

Лаб №5 по дисциплине Моделирование сетей передачи данных

Эмуляция и измерение потерь пакетов в глобальных сетях

Шаповалова Диана Дмитриевна

11 декабря 2024

Российский университет дружбы народов, Москва, Россия

Вводная часть

Основной целью работы является получение навыков проведения интерактивных экспериментов в среде Mininet по исследованию параметров сети, связанных с потерей, дублированием, изменением порядка и повреждением пакетов при передаче данных. Эти параметры влияют на производительность протоколов и сетей.

Выполнение работы

Интерактивные эксперименты. Добавление потери пакетов на интерфейс, подключённый к эмулируемой глобальной сети

```
host: h1~@mininet-vm
64 bytes from 10.0.0.2: icmp_seq=84 ttl=64 time=0.061 ms
64 bytes from 10.0.0.2: icmp_seq=85 ttl=64 time=0.050 ms
64 bytes from 10.0.0.2: icmp_seq=86 ttl=64 time=0.070 ms
64 bytes from 10.0.0.2: icmp_seq=87 ttl=64 time=0.050 ms
64 bytes from 10.0.0.2: icmp_seq=89 ttl=64 time=0.083 ms
64 bytes from 10.0.0.2: icmp_seq=90 ttl=64 time=0.056 ms
64 bytes from 10.0.0.2: icmp_seq=91 ttl=64 time=0.051 ms
64 bytes from 10.0.0.2: icmp_seq=92 ttl=64 time=0.051 ms
64 bytes from 10.0.0.2: icmp_seq=93 ttl=64 time=0.068 ms
64 bytes from 10.0.0.2: icmp_seq=94 ttl=64 time=0.053 ms
64 bytes from 10.0.0.2: icmp_seq=95 ttl=64 time=0.053 ms
64 bytes from 10.0.0.2: icmp_seq=96 ttl=64 time=0.071 ms
64 bytes from 10.0.0.2: icmp_seq=98 ttl=64 time=0.050 ms
64 bytes from 10.0.0.2: icmp_seq=99 ttl=64 time=0.055 ms
64 bytes from 10.0.0.2: icmp_seq=100 ttl=64 time=0.064 ms

--- 10.0.0.2 ping statistics ---
100 packets transmitted, 86 received, 14% packet loss, time 101381ms
rtt min/avg/max/mdev = 0.043/0.068/0.526/0.066 ms
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth1

host: h2~@mininet-vm
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 1964 bytes 985100 (985.1 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 1964 bytes 985100 (985.1 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

root@mininet-vm:/home/mininet# sudo tc qdisc add dev h2-rth0 root netem loss 10%
Cannot find device "h2-rth0"
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h2-eth0 root netem loss 10%
root@mininet-vm:/home/mininet#
```

Рис. 1: Добавление потери пакетов на интерфейс

Добавление значения корреляции для потери пакетов в эмулируемой глобальной сети

```

X "host: h1" @mininet-vm
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=0.047 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=0.063 ms
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=0.048 ms
64 bytes from 10.0.0.2: icmp_seq=27 ttl=64 time=0.052 ms
64 bytes from 10.0.0.2: icmp_seq=29 ttl=64 time=0.050 ms
64 bytes from 10.0.0.2: icmp_seq=30 ttl=64 time=0.052 ms
64 bytes from 10.0.0.2: icmp_seq=33 ttl=64 time=0.072 ms
64 bytes from 10.0.0.2: icmp_seq=35 ttl=64 time=0.050 ms
64 bytes from 10.0.0.2: icmp_seq=36 ttl=64 time=0.049 ms
64 bytes from 10.0.0.2: icmp_seq=38 ttl=64 time=0.057 ms
64 bytes from 10.0.0.2: icmp_seq=41 ttl=64 time=0.066 ms
64 bytes from 10.0.0.2: icmp_seq=42 ttl=64 time=0.056 ms
64 bytes from 10.0.0.2: icmp_seq=43 ttl=64 time=0.070 ms
64 bytes from 10.0.0.2: icmp_seq=44 ttl=64 time=0.056 ms
64 bytes from 10.0.0.2: icmp_seq=45 ttl=64 time=0.050 ms

--- 10.0.0.2 ping statistics ---
50 packets transmitted, 27 received, 46% packet loss, time 501
79ms
rtt min/avg/max/mdev = 0.047/0.097/0.557/0.130 ms
root@mininet-vm: /home/mininet#
```

Добавление повреждения пакетов в эмулируемой глобальной сети

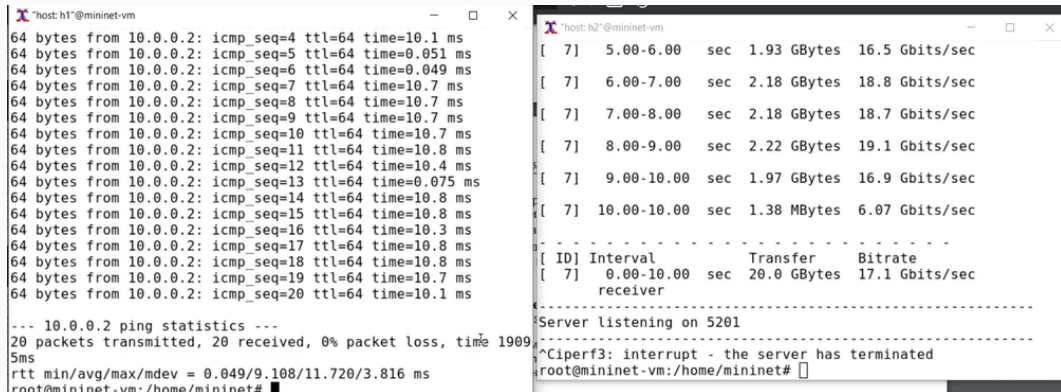
```
host: h1" @mininet-vm
[ 7] 4.00-5.00 sec 1.35 GBytes 11.6 Gbits/sec 3
12 KBytes
[ 7] 5.00-6.00 sec 1.93 GBytes 16.6 Gbits/sec 1
50 KBytes
[ 7] 6.00-7.00 sec 2.18 GBytes 18.8 Gbits/sec 2
02 KBytes
[ 7] 7.00-8.00 sec 2.18 GBytes 18.7 Gbits/sec 1
15 KBytes
[ 7] 8.00-9.00 sec 2.22 GBytes 19.1 Gbits/sec 3
01 KBytes
[ 7] 9.00-10.00 sec 1.97 GBytes 16.9 Gbits/sec 7
08 KBytes
-----
[ ID] Interval      Transfer    Bitrate    Retr
[ 7] 0.00-10.00 sec 20.0 GBytes 17.2 Gbits/sec 38
sender
[ 7] 0.00-10.00 sec 20.0 GBytes 17.1 Gbits/sec
receiver

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

host: h2" @mininet-vm
[ 7] 5.00-6.00 sec 1.93 GBytes 16.5 Gbits/sec
[ 7] 6.00-7.00 sec 2.18 GBytes 18.8 Gbits/sec
[ 7] 7.00-8.00 sec 2.18 GBytes 18.7 Gbits/sec
[ 7] 8.00-9.00 sec 2.22 GBytes 19.1 Gbits/sec
[ 7] 9.00-10.00 sec 1.97 GBytes 16.9 Gbits/sec
[ 7] 10.00-10.00 sec 1.38 MBytes 6.07 Gbits/sec
-----
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-10.00 sec 20.0 GBytes 17.1 Gbits/sec
receiver
-----
Server listening on 5201
-----
^Ciperf3: interrupt - the server has terminated
root@mininet-vm:/home/mininet#
```

Рис. 3: Добавление повреждения пакетов

Добавление переупорядочивания пакетов в интерфейс подключения к эмулируемой глобальной сети



```
"host: h1"@mininet-vm
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=10.1 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.051 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.049 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=10.8 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=0.075 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=10.3 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=10.7 ms
64 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=10.1 ms

--- 10.0.0.2 ping statistics ---
20 packets transmitted, 20 received, 0% packet loss, time 1909.5ms
rtt min/avg/max/mdev = 0.049/9.108/11.720/3.816 ms
root@mininet-vm:/home/mininet#
```

```
"host: h2"@mininet-vm
[ 7] 5.00-6.00 sec 1.93 GBytes 16.5 Gbits/sec
[ 7] 6.00-7.00 sec 2.18 GBytes 18.8 Gbits/sec
[ 7] 7.00-8.00 sec 2.18 GBytes 18.7 Gbits/sec
[ 7] 8.00-9.00 sec 2.22 GBytes 19.1 Gbits/sec
[ 7] 9.00-10.00 sec 1.97 GBytes 16.9 Gbits/sec
[ 7] 10.00-10.00 sec 1.38 MBytes 6.07 Gbits/sec

- - - - -
[ ID] Interval          Transfer    Bitrate
[ 7] 0.00-10.00 sec 20.0 GBytes 17.1 Gbits/sec
receiver
-----
Server listening on 5201
^Ciperf3: interrupt - the server has terminated
root@mininet-vm:/home/mininet#
```

Рис. 4: Добавление переупорядочивания пакетов

Добавление дублирования пакетов в интерфейс подключения к эмулируемой глобальной сети

```
host: h1" @mininet-vm
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=0.048 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.271 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.271 ms (DUP!)
)
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=0.055 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=0.056 ms (DUP!)
)
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=0.050 ms
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=0.050 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=0.045 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=0.050 ms
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=0.069 ms
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=0.057 ms
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=0.057 ms (DUP!)
)
64 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=0.054 ms

--- 10.0.0.2 ping statistics ---
20 packets transmitted, 20 received, +8 duplicates, 0% packet
loss, time 19425ms
```

Воспроизведение экспериментов

```
[2]+  Stopped                  sudo mn --topo=single,2 -x
mininet@mininet-vm:~$ mkdir -p ~/work/lab_netem_ii/simple-drop
mininet@mininet-vm:~$ mkdir -p ~/work/lab_netem_ii/correlation-drop
mininet@mininet-vm:~$ mkdir -p ~/work/lab_netem_ii/package-damage
mininet@mininet-vm:~$ mkdir -p ~/work/lab_netem_ii/reordering-packages
mininet@mininet-vm:~$ mkdir -p ~/work/lab_netem_ii/duplicating-packages
mininet@mininet-vm:~$ ls
```

Рис. 6: Создаем каталоги

Создаем скрипт

```
mininet@mininet-vm: ~/work/lab_netem_ii/simple-drop
/home/mininet@mininet-vm: ~/work/lab_netem_ii/simple-drop
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)

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

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

1Help 2Save 3Mark 4Replac 5Copy 6Move 7Search 8Delete 9PullDn10Quit
```

Выполняем эксперимент

```
*** 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 "time=" | awk \'{print $5, $7}\\' |
sed -e \'s/time=//g\' -e \'s/icmp_seq=//g\' > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 2 links
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
mininet@mininet-vm:~/work/lab_netem_ii/correlation-drop$ make stats
python stats.py
Total packets: 100
Lost packets: 20
Lost packet numbers: [3, 17, 19, 24, 27, 32, 35, 36, 49, 59, 62, 69, 75, 76, 77
, 92, 93, 94, 96, 100]
Loss percentage: 20.00%
```

Задание для самостоятельной работы

Самостоятельно реализуйте воспроизводимые эксперименты по исследованию параметров сети, связанных с потерей, изменением порядка

и повреждением пакетов при передаче данных.

```
*** 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 "time=" | awk \'{print $5, $7}\\' |
sed -e \'s/time=//g\' -e \'s/icmp_seq=//g\' > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 2 links
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
mininet@mininet-vm:~/work/lab_netem_ii/correlation-drop$ make stats
python stats.py
Total packets: 100
```

Добавление значения корреляции для потери пакетов в эмулируемой глобальной сети

```
mininet@mininet-vm: ~/work/lab_netem_ii/correlation-drop
*** 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, $7}\'' |
sed -e \'/time=//g\' -e \'/icmp_seq=//g\' > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 2 links
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
mininet@mininet-vm:~/work/lab_netem_ii/correlation-drop$ make stats
python stats.py
Total packets: 100
Lost packets: 53
Lost packet numbers: [2, 3, 4, 11, 12, 13, 14, 15, 17, 20, 21, 22, 26, 27, 28,
29, 30, 35, 36, 37, 38, 42, 44, 46, 54, 55, 60, 62, 63, 64, 65, 68, 69, 70, 73,
77, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 91, 93, 95, 98, 99, 100]
Loss percentage: 53.00%
mininet@mininet-vm:~/work/lab_netem_ii/correlation-drop$
```


Добавление повреждения пакетов в эмулируемой глобальной сети

```
mininet@mininet-vm: ~/work/lab_netem_ii/package-damage
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
python stats.py
Total packets: 100
Lost packets: 13
Lost packet numbers: [13, 41, 56, 66, 67, 70, 80, 81, 83, 93, 96, 98, 99]
Loss percentage: 13.00%
mininet@mininet-vm:~/work/lab_netem_ii/package-damage$
```

Добавление переупорядочивания пакетов в интерфейс подключения к эмулируемой глобальной сети

```
mininet@mininet-vm: ~/work/lab_netem_ii/reordering-packages
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
python stats.py
Total packets: 100
Lost packets: 8
Lost packet numbers: [11, 58, 65, 66, 67, 72, 73, 95]
```

Выводы

Мы получили навыки проведения интерактивных экспериментов в среде Mininet по исследованию параметров сети, связанных с потерей, дублированием, изменением порядка и повреждением пакетов при передаче данных.