

Лабораторная работа № 5. Эмуляция и измерение потерь пакетов в глобальных сетях

Моделирование сетей передачи данных

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Введение

Цель работы

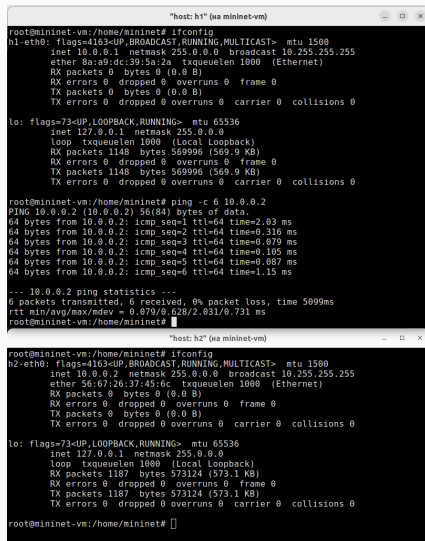
Основной целью работы является получение навыков проведения интерактивных экспериментов в среде Mininet по исследованию параметров сети, связанных с потерей, дублированием, изменением порядка и повреждением пакетов при передаче данных. Эти параметры влияют на производительность протоколов и сетей.inet.

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.
3. Реализуйте воспроизводимый эксперимент по добавлению правила отбрасывания пакетов в эмулируемой глобальной сети. На экран выведите сводную информацию о

Выполнение лабораторной работы

Запуск лабораторной топологии



```

"host: h1" (на mininet-vm)
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 8a:a9:dc:39:5a:2a  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 1148  bytes 569996 (569.9 KB)
    RX errors 0  dropped 0  overruns 0  frame 0
    TX packets 1148  bytes 569996 (569.9 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=2.03 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.316 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.079 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.105 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.087 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=1.15 ms

--- 10.0.0.2 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5099ms
rtt min/avg/max/mdev = 0.079/0.628/2.031/0.731 ms
root@mininet-vm:/home/mininet#

"host: h2" (на mininet-vm)
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 56:67:26:37:45:6c  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 1187  bytes 573124 (573.1 KB)
    RX errors 0  dropped 0  overruns 0  frame 0
    TX packets 1187  bytes 573124 (573.1 KB)
    TX errors 0  dropped 0  overruns 0  carrier 0  collisions 0

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

Добавление потери пакетов на интерфейс, подключённый к эмулируемой глобальной сети

```
"host: h1" (на mininet-vn)
64 bytes from 10.0.0.2: icmp_seq=74 ttl=64 time=0.071 ms
64 bytes from 10.0.0.2: icmp_seq=75 ttl=64 time=0.126 ms
64 bytes from 10.0.0.2: icmp_seq=77 ttl=64 time=0.075 ms
64 bytes from 10.0.0.2: icmp_seq=78 ttl=64 time=0.225 ms
64 bytes from 10.0.0.2: icmp_seq=79 ttl=64 time=0.063 ms
64 bytes from 10.0.0.2: icmp_seq=80 ttl=64 time=0.105 ms
64 bytes from 10.0.0.2: icmp_seq=81 ttl=64 time=0.062 ms
64 bytes from 10.0.0.2: icmp_seq=82 ttl=64 time=0.098 ms
64 bytes from 10.0.0.2: icmp_seq=83 ttl=64 time=0.117 ms
64 bytes from 10.0.0.2: icmp_seq=84 ttl=64 time=0.065 ms
64 bytes from 10.0.0.2: icmp_seq=85 ttl=64 time=0.083 ms
64 bytes from 10.0.0.2: icmp_seq=86 ttl=64 time=0.069 ms
64 bytes from 10.0.0.2: icmp_seq=87 ttl=64 time=0.109 ms
64 bytes from 10.0.0.2: icmp_seq=88 ttl=64 time=0.072 ms
64 bytes from 10.0.0.2: icmp_seq=89 ttl=64 time=0.097 ms
64 bytes from 10.0.0.2: icmp_seq=90 ttl=64 time=0.070 ms
64 bytes from 10.0.0.2: icmp_seq=91 ttl=64 time=0.094 ms
64 bytes from 10.0.0.2: icmp_seq=92 ttl=64 time=0.111 ms
64 bytes from 10.0.0.2: icmp_seq=93 ttl=64 time=0.064 ms
64 bytes from 10.0.0.2: icmp_seq=94 ttl=64 time=0.079 ms
64 bytes from 10.0.0.2: icmp_seq=95 ttl=64 time=0.099 ms
64 bytes from 10.0.0.2: icmp_seq=96 ttl=64 time=0.106 ms
64 bytes from 10.0.0.2: icmp_seq=97 ttl=64 time=0.062 ms
64 bytes from 10.0.0.2: icmp_seq=98 ttl=64 time=0.089 ms
64 bytes from 10.0.0.2: icmp_seq=99 ttl=64 time=0.070 ms

--- 10.0.0.2 ping statistics ---
100 packets transmitted, 86 received, 14% packet loss, time 101363ms
rtt min/avg/max/mdev = 0.054/0.102/0.257/0.050 ms
root@mininet-vn:/home/mininet#
```

Рис. 2: Потери 10% на хосте h1

Добавление потери пакетов на интерфейс, подключённый к эмулируемой глобальной сети

```
"host: h1" (на mininet-virtual-machine)
64 bytes from 10.0.0.2: icmp_seq=62 ttl=64 time=0.064 ms
64 bytes from 10.0.0.2: icmp_seq=64 ttl=64 time=0.093 ms
64 bytes from 10.0.0.2: icmp_seq=65 ttl=64 time=0.057 ms
64 bytes from 10.0.0.2: icmp_seq=66 ttl=64 time=0.209 ms
64 bytes from 10.0.0.2: icmp_seq=67 ttl=64 time=0.157 ms
64 bytes from 10.0.0.2: icmp_seq=68 ttl=64 time=0.079 ms
64 bytes from 10.0.0.2: icmp_seq=70 ttl=64 time=0.063 ms
64 bytes from 10.0.0.2: icmp_seq=74 ttl=64 time=0.114 ms
64 bytes from 10.0.0.2: icmp_seq=75 ttl=64 time=0.104 ms
64 bytes from 10.0.0.2: icmp_seq=76 ttl=64 time=0.070 ms
64 bytes from 10.0.0.2: icmp_seq=78 ttl=64 time=0.117 ms
64 bytes from 10.0.0.2: icmp_seq=79 ttl=64 time=0.088 ms
64 bytes from 10.0.0.2: icmp_seq=80 ttl=64 time=0.066 ms
64 bytes from 10.0.0.2: icmp_seq=81 ttl=64 time=0.079 ms
64 bytes from 10.0.0.2: icmp_seq=84 ttl=64 time=0.092 ms
64 bytes from 10.0.0.2: icmp_seq=85 ttl=64 time=0.136 ms
64 bytes from 10.0.0.2: icmp_seq=86 ttl=64 time=0.060 ms
64 bytes from 10.0.0.2: icmp_seq=87 ttl=64 time=0.083 ms
64 bytes from 10.0.0.2: icmp_seq=88 ttl=64 time=0.166 ms
64 bytes from 10.0.0.2: icmp_seq=89 ttl=64 time=0.107 ms
64 bytes from 10.0.0.2: icmp_seq=90 ttl=64 time=0.158 ms
64 bytes from 10.0.0.2: icmp_seq=93 ttl=64 time=0.154 ms
64 bytes from 10.0.0.2: icmp_seq=96 ttl=64 time=0.083 ms
64 bytes from 10.0.0.2: icmp_seq=97 ttl=64 time=0.080 ms
64 bytes from 10.0.0.2: icmp_seq=100 ttl=64 time=0.067 ms

--- 10.0.0.2 ping statistics ---
100 packets transmitted, 73 received, 27% packet loss, time 101376ms
rtt min/avg/max/mdev = 0.055/0.110/0.341/0.056 ms
root@mininet-virtual-machine: /home/mininet#
```

Рис. 3: Потери 10% на хосте h1 и h2

Добавление значения корреляции для потери пакетов в эмулируемой глобальной сети

```
"host: h1" (на mininet-vm)
100 packets transmitted, 73 received, 27% packet loss, time 101376ms
rtt min/avg/max/mdev = 0.055/0.110/0.341/0.056 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 loss 50
% 50%
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=1 ttl=64 time=2.07 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.734 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.193 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.082 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.334 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=0.121 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=0.071 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=0.102 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=0.108 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.227 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=0.175 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=0.070 ms
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=0.086 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=0.117 ms
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=0.078 ms
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=0.083 ms
64 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=0.069 ms
64 bytes from 10.0.0.2: icmp_seq=21 ttl=64 time=0.070 ms
64 bytes from 10.0.0.2: icmp_seq=22 ttl=64 time=0.066 ms
64 bytes from 10.0.0.2: icmp_seq=26 ttl=64 time=0.082 ms
64 bytes from 10.0.0.2: icmp_seq=27 ttl=64 time=0.077 ms
64 bytes from 10.0.0.2: icmp_seq=28 ttl=64 time=0.143 ms
64 bytes from 10.0.0.2: icmp_seq=29 ttl=64 time=0.078 ms
64 bytes from 10.0.0.2: icmp_seq=38 ttl=64 time=0.083 ms
64 bytes from 10.0.0.2: icmp_seq=42 ttl=64 time=0.077 ms
64 bytes from 10.0.0.2: icmp_seq=47 ttl=64 time=0.061 ms
64 bytes from 10.0.0.2: icmp_seq=49 ttl=64 time=0.216 ms
64 bytes from 10.0.0.2: icmp_seq=50 ttl=64 time=0.082 ms

--- 10.0.0.2 ping statistics ---
50 packets transmitted, 29 received, 42% packet loss, time 50143ms
rtt min/avg/max/mdev = 0.061/0.200/2.072/0.376 ms
root@mininet-vm:/home/mininet#
```

Рис. 4: Добавление значения корреляции для потери пакетов на h1

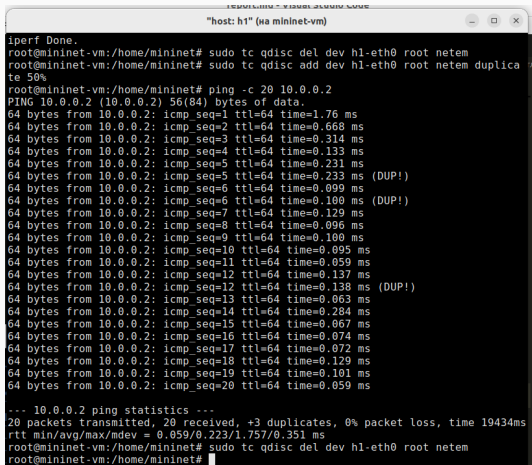
Добавление повреждения пакетов в эмулируемой глобальной сети

```
"host: h1" (на mininet-vm)
rtt min/avg/max/mdev = 0.061/0.200/2.072/0.376 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 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 41244 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer     Bitrate      Retr  Cwnd
[ 7] 0.00-1.00 sec  2.20 GBytes  18.9 Gbits/sec  5    1.87 MBytes
[ 7] 1.00-2.00 sec  2.09 GBytes  18.0 Gbits/sec  9    2.50 MBytes
[ 7] 2.00-3.00 sec  2.18 GBytes  18.7 Gbits/sec  17   2.50 MBytes
[ 7] 3.00-4.00 sec  2.12 GBytes  18.2 Gbits/sec  15   1.75 MBytes
[ 7] 4.00-5.00 sec  2.16 GBytes  18.5 Gbits/sec  12   2.50 MBytes
[ 7] 5.00-6.00 sec  2.16 GBytes  18.5 Gbits/sec  17   2.50 MBytes
[ 7] 6.00-7.00 sec  2.08 GBytes  17.9 Gbits/sec  13   1.22 MBytes
[ 7] 7.00-8.00 sec  2.21 GBytes  18.9 Gbits/sec  9     877 KBytes
[ 7] 8.00-9.00 sec  2.06 GBytes  17.7 Gbits/sec  12   1.22 MBytes
[ 7] 9.00-10.00 sec 2.19 GBytes  18.8 Gbits/sec  12   1.22 MBytes
-----
[ ID] Interval      Transfer     Bitrate      Retr
[ 7] 0.00-10.00 sec 21.4 GBytes  18.4 Gbits/sec  121
[ 7] 0.00-10.00 sec 21.4 GBytes  18.4 Gbits/sec
-----
iperf Done.
root@mininet-vm:/home/mininet#

"host: h2" (на mininet-vm)
Server listening on 5201
Accepted connection from 10.0.0.1, port 41242
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 41244
[ ID] Interval      Transfer     Bitrate
[ 7] 0.00-1.00 sec  2.19 GBytes  18.8 Gbits/sec
[ 7] 1.00-2.00 sec  2.07 GBytes  17.8 Gbits/sec
[ 7] 2.00-3.00 sec  2.18 GBytes  18.7 Gbits/sec
[ 7] 3.00-4.00 sec  2.12 GBytes  18.2 Gbits/sec
[ 7] 4.00-5.00 sec  2.16 GBytes  18.5 Gbits/sec
[ 7] 5.00-6.00 sec  2.16 GBytes  18.5 Gbits/sec
[ 7] 6.00-7.00 sec  2.08 GBytes  17.9 Gbits/sec
[ 7] 7.00-8.00 sec  2.21 GBytes  18.9 Gbits/sec
[ 7] 8.00-9.00 sec  2.06 GBytes  17.7 Gbits/sec
[ 7] 9.00-10.00 sec 2.19 GBytes  18.9 Gbits/sec
-----
[ ID] Interval      Transfer     Bitrate
[ 7] 0.00-10.00 sec 21.4 GBytes  18.4 Gbits/sec
-----
Server listening on 5201
```

Рис. 5: Добавление повреждения пакетов и проверка

Добавление дублирования пакетов в интерфейс подключения к эмулируемой глобальной сети



```

"host: h1" (на mininet-vm)
iperf Done.
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 duplica
te 50%
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=1.76 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.668 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.314 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.133 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.231 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.233 ms (DUP!)
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.099 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.100 ms (DUP!)
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=0.096 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=0.100 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=0.095 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.059 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=0.137 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=0.138 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=0.284 ms
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=0.067 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=0.074 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=0.072 ms
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=0.129 ms
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=0.101 ms
64 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=0.059 ms

--- 10.0.0.2 ping statistics ---
20 packets transmitted, 20 received, +3 duplicates, 0% packet loss, time 19434ms
rtt min/avg/max/mdev = 0.059/0.223/1.757/0.351 ms
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root netem
root@mininet-vm:/home/mininet#
```

Рис. 6: Добавление дублирования пакетов

Воспроизведение экспериментов

```
Make: *** [makefile:3: ping.dat] Error 1
mininet@mininet-vm:~/work/lab_netem_ii/simple-drop$ nano lab_netem_ii.py
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, $8}\'}')
22% packet loss,
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 2 links
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
mininet@mininet-vm:~/work/lab_netem_ii/simple-drop$
```

Рис. 7: Проведение эксперимента

Выводы

В результате выполнения 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. Эти параметры влияют на производительность протоколов и сетей.

1. Mininet [Электронный ресурс]. Mininet Project Contributors. URL: <http://mininet.org/> (дата обращения: 11.12.2024).