

Лаб №4 по дисциплине Моделирование сетей передачи данных

Эмуляция и измерение задержек в глобальных сетях

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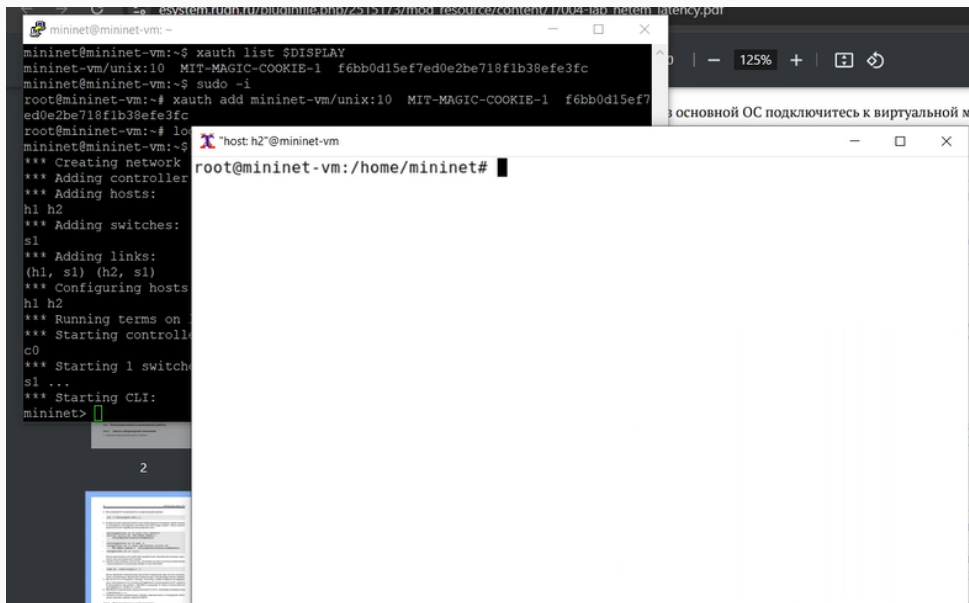
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Вводная часть

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.

Выполнение работы

Запуск лабораторной топологии



Интерактивные эксперименты. Добавление/изменение задержки в эмулируемой глобальной сети

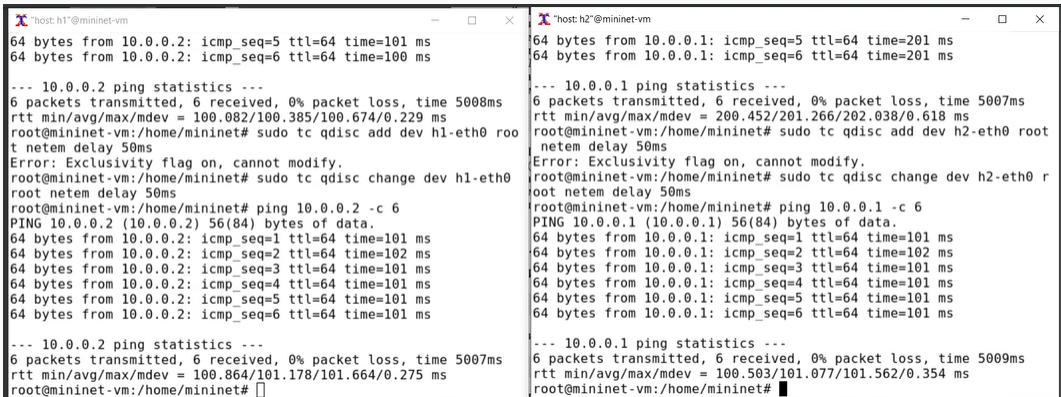
```
host: h2"@mininet-vm

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 1773 bytes 452964 (452.9 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 1773 bytes 452964 (452.9 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=202 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=201 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=201 ms
64 bytes from 10.0.0.1: icmp_seq=6 ttl=64 time=201 ms

--- 10.0.0.1 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5007ms
```

Изменение задержки в эмулируемой глобальной сети



```
host: h1@mininet-vm
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=101 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=100 ms

--- 10.0.0.2 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5008ms
rtt min/avg/max/mdev = 100.082/100.385/100.674/0.229 ms
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root
t netem delay 50ms
Error: Exclusivity flag on, cannot modify.
root@mininet-vm:/home/mininet# sudo tc qdisc change dev h1-eth0
root netem delay 50ms
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=101 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=102 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=101 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=101 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=101 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=101 ms

--- 10.0.0.2 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5007ms
rtt min/avg/max/mdev = 100.864/101.178/101.664/0.275 ms
root@mininet-vm:/home/mininet#
```

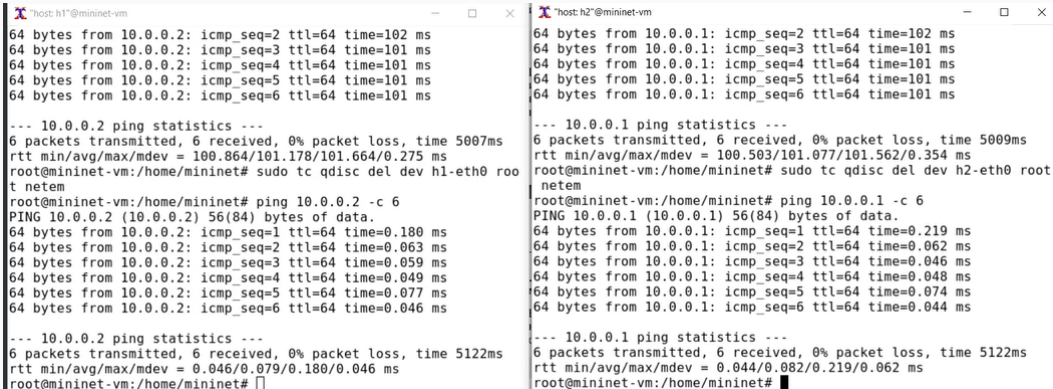
```
host: h2@mininet-vm
64 bytes from 10.0.0.1: icmp_seq=5 ttl=64 time=201 ms
64 bytes from 10.0.0.1: icmp_seq=6 ttl=64 time=201 ms

--- 10.0.0.1 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5007ms
rtt min/avg/max/mdev = 200.452/201.266/202.038/0.618 ms
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h2-eth0 root
netem delay 50ms
Error: Exclusivity flag on, cannot modify.
root@mininet-vm:/home/mininet# sudo tc qdisc change dev h2-eth0 r
oot netem delay 50ms
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=101 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=102 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=101 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=101 ms
64 bytes from 10.0.0.1: icmp_seq=5 ttl=64 time=101 ms
64 bytes from 10.0.0.1: icmp_seq=6 ttl=64 time=101 ms

--- 10.0.0.1 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5009ms
rtt min/avg/max/mdev = 100.503/101.077/101.562/0.354 ms
root@mininet-vm:/home/mininet#
```

Рис. 3: Изменяем задержку

Восстановление исходных значений (удаление правил) задержки в эмулируемой глобальной сети



```
host: h1@mininet-vm
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=102 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=101 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=101 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=101 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=101 ms

--- 10.0.0.2 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5007ms
rtt min/avg/max/mdev = 100.864/101.178/101.664/0.275 ms
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root
netem
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=0.180 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.063 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.059 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.049 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.077 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.046 ms

--- 10.0.0.2 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5122ms
rtt min/avg/max/mdev = 0.046/0.079/0.180/0.046 ms
root@mininet-vm:/home/mininet#
```

```
host: h2@mininet-vm
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=102 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=101 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=101 ms
64 bytes from 10.0.0.1: icmp_seq=5 ttl=64 time=101 ms
64 bytes from 10.0.0.1: icmp_seq=6 ttl=64 time=101 ms

--- 10.0.0.1 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5009ms
rtt min/avg/max/mdev = 100.503/101.077/101.562/0.354 ms
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h2-eth0 root
netem
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=0.219 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=0.062 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=0.046 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=0.048 ms
64 bytes from 10.0.0.1: icmp_seq=5 ttl=64 time=0.074 ms
64 bytes from 10.0.0.1: icmp_seq=6 ttl=64 time=0.044 ms

--- 10.0.0.1 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5122ms
rtt min/avg/max/mdev = 0.044/0.082/0.219/0.062 ms
root@mininet-vm:/home/mininet#
```

Рис. 4: Восстанавливаем конфигурацию

Добавление значения дрожания задержки в интерфейс подключения к эмулируемой глобальной сети

```
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root
netem delay 100ms 10ms
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=104 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=103 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=92.0 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=92.7 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=108 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=109 ms
```

Рис. 5: Добавление значения дрожания задержки

Добавление значения корреляции для джиттера и задержки в интерфейс подключения к эмулируемой глобальной сети

```
t netem
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root
t netem delay 100ms 10ms 25%
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=94.5 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=93.7 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=102 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=105 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=98.6 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=107 ms
```

Рис. 6: Добавление значения корреляции для джиттера и задержки

```
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root netem delay 100ms 20ms distribution normal
root@mininet-vm:/home/mininet# ping 10.0.0.2 -c 10
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=91.8 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=82.9 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=79.7 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=105 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=122 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=108 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=84.4 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=130 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=122 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=115 ms

--- 10.0.0.2 ping statistics ---
10 packets transmitted, 10 received, 0% packet loss, time 9015ms
rtt min/avg/max/mdev = 79.729/104.064/129.859/17.341 ms
root@mininet-vm:/home/mininet# ping 10.0.0.2 -c 6
```

```
Processing triggers for sgml-base (1.29.1) ...  
mininet@mininet-vm:~$ mkdir -p ~/work/lab_netem_i/simple delay  
mininet@mininet-vm:~$ mkdir -p ~/work/lab_netem_i/simple-delay  
mininet@mininet-vm:~$ mkdir -p ~/work/lab_netem_i/change-delay  
mininet@mininet-vm:~$ mkdir -p ~/work/lab_netem_i/jitter-delay  
mininet@mininet-vm:~$ mkdir -p ~/work/lab_netem_i/correlation-delay  
mininet@mininet-vm:~$
```

Рис. 8: Создаем репозитории

Добавление задержки для интерфейса, подключающегося к эмулируемой глобальной сети

```
mininet@mininet-vm: ~/work/lab_netem_i/simple-delay
/home/mininet@mininet-vm:~/work/lab_netem_i/simple-delay$ python /home/mininet@mininet-vm:~/work/lab_netem_i/simple-delay
#!/usr/bin/env python

"""
Simple experiment.
Output: ping.dat
"""

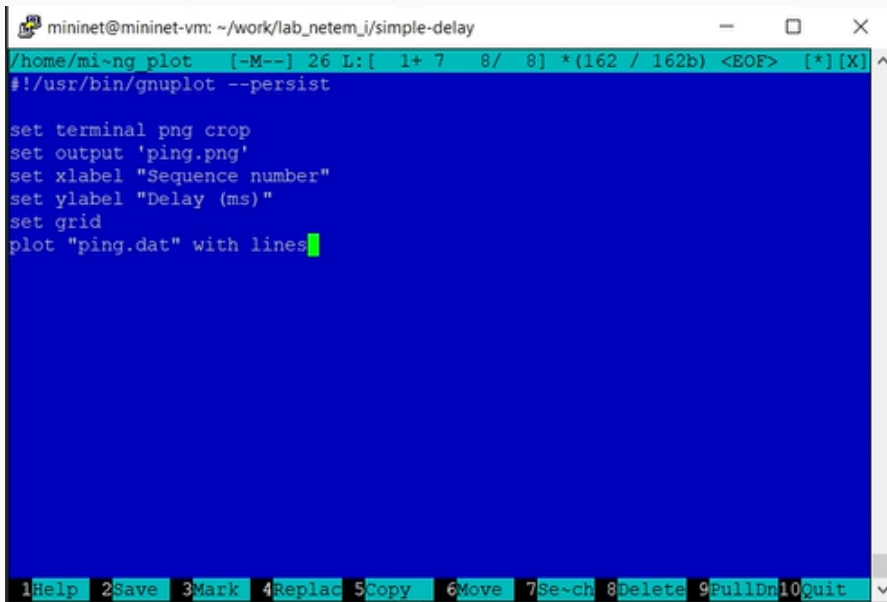
from mininet.net import Mininet
from mininet.node import Controller
from mininet.cli import CLI
from mininet.log import setLogLevel, info
import time

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 =
```

Добавление задержки для интерфейса, подключающегося к эмулируемой глобальной сети



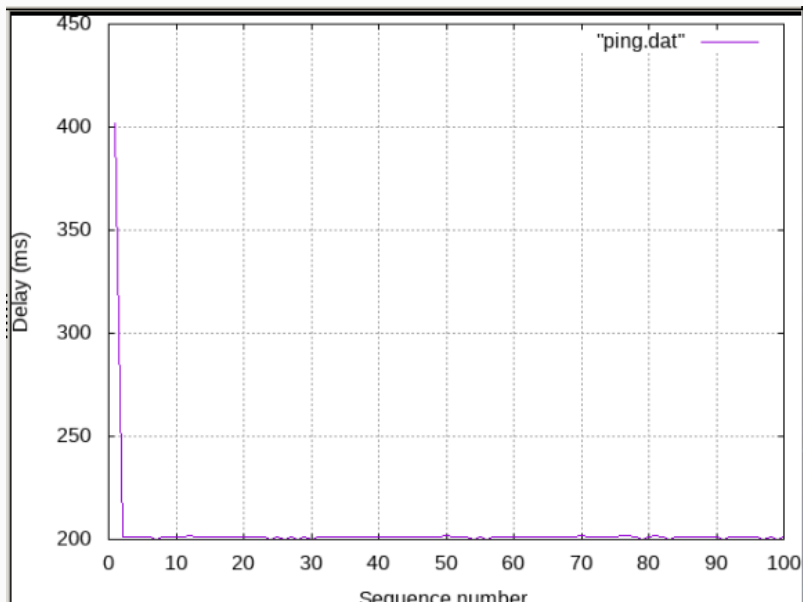
The screenshot shows a terminal window with a blue background. The title bar reads "mininet@mininet-vm: ~/work/lab_netem_i/simple-delay". The terminal content shows the execution of the "gnuplot" command, which has entered its interactive mode. The first line of the prompt is "/home/mi~ng plot [-M--] 26 L:[1+ 7 8/ 8] *(162 / 162b) <EOF> [*] [X] ^". The subsequent lines are configuration commands for the plot: "set terminal png crop", "set output 'ping.png'", "set xlabel 'Sequence number'", "set ylabel 'Delay (ms)'", "set grid", and "plot 'ping.dat' with lines". The cursor is positioned at the end of the last line. At the bottom of the terminal, there is a status bar with a menu of shortcuts: "1Help 2Save 3Mark 4Replac 5Copy 6Move 7Se~ch 8Delete 9PullDn10Quit".

```
mininet@mininet-vm: ~/work/lab_netem_i/simple-delay
/home/mi~ng plot [-M--] 26 L:[ 1+ 7 8/ 8] *(162 / 162b) <EOF> [*] [X] ^
#!/usr/bin/gnuplot --persist

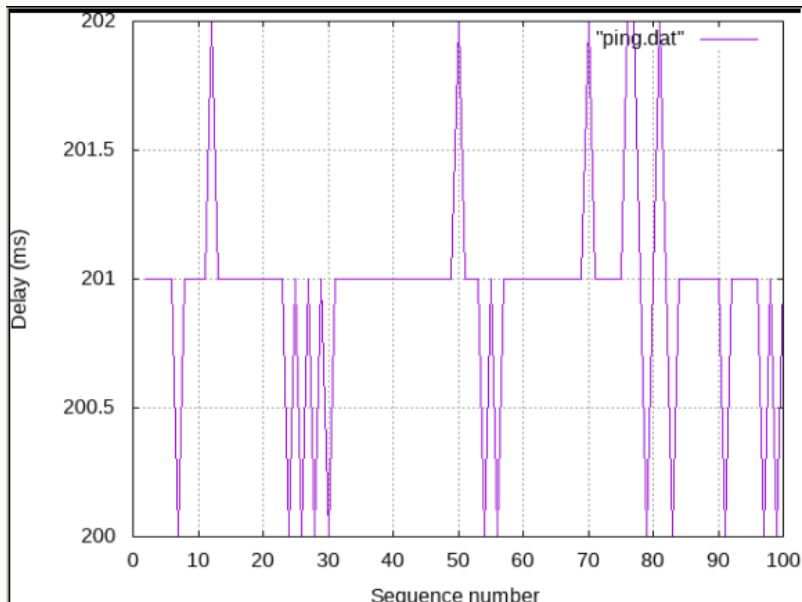
set terminal png crop
set output 'ping.png'
set xlabel "Sequence number"
set ylabel "Delay (ms)"
set grid
plot "ping.dat" with lines
```

1Help 2Save 3Mark 4Replac 5Copy 6Move 7Se~ch 8Delete 9PullDn10Quit

Добавление задержки для интерфейса, подключающегося к эмулируемой глобальной сети



Добавление задержки для интерфейса, подключающегося к эмулируемой глобальной сети



Задание для самостоятельной работы

Эксперимент по изменению задержки

```
mininet@mininet-vm: ~/work/lab_netem_i/change-delay
/home/mininet@mininet-vm:~/work/lab_netem_i/change-delay$ python i.py [B---] 0 L: [ 5+33 38/ 51] *(767 /1199b) 32 0x020 [*][X] ^
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 delay 50ms')
    h2.cmdPrint('tc qdisc add dev h2-eth0 root netem delay 50ms')

    time.sleep(10)

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

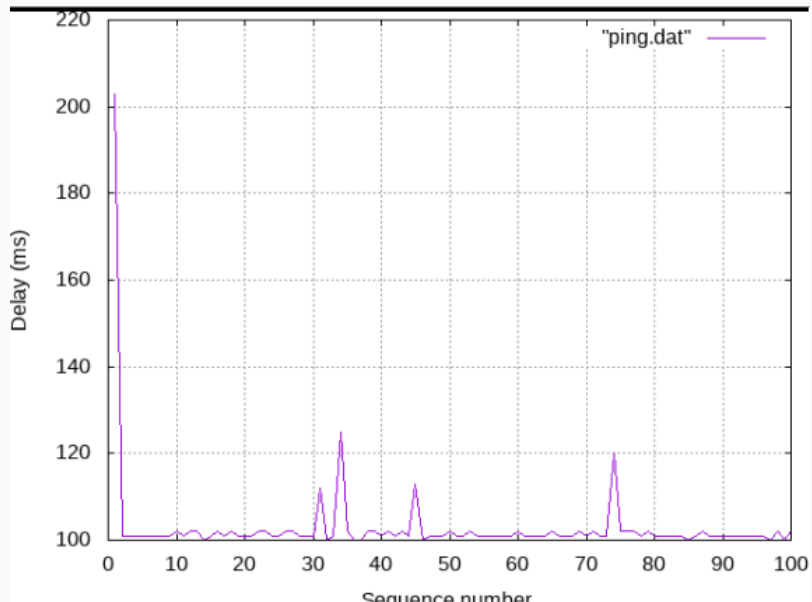
    info('*** Stopping network')
    net.stop()

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

Эксперимент по изменению задержки

```
mininet@mininet-vm: ~/work/lab_netem_i/change-delay
mininet@mininet-vm:~/work/lab_netem_i/change-delay$ make clean
rm -f *.dat *.png
mininet@mininet-vm:~/work/lab_netem_i/change-delay$ make
sudo python lab_netem_i.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 50ms',)
*** h2 : ('tc qdisc add dev h2-eth0 root netem delay 50ms',)
*** Ping
*** h1 : ('ping -c 100', '10.0.0.2', '| grep "time=" | awk \'{print $5, $7}\\' |
sed -e \'s/time=//g\' -e \'s/icmp_seq=//g\' > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 2 links
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
./ping_plot
mininet@mininet-vm:~/work/lab_netem_i/change-delay$ make stats
python rtt.py
Min time: 100.0 ms
Avg time: 102.87 ms
Max time: 203.0 ms
Std dev: 10.62605759442325 ms
mininet@mininet-vm:~/work/lab_netem_i/change-delay$
```

Эксперимент по изменению задержки



Эксперимент по изменению джиттера

```
mininet@mininet-vm: ~/work/lab_netem_i/jitter-delay
/home/miniem i.py [BM--] 0 L: [ 1+37 38/ 51] *(767 /1206b) 32 0x020 [*][X] ^
#!/usr/bin/env 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 delay 100ms 10ms')
    h2.cmdPrint('tc qdisc add dev h2-eth0 root netem delay 100ms')

    time.sleep(10)

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

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

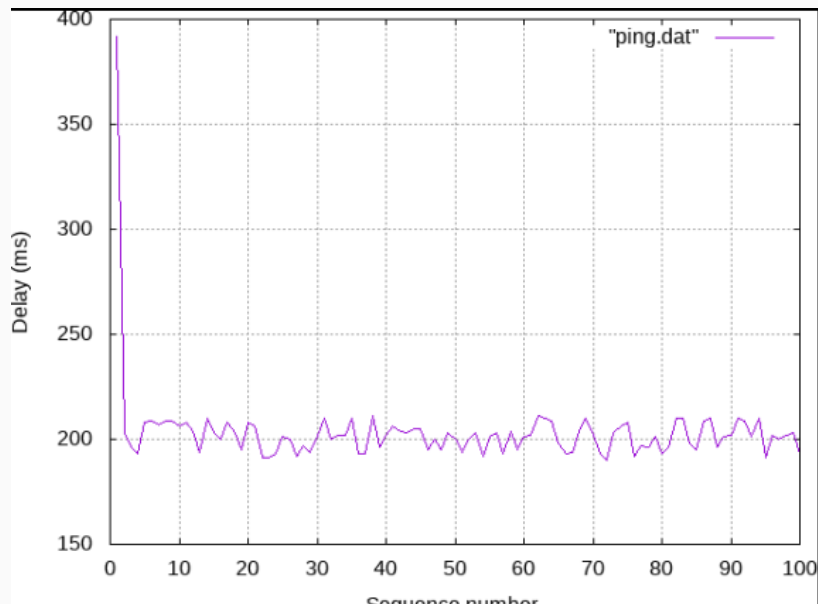
if __name__ == '__main__':
    emptyNet()
```

Эксперимент по изменению джиттера

```
mininet@mininet-vm: ~/work/lab_netem_i/jitter-delay
mininet@mininet-vm:~/work/lab_netem_i/jitter-delay$ make
sudo python lab_netem_i.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 100ms 10ms',)
*** 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, $7}\''
sed -e 's/time=//g\' -e 's/icmp_seq=//g\' > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 2 links
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
./ping_plot
mininet@mininet-vm:~/work/lab_netem_i/jitter-delay$ make stats
python rtt.py
  File "rtt.py", line 16
    data = file.readlines()
                    ^
TabError: inconsistent use of tabs and spaces in indentation
make: *** [Makefile:11: stats] Error 1
mininet@mininet-vm:~/work/lab_netem_i/jitter-delay$ mcedit rtt.py

mininet@mininet-vm:~/work/lab_netem_i/jitter-delay$ make stats
python rtt.py
Min time: 190.0 ms
Avg time: 203.13 ms
Max time: 392.0 ms
Std dev: 19.928198614024296 ms
mininet@mininet-vm:~/work/lab_netem_i/jitter-delay$
```

Эксперимент по изменению джиттера



Эксперимент по изменению значения корреляции для джиттера и задержки

```
mininet@mininet-vm: ~/work/lab_netem_i/correlation-delay
mininet@mininet-vm:~/work/lab_netem_i/correlation-delay$ cp ~/work/lab_netem_i/
jitter-delay/rtt.py rtt.py
mininet@mininet-vm:~/work/lab_netem_i/correlation-delay$ cp ~/work/lab_netem_i/
jitter-delay/Makefile Makefile
mininet@mininet-vm:~/work/lab_netem_i/correlation-delay$ cp ~/work/lab_netem_i/
jitter-delay/ping_plot ping_plot
mininet@mininet-vm:~/work/lab_netem_i/correlation-delay$ ls
lab_netem_i.py  Makefile  ping_plot  rtt.py
mininet@mininet-vm:~/work/lab_netem_i/correlation-delay$ mcredit lab_netem_i.py

mininet@mininet-vm:~/work/lab_netem_i/correlation-delay$ make
sudo python lab_netem_i.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 100ms 10ms 25%,)
*** 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, $7}\''
sed -e 's/time=//g\' -e 's/icmp_seq=//g\' > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 2 links
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
./ping_plot
mininet@mininet-vm:~/work/lab_netem_i/correlation-delay$ make stats
python rtt.py
Min time: 191.0 ms
Avg time: 202.26 ms
Max time: 400.0 ms
Std dev: 20.706337194202167 ms
mininet@mininet-vm:~/work/lab_netem_i/correlation-delay$
```


Эксперимент по изменению значения корреляции для джиттера и задержки

```
mininet@mininet-vm: ~/work/lab_netem_/correlation-delay
/home/mi-em i.py [B---] 0 L:[ 5+33 38/ 51] *(767 /1210b) 32 0x020 [*][X] ^
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 delay 100ms 10ms 25%')
    h2.cmdPrint('tc qdisc add dev h2-eth0 root netem delay 100ms')

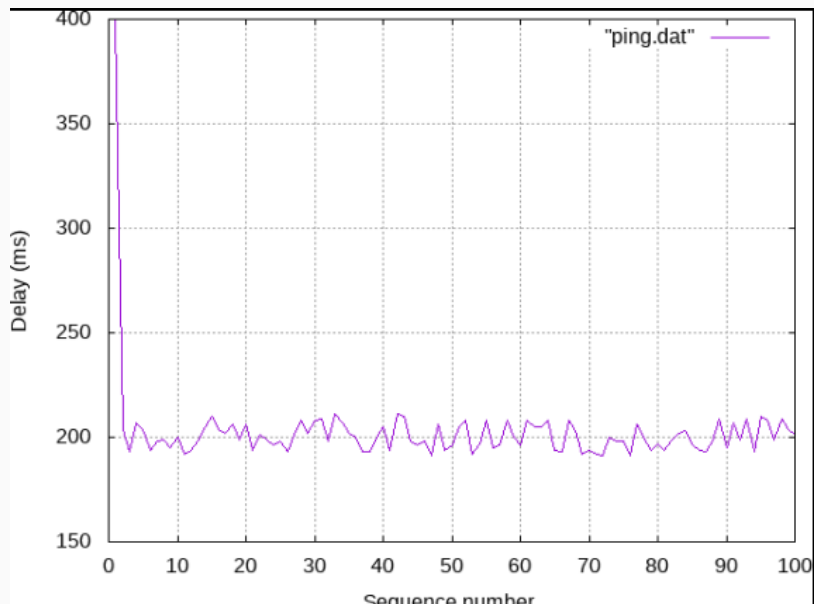
    time.sleep(10)

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

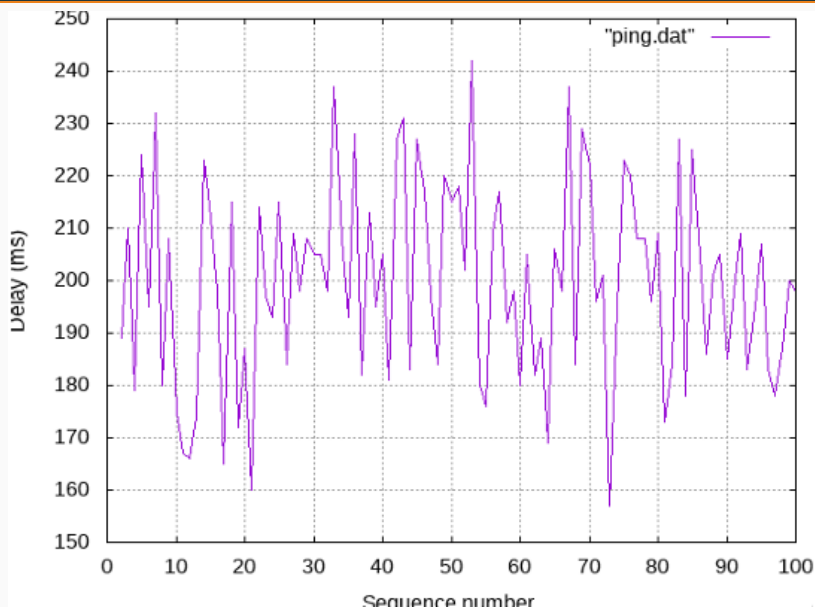
    info('*** Stopping network')
    net.stop()

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

Эксперимент по изменению значения корреляции для джиттера и задержки



Распределения времени задержки в эмулируемой глобальной сети



Выводы

Мы познакомились с NETEM — инструментом для тестирования производительности приложений в виртуальной сети, а также получили навыки проведения интерактивного и воспроизводимого экспериментов по измерению задержки и её дрожания (jitter) в моделируемой сети в среде Mininet.