь с корреляцией

```
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=0.744 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.275 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.185 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=0.059 ms
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=0.039 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=0.075 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=0.038 ms
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=0.037 ms
64 bytes from 10.0.0.2: icmp_seq=22 ttl=64 time=0.062 ms
64 bytes from 10.0.0.2: icmp_seq=23 ttl=64 time=0.040 ms
64 bytes from 10.0.0.2: icmp_seq=24 ttl=64 time=0.038 ms
64 bytes from 10.0.0.2: icmp_seq=33 ttl=64 time=0.039 ms
64 bytes from 10.0.0.2: icmp_seq=34 ttl=64 time=0.039 ms
64 bytes from 10.0.0.2: icmp_seq=35 ttl=64 time=0.038 ms
64 bytes from 10.0.0.2: icmp_seq=36 ttl=64 time=0.039 ms
64 bytes from 10.0.0.2: icmp_seq=37 ttl=64 time=0.041 ms
64 bytes from 10.0.0.2: icmp_seq=45 ttl=64 time=0.039 ms
64 bytes from 10.0.0.2: icmp_seq=46 ttl=64 time=0.037 ms
64 bytes from 10.0.0.2: icmp_seq=47 ttl=64 time=0.039 ms
64 bytes from 10.0.0.2: icmp_seq=48 ttl=64 time=0.041 ms
64 bytes from 10.0.0.2: icmp_seq=49 ttl=64 time=0.041 ms

--- 10.0.0.2 ping statistics ---
50 packets transmitted, 21 received, 58% packet loss, time 50183ms
rtt min/avg/max/mdev = 0.037/0.094/0.744/0.156 ms
root@mininet-vm:/home/mininet#
```

Рис. 13: Пингование

```
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root netem corrupt 0.01%
root@mininet-vm:/home/mininet# █
```

Рис. 14: *Добавление повреждения*

```
root@mininet-vm:/home/mininet# iperf3 -s
warning: this system does not seem to support IPv6 - trying IPv4
-----
Server listening on 5201
-----
```

Рис. 15: *Запуск сервера*

```

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 51438 connected to 10.0.0.2 port 5201
[ ID] Interval           Transfer     Bitrate      Retr  Cwnd
[ 7]  0.00-1.00    sec   3.23 GBytes  27.7 Gbits/sec    9   650 KBytes
[ 7]  1.00-2.00    sec   3.16 GBytes  27.1 Gbits/sec   12   665 KBytes
[ 7]  2.00-3.00    sec   3.17 GBytes  27.3 Gbits/sec    7   617 KBytes
[ 7]  3.00-4.00    sec   3.06 GBytes  26.3 Gbits/sec    6   611 KBytes
[ 7]  4.00-5.00    sec   3.08 GBytes  26.5 Gbits/sec    9   622 KBytes
[ 7]  5.00-6.00    sec   3.25 GBytes  27.9 Gbits/sec   11   584 KBytes
[ 7]  6.00-7.00    sec   3.25 GBytes  27.9 Gbits/sec    9   608 KBytes
[ 7]  7.00-8.00    sec   3.20 GBytes  27.5 Gbits/sec    6   631 KBytes
[ 7]  8.00-9.00    sec   3.28 GBytes  28.1 Gbits/sec    6   656 KBytes
[ 7]  9.00-10.00   sec   3.30 GBytes  28.4 Gbits/sec    3   653 KBytes
- - - - -
[ ID] Interval           Transfer     Bitrate      Retr
[ 7]  0.00-10.00   sec   32.0 GBytes  27.5 Gbits/sec   78
[ 7]  0.00-10.00   sec   32.0 GBytes  27.4 Gbits/sec

sender
receiver

iperf Done.

```

Рис. 16: Запуск клиента


```
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 переупорядочивания пакетов*

```
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=0.780 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.230 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.120 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=10.7 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=10.7 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=10.7 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=10.7 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=10.7 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=10.7 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=10.7 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=10.7 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=10.8 ms
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=10.7 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=10.7 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=10.9 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=10.8 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=10.8 ms
64 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=10.7 ms

--- 10.0.0.2 ping statistics ---
20 packets transmitted, 20 received, 0% packet loss, time 19094ms
rtt min/avg/max/mdev = 0.120/9.188/10.856/3.703 ms
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.
```

Рис. 18: Пингование

```
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root netem duplicate 50%
root@mininet-vm:/home/mininet# █
```

Рис. 19: *Добавление дублирования*

```

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=0.880 ms
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=0.985 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.212 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.138 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.058 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.058 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.038 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.040 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.041 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=0.038 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=0.040 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=0.092 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=0.093 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=0.038 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.067 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.068 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=0.039 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=0.039 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=0.057 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=0.043 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=0.043 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=0.039 ms
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=0.040 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=0.040 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=0.037 ms
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=0.070 ms
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=0.039 ms
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=0.039 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=0.037 ms

--- 10.0.0.2 ping statistics ---
20 packets transmitted, 20 received, +9 duplicates, 0% packet loss, time 19435ms
rtt min/avg/max/mdev = 0.037/0.118/0.985/0.224 ms

```

Рис. 20: Пингование

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

Рис. 21: Создание каталога

```
mininet@mininet-vm:~$ mkdir -p ~/work/lab_netem_ii/simple_drop
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
```

Рис. 22: Создание подкаталога

```

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 \'/time=//g\' -e \'/icmp_seq=//g\' > ping.dat' )

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

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

```

Рис. 23: Скрипт lab_netem_ii.py

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

Рис. 24: Изменение в скрипте *lab_netem_ii.py*


```
all: ping.dat

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

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

Рис. 25: Создание Makefile

```
mininet@mininet-vm:~/work/lab_netem_ii/simple_drop$ make
sudo python lab_netem_ii.py
*** Adding controller
*** Adding hosts
*** Adding switch
*** Creating links
*** Starting network
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ...
*** Waiting for switches to connect
s1
*** Set delay
*** h1 : ('tc qdisc add dev h1-eth0 root netem loss 10%,)
*** h2 : ('tc qdisc add dev h2-eth0 root netem loss 10%,)
*** Ping
*** h1 : ('ping -c 100', '10.0.0.2', '| grep "packet loss" | awk \'{print $6, $7, $8}\'} > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 2 links
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
mininet@mininet-vm:~/work/lab_netem_ii/simple_drop$ cat ping.dat
15% packet loss,
mininet@mininet-vm:~/work/lab_netem_ii/simple_drop$
```

Рис. 26: Выполнение эксперимента

```
info( '*** Set delay\n')  
h1.cmdPrint( 'tc qdisc add dev h1-eth0 root netem loss 50% 50%  
#h2.cmdPrint( 'tc qdisc add dev h2-eth0 root netem loss 10%' )
```

Рис. 27: Добавление коэффициента потерь с корреляцией

```
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 50% 50%',)
*** Ping
*** h1 : ('ping -c 100', '10.0.0.2', '| grep "packet loss" | awk \'{print $6, $7, $8}\'' > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 2 links
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
mininet@mininet-vm:~/work/lab_netem_ii/simple_drop$ cat ping.dat
49% packet loss,
```

Рис. 28: Выполнение эксперимента

```
INFO( *** See delay(n) )  
h1.cmdPrint( 'tc qdisc add dev h1-eth0 root netem corrupt 0.01%' )  
#h2.cmdPrint( 'tc qdisc add dev h2-eth0 root netem loss 10%' )
```

Рис. 29: Добавление повреждения

```
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 corrupt 0.01%',)
*** Ping
*** h1 : ('ping -c 100', '10.0.0.2', '| grep "packet loss" | awk \'{print $6, $7, $8}\'' > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 2 links
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
mininet@mininet-vm:~/work/lab_netem_ii/simple_drop$ cat ping.dat
0% packet loss,
```

Рис. 30: Выполнение эксперимента

```
info( '*** Set delay\n')  
h1.cmdPrint( 'tc qdisc add dev h1-eth0 root netem delay 10ms reorder 25% 50%' )  
#h2.cmdPrint( 'tc qdisc add dev h2-eth0 root netem loss 10%' )
```

Рис. 31: Добавление переупорядочивания пакетов

```
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 delay 10ms reorder 25% 50%',)
*** Ping
*** h1 : ('ping -c 100', '10.0.0.2', '| grep "packet loss" | awk \'{print $6, $7, $8}\'' > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 2 links
..
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
mininet@mininet-vm:~/work/lab_netem_ii/simple_drop$ cat ping.dat
0% packet loss,
mininet@mininet-vm:~/work/lab_netem_ii/simple_drop$
```

Рис. 32: Выполнение эксперимента


```
info( '*** Set delay\n')  
h1.cmdPrint( 'tc qdisc add dev h1-eth0 root netem duplicate 50% ' )  
#h2.cmdPrint( 'tc qdisc add dev h2-eth0 root netem loss 10%' )
```

Рис. 33: Добавление дублирования

```
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 duplicate 50%',)
*** Ping
*** h1 : ('ping -c 100', '10.0.0.2', '| grep "packet loss" | awk \'{print $6, $7, $8}\'' > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 2 links
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
mininet@mininet-vm:~/work/lab_netem_ii/simple_drop$ cat ping.dat
+58 duplicates, 0%
```

Рис. 34: Выполнение эксперимента

Вывод

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.