

Лабораторная работа № 4

Эмуляция и измерение задержек в глобальных сетях

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Информация

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Вводная часть

Цели и задачи

Основной целью работы является знакомство с NETEM — инструментом для тестирования производительности приложений в виртуальной сети, а также получение навыков проведения интерактивного и воспроизводимого экспериментов по измерению задержки и её дрожания (jitter) в моделируемой сети в среде Mininet.

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 добавлению/изменению задержки, джиттера, значения корреляции для джиттера и задержки, распределения времени задержки в эмулируемой глобальной сети.
3. Реализуйте воспроизводимый эксперимент по заданию значения задержки в эмулируемой глобальной сети. Постройте график.
4. Самостоятельно реализуйте воспроизводимые эксперименты по изменению задержки, джиттера, значения корреляции для джиттера и задержки, распределения времени задержки в эмулируемой глобальной сети. Постройте графики.

Результаты

Поставленные боевые задачи были выполнены, все цели достигнуты.

Выполнение лабораторной работы

1. Подключение по ssh и выдача прав графическим приложениям

```
via v22.11.0
) ssh -Y mininet@192.168.56.101
mininet@192.168.56.101's password:
Warning: No xauth data; using fake authentication data for X11 forwarding.
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

New release '22.04.5 LTS' available.
Run 'do-release-upgrade' to upgrade to it.

Last login: Thu Dec  5 10:28:23 2024
mininet@mininet-vm:~$ xauth list $DISPLAY
mininet-vm/unix:10 MIT-MAGIC-COOKIE-1 a752fa358e4cb4864df44322bbd801bc
mininet@mininet-vm:~$ MIT-MAGIC-COOKIE-1 a752fa358e4cb4864df44322bbd801bc
MIT-MAGIC-COOKIE-1: command not found
mininet@mininet-vm:~$ sudo -i
root@mininet-vm:~# auth add mininet-vm/unix:10 MIT-MAGIC-COOKIE-1 a752fa358e4cb4864df44322bbd801bc

Command 'auth' not found, did you mean:

  command 'iauth' from deb ircd-irc2 (2.11.2p3~dfsg-5build1)
  command 'oauth' from deb ruby-oauth (0.5.4-1)
  command 'xauth' from deb xauth (1:1.1-0ubuntu1)

Try: apt install <deb name>

root@mininet-vm:~# xauth add mininet-vm/unix:10 MIT-MAGIC-COOKIE-1 a752fa358e4cb4864df44322bbd801bc
root@mininet-vm:~# logout
mininet@mininet-vm:~$
```

Step 1

2. Терминалы хостов h1 и h2.

```
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 fa:ed:9d:e7:df:33 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 1074 bytes 270456 (270.4 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 1074 bytes 270456 (270.4 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

root@mininet-vm:/home/mininet# whoami
root
root@mininet-vm:/home/mininet# tty
/dev/pts/8
root@mininet-vm:/home/mininet#
```

```
root@mininet-vm:/home/mininet# tty
/dev/pts/5
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 9a:67:53:f7:d5:fb 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 1261 bytes 285372 (285.3 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 1261 bytes 285372 (285.3 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

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

Step 2

3. ping (h2 - слева, h1 - справа)

```
root@mininet-vm:/home/mininet# 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=2.22 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=0.124 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=0.027 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=0.020 ms
64 bytes from 10.0.0.1: icmp_seq=5 ttl=64 time=0.029 ms
64 bytes from 10.0.0.1: icmp_seq=6 ttl=64 time=0.026 ms

--- 10.0.0.1 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5093ms
rtt min/avg/max/mdev = 0.020/0.407/2.218/0.810 ms
root@mininet-vm:/home/mininet#
```

```
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=2.00 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.032 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.030 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.030 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.027 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.022 ms

--- 10.0.0.2 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5097ms
rtt min/avg/max/mdev = 0.022/0.356/1.998/0.734 ms
root@mininet-vm:/home/mininet#
```

Step 3

4. ping с установленными задержками

```
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root netem delay 100ms
[cannot find device "h1-eth0"]
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 fa:ed:9d:e7:df:33 txqueuelen 1000 (Ethernet)
    RX packets 14 bytes 1260 (1.2 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 14 bytes 1260 (1.2 KB)
    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 2589 bytes 517844 (517.8 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 2589 bytes 517844 (517.8 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

root@mininet-vm:/home/mininet# sudo tc qdisc add dev h2-eth0 root netem delay 100ms
root@mininet-vm:/home/mininet# 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=205 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=206 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=206 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=203 ms
64 bytes from 10.0.0.1: icmp_seq=5 ttl=64 time=205 ms
64 bytes from 10.0.0.1: icmp_seq=6 ttl=64 time=203 ms

--- 10.0.0.1 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5007ms
rtt min/avg/max/mdev = 202.635/204.563/206.384/1.426 ms
root@mininet-vm:/home/mininet#
```

```
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h2-eth0 root netem delay 100ms
[cannot find device "h2-eth0"]
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=201 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=203 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=202 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=201 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=201 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=202 ms

--- 10.0.0.2 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5017ms
rtt min/avg/max/mdev = 200.729/201.713/202.731/0.627 ms
root@mininet-vm:/home/mininet#
```

Step 4

5. ping с задержками 50мс

<pre>root@mininet-vn:/home/mininet# sudo tc qdisc change dev h2-eth0 root netem delay 50ms root@mininet-vn:/home/mininet# 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=151 ms 64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=153 ms 64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=151 ms 64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=151 ms 64 bytes from 10.0.0.1: icmp_seq=5 ttl=64 time=154 ms 64 bytes from 10.0.0.1: icmp_seq=6 ttl=64 time=153 ms --- 10.0.0.1 ping statistics --- 6 packets transmitted, 6 received, 0% packet loss, time 5012ms rtt min/avg/max/mdev = 151.179/152.296/153.847/1.049 ms root@mininet-vn:/home/mininet#</pre>	<pre>root@mininet-vn:/home/mininet# sudo tc qdisc change dev h1-eth0 root netem delay 100ms root@mininet-vn:/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=151 ms 64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=151 ms 64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=150 ms 64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=155 ms 64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=153 ms 64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=155 ms --- 10.0.0.2 ping statistics --- 6 packets transmitted, 6 received, 0% packet loss, time 5016ms rtt min/avg/max/mdev = 150.440/152.593/155.152/1.885 ms root@mininet-vn:/home/mininet#</pre>
---	--

Step 5

6. Удаление задержек

<pre>root@mininet-vn:/home/mininet# sudo tc qdisc add dev h1-eth0 root netem delay 100ms 10ms Cannot find device "h1-eth0" root@mininet-vn:/home/mininet# sudo tc qdisc add dev h2-eth0 root netem delay 100ms 10ms root@mininet-vn:/home/mininet# 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=193 ms 64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=204 ms 64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=211 ms 64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=212 ms 64 bytes from 10.0.0.1: icmp_seq=5 ttl=64 time=205 ms 64 bytes from 10.0.0.1: icmp_seq=6 ttl=64 time=204 ms --- 10.0.0.1 ping statistics --- 6 packets transmitted, 6 received, 0% packet loss, time 5013ms rtt min/avg/max/mdev = 192.047/204.541/211.730/6.110 ms root@mininet-vn:/home/mininet#</pre>	<pre>root@mininet-vn:/home/mininet# sudo tc qdisc add dev h1-eth0 root netem delay 100ms 10 root@mininet-vn:/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=193 ms 64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=199 ms 64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=187 ms 64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=198 ms 64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=189 ms 64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=200 ms --- 10.0.0.2 ping statistics --- 6 packets transmitted, 6 received, 0% packet loss, time 5007ms rtt min/avg/max/mdev = 187.200/194.522/200.338/5.065 ms root@mininet-vn:/home/mininet#</pre>
--	--

Step 6

7. Дрожание задержки

<pre>root@mininet-vn:/home/mininet# sudo tc qdisc add dev h2-eth0 root netem delay 100ms 10ms 25% Error: Exclusivity flag on, cannot modify. root@mininet-vn:/home/mininet# sudo tc qdisc change dev h2-eth0 root netem delay 100ms 10ms 25% root@mininet-vn:/home/mininet# 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=203 ms 64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=205 ms 64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=200 ms 64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=202 ms 64 bytes from 10.0.0.1: icmp_seq=5 ttl=64 time=205 ms 64 bytes from 10.0.0.1: icmp_seq=6 ttl=64 time=204 ms --- 10.0.0.1 ping statistics --- 6 packets transmitted, 6 received, 0% packet loss, time 5015ms rtt min/avg/max/mdev = 200.158/203.147/205.446/1.706 ms root@mininet-vn:/home/mininet#</pre>	<pre>root@mininet-vn:/home/mininet# sudo tc qdisc add dev h1-eth0 root netem delay 100ms 10ms root@mininet-vn:/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=193 ms 64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=199 ms 64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=187 ms 64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=198 ms 64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=189 ms 64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=200 ms --- 10.0.0.2 ping statistics --- 6 packets transmitted, 6 received, 0% packet loss, time 5007ms rtt min/avg/max/mdev = 187.200/194.522/200.338/5.065 ms root@mininet-vn:/home/mininet# sudo tc qdisc change dev h1-eth0 root netem delay 100ms 10ms 2 Command "changew" is unknown, try "tc qdisc help". root@mininet-vn:/home/mininet# sudo tc qdisc change dev h1-eth0 root netem delay 100ms 10ms 25% root@mininet-vn:/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=193 ms 64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=195 ms 64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=186 ms 64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=204 ms 64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=212 ms 64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=185 ms --- 10.0.0.2 ping statistics --- 6 packets transmitted, 6 received, 0% packet loss, time 5013ms rtt min/avg/max/mdev = 185.484/195.932/211.556/9.295 ms root@mininet-vn:/home/mininet#</pre>
---	---

Step 7

8. Дрожание задержки с вариациями

<pre>root@mininet-vn:/home/mininet# sudo tc qdisc change dev h2-eth0 root netem delay 100ms 20ms distribution normal root@mininet-vn:/home/mininet# 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=147 ms 64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=106 ms 64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=177 ms 64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=213 ms 64 bytes from 10.0.0.1: icmp_seq=5 ttl=64 time=235 ms 64 bytes from 10.0.0.1: icmp_seq=6 ttl=64 time=168 ms --- 10.0.0.1 ping statistics --- 6 packets transmitted, 6 received, 0% packet loss, time 5017ms rtt min/avg/max/mdev = 106.206/174.150/234.862/42.024 ms root@mininet-vn:/home/mininet#</pre>	<pre>root@mininet-vn:/home/mininet# sudo tc qdisc change dev h1-eth0 root netem delay 100ms 30ms distribution normal root@mininet-vn:/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=187 ms 64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=213 ms 64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=186 ms 64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=255 ms 64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=189 ms 64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=188 ms --- 10.0.0.2 ping statistics --- 6 packets transmitted, 6 received, 0% packet loss, time 5010ms rtt min/avg/max/mdev = 186.811/203.074/254.947/25.059 ms root@mininet-vn:/home/mininet#</pre>
--	--

Step 8

9. Задержки с нормальным распределением

```
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 delay 100ms' )
    h2.cmdPrint( 'tc qdisc add dev h2-eth0 root netem delay 100ms' )

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

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

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

lab_netem_i.py

44,0-1

Bot

"lab_netem_i.py" 47L, 1226C written

Step 9

10. lab_netem script

```
ll: ping.dat ping.png

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

ping.png: ping.dat
./ping_plot

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

Step 10

11. Makefile

```
ll: ping.dat ping.png

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

ping.png: ping.dat
    ./ping_plot

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

Step 11

12. Автоматизированное проведение эксперимента

```
*** Starting network
*** Configuring hosts
h1 h2
*** Starting controller
t0
*** Starting 1 switches
s1 ...
*** Waiting for switches to connect
s1
*** Set delay
*** h1 : ('tc qdisc add dev h1-eth0 root netem delay 100ms',)
*** h2 : ('tc qdisc add dev h2-eth0 root netem delay 100ms',)
*** Ping
*** h1 : ('ping -c 100', '10.0.0.2', '| grep "time=" | awk \'{print $5, $7}\'' | sed -e \'/time=//g\' -e
s/icmp_seq=//g\' > ping.dat')
*** Stopping network*** Stopping 1 controllers
t0
*** Stopping 2 links
.
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
ping.png: ping.dat
make: ping.png: Command not found
make: *** [Makefile:6: ping.dat] Error 127
mininet@mininet-vm:~/work/lab_netem_i/simple-delay$ cat Makefile
all: ping.dat ping.png

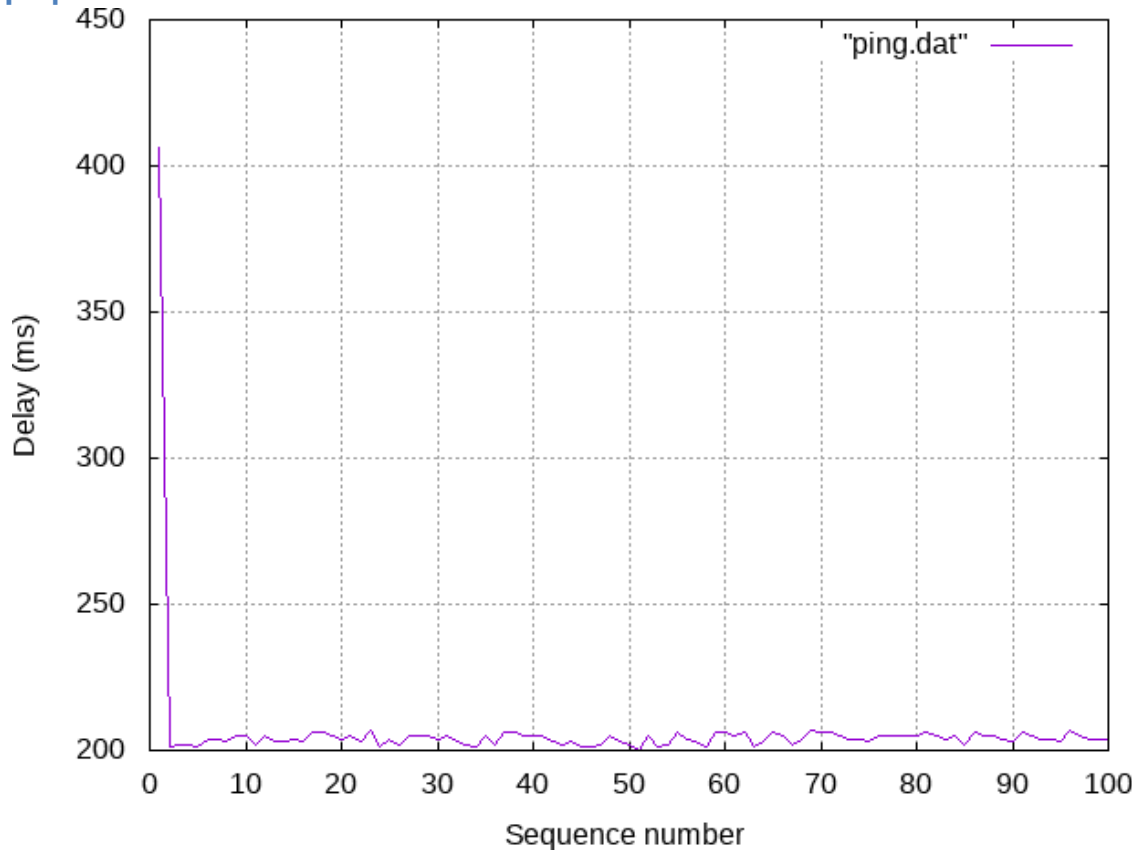
ping.dat:
    sudo python lab_netem_i.py
    sudo chown mininet:mininet ping.dat

ping.png: ping.dat
    ./ping_plot

clean:
    -rm -f *.dat *.png
mininet@mininet-vm:~/work/lab_netem_i/simple-delay$ nvim Makefile
mininet@mininet-vm:~/work/lab_netem_i/simple-delay$ make
./ping_plot
mininet@mininet-vm:~/work/lab_netem_i/simple-delay$ ls
lab_netem_i.py Makefile ping.dat ping_plot ping.png
mininet@mininet-vm:~/work/lab_netem_i/simple-delay$ nvim Makefile
mininet@mininet-vm:~/work/lab_netem_i/simple-delay$ make ping.png
make: 'ping.png' is up to date.
mininet@mininet-vm:~/work/lab_netem_i/simple-delay$ make clean
rm -f *.dat *.png
mininet@mininet-vm:~/work/lab_netem_i/simple-delay$
```

Step 12

Графики



ping

Выводы

Я познакомился с NETEM — инструментом для тестирования производительности приложений в виртуальной сети, а также получение навыков проведения интерактивного и воспроизводимого экспериментов по измерению задержки и её дрожания (jitter) в моделируемой сети в среде Mininet.