

به نام خدا

## گزارشکار جلسه اول آزمایشگاه شبکه‌های کامپیوتری: آشنایی با Mininet

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1- در این سوال با استفاده از دستور ping، تعدادی request را ارسال می‌کنیم.

### RTT (Round-Trip Time)

RTT نشان‌دهنده زمان لازم برای ارسال یک بسته داده از یک دستگاه به دستگاه دیگر و دریافت پاسخ از آن دستگاه است. این زمان شامل تاخیر در ارسال داده‌ها، پردازش در مقصد و بازگشت اطلاعات به مبدأ است. RTT معیار مهمی برای ارزیابی عملکرد شبکه است، زیرا تأثیر مستقیم بر تجربه کاربر در هنگام استفاده از خدمات آنلاین دارد. مقادیر پایین‌تر RTT به معنای پاسخگویی سریع‌تر شبکه است.

### TTL (Time-To-Live)

TTL یک مقدار محدودکننده در بسته‌های داده‌ای است که تعیین می‌کند بسته برای چه مدت (یا چند هاپ) در شبکه زنده باقی می‌ماند تا به مقصد برسد. هر زمان که بسته‌ای از یک روتر به روتر دیگر منتقل می‌شود، مقدار TTL آن یک واحد کاهش می‌یابد. اگر TTL به صفر برسد و بسته هنوز به مقصد نرسیده باشد، بسته دور ریخته می‌شود. این مکانیزم جلوی حلقه‌های بی‌پایان در شبکه را می‌گیرد و اطمینان می‌دهد که بسته‌های گمشده یا خراب به طور بی‌پایان در شبکه گردش نکنند.

### رابطه بین RTT و TTL

در حالی که RTT و TTL هر دو مربوط به ارسال داده‌ها در شبکه‌ها هستند، آنها جنبه‌های مختلفی را نشان می‌دهند. RTT معیاری برای اندازه‌گیری سرعت و کارایی شبکه است، در حالی که TTL امنیت و قابلیت اطمینان شبکه را توسط جلوگیری از چرخش بی‌پایان بسته‌ها افزایش می‌دهد.

```

bahareh@bahareh:~$ ping www.google.com
PING www.google.com (216.239.38.120) 56(84) bytes of data.
64 bytes from any-in-2678.1e100.net (216.239.38.120): icmp_seq=1 ttl=49 time=305 ms
64 bytes from any-in-2678.1e100.net (216.239.38.120): icmp_seq=2 ttl=49 time=187 ms
64 bytes from any-in-2678.1e100.net (216.239.38.120): icmp_seq=3 ttl=49 time=113 ms
64 bytes from any-in-2678.1e100.net (216.239.38.120): icmp_seq=4 ttl=49 time=132 ms
64 bytes from any-in-2678.1e100.net (216.239.38.120): icmp_seq=5 ttl=49 time=155 ms
64 bytes from any-in-2678.1e100.net (216.239.38.120): icmp_seq=6 ttl=49 time=179 ms
64 bytes from any-in-2678.1e100.net (216.239.38.120): icmp_seq=7 ttl=49 time=109 ms
64 bytes from any-in-2678.1e100.net (216.239.38.120): icmp_seq=8 ttl=49 time=110 ms
64 bytes from any-in-2678.1e100.net (216.239.38.120): icmp_seq=9 ttl=49 time=110 ms
64 bytes from any-in-2678.1e100.net (216.239.38.120): icmp_seq=10 ttl=49 time=113 ms
64 bytes from any-in-2678.1e100.net (216.239.38.120): icmp_seq=11 ttl=49 time=109 ms
64 bytes from any-in-2678.1e100.net (216.239.38.120): icmp_seq=12 ttl=49 time=110 ms
64 bytes from any-in-2678.1e100.net (216.239.38.120): icmp_seq=13 ttl=49 time=109 ms
64 bytes from any-in-2678.1e100.net (216.239.38.120): icmp_seq=14 ttl=49 time=114 ms
64 bytes from any-in-2678.1e100.net (216.239.38.120): icmp_seq=15 ttl=49 time=110 ms
64 bytes from any-in-2678.1e100.net (216.239.38.120): icmp_seq=16 ttl=49 time=111 ms
^C
--- www.google.com ping statistics ---
16 packets transmitted, 16 received, 0% packet loss, time 15787ms
rtt min/avg/max/mdev = 108.794/136.014/304.837/50.219 ms

bahareh@bahareh:~$ ping www.github.com
PING github.com (140.82.121.3) 56(84) bytes of data.
64 bytes from lb-140-82-121-3-fra.github.com (140.82.121.3): icmp_seq=1 ttl=43 time=121 ms
64 bytes from lb-140-82-121-3-fra.github.com (140.82.121.3): icmp_seq=2 ttl=43 time=253 ms
64 bytes from lb-140-82-121-3-fra.github.com (140.82.121.3): icmp_seq=3 ttl=43 time=174 ms
64 bytes from lb-140-82-121-3-fra.github.com (140.82.121.3): icmp_seq=4 ttl=43 time=97.8 ms
64 bytes from lb-140-82-121-3-fra.github.com (140.82.121.3): icmp_seq=5 ttl=43 time=95.4 ms
64 bytes from lb-140-82-121-3-fra.github.com (140.82.121.3): icmp_seq=6 ttl=43 time=98.2 ms
64 bytes from lb-140-82-121-3-fra.github.com (140.82.121.3): icmp_seq=7 ttl=43 time=97.4 ms
64 bytes from lb-140-82-121-3-fra.github.com (140.82.121.3): icmp_seq=8 ttl=43 time=95.3 ms
64 bytes from lb-140-82-121-3-fra.github.com (140.82.121.3): icmp_seq=9 ttl=43 time=95.0 ms
64 bytes from lb-140-82-121-3-fra.github.com (140.82.121.3): icmp_seq=10 ttl=43 time=94.4 ms
64 bytes from lb-140-82-121-3-fra.github.com (140.82.121.3): icmp_seq=11 ttl=43 time=94.7 ms
^C
--- github.com ping statistics ---
11 packets transmitted, 11 received, 0% packet loss, time 15626ms
rtt min/avg/max/mdev = 94.435/119.652/252.567/47.807 ms
bahareh@bahareh:~$

bahareh@bahareh:~$ ping www.quera.org
PING www.quera.org (185.143.233.61) 56(84) bytes of data.
64 bytes from 185.143.233.61 (185.143.233.61): icmp_seq=1 ttl=50 time=102 ms
64 bytes from 185.143.233.61 (185.143.233.61): icmp_seq=2 ttl=50 time=9.03 ms
64 bytes from 185.143.233.61 (185.143.233.61): icmp_seq=3 ttl=50 time=7.43 ms
64 bytes from 185.143.233.61 (185.143.233.61): icmp_seq=4 ttl=50 time=48.9 ms
64 bytes from 185.143.233.61 (185.143.233.61): icmp_seq=5 ttl=50 time=6.94 ms
64 bytes from 185.143.233.61 (185.143.233.61): icmp_seq=6 ttl=50 time=12.0 ms
64 bytes from 185.143.233.61 (185.143.233.61): icmp_seq=7 ttl=50 time=7.63 ms
64 bytes from 185.143.233.61 (185.143.233.61): icmp_seq=8 ttl=50 time=11.8 ms
64 bytes from 185.143.233.61 (185.143.233.61): icmp_seq=9 ttl=50 time=7.53 ms
64 bytes from 185.143.233.61 (185.143.233.61): icmp_seq=10 ttl=50 time=8.10 ms
64 bytes from 185.143.233.61 (185.143.233.61): icmp_seq=11 ttl=50 time=11.5 ms
^C64 bytes from 185.143.233.61: icmp_seq=12 ttl=50 time=7.25 ms

--- www.quera.org ping statistics ---
12 packets transmitted, 12 received, 0% packet loss, time 17716ms
rtt min/avg/max/mdev = 6.938/19.983/101.762/27.054 ms
bahareh@bahareh:~$

```

```

bahareh@bahareh:~$ ping -c 5 www.iust.ac.ir
PING www.iust.ac.ir (194.225.230.88) 56(84) bytes of data.
64 bytes from www.iust.ac.ir (194.225.230.88): icmp_seq=1 ttl=60 time=5.09 ms
64 bytes from www.iust.ac.ir (194.225.230.88): icmp_seq=2 ttl=60 time=11.8 ms
64 bytes from www.iust.ac.ir (194.225.230.88): icmp_seq=3 ttl=60 time=7.79 ms
64 bytes from www.iust.ac.ir (194.225.230.88): icmp_seq=4 ttl=60 time=10.1 ms
64 bytes from www.iust.ac.ir (194.225.230.88): icmp_seq=5 ttl=60 time=3.66 ms

--- www.iust.ac.ir ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4007ms
rtt min/avg/max/mdev = 3.658/7.686/11.796/3.022 ms
bahareh@bahareh:~$ ping -c 5 www.stackoverflow.com
PING www.stackoverflow.com (104.18.32.7) 56(84) bytes of data.
64 bytes from 104.18.32.7 (104.18.32.7): icmp_seq=1 ttl=47 time=267 ms
64 bytes from 104.18.32.7 (104.18.32.7): icmp_seq=2 ttl=47 time=384 ms
64 bytes from 104.18.32.7: icmp_seq=3 ttl=47 time=103 ms
64 bytes from 104.18.32.7 (104.18.32.7): icmp_seq=4 ttl=47 time=103 ms
64 bytes from 104.18.32.7: icmp_seq=5 ttl=47 time=169 ms

--- www.stackoverflow.com ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 19754ms
rtt min/avg/max/mdev = 103.017/205.330/383.946/107.561 ms
bahareh@bahareh:~$

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- در مرحله اول ip خود را با دستور ipconfig پیدا می کنیم.
- با دستور ping -c 5 [ip]، 5 بسته را پشت سر هم ارسال می کنیم.
- در برنامه Wireshark پنل any را باز می کنیم و فیلتر icmp را اعمال می کنیم (زیرا ارتباط بین این دو دستگاه از نوع icmp می باشد) و capture کردن را آغاز می کنیم.

ارسال بسته از host به VM:

The image shows a network packet capture in Wireshark and a terminal window. The Wireshark capture shows ICMP Echo (ping) requests and replies between 192.168.64.1 and 192.168.64.2. The terminal window shows the output of a ping command from a host to a VM.

| No. | Time        | Source       | Destination  | Protocol | Length | Info                |
|-----|-------------|--------------|--------------|----------|--------|---------------------|
| 1   | 0.000000000 | 192.168.64.1 | 192.168.64.2 | ICMP     | 100    | Echo (ping) request |
| 3   | 0.000250792 | 192.168.64.2 | 192.168.64.1 | ICMP     | 100    | Echo (ping) reply   |
| 5   | 1.005282583 | 192.168.64.1 | 192.168.64.2 | ICMP     | 100    | Echo (ping) request |
| 6   | 1.005395417 | 192.168.64.2 | 192.168.64.1 | ICMP     | 100    | Echo (ping) reply   |
| 7   | 2.010387083 | 192.168.64.1 | 192.168.64.2 | ICMP     | 100    | Echo (ping) request |
| 8   | 2.010485833 | 192.168.64.2 | 192.168.64.1 | ICMP     | 100    | Echo (ping) reply   |
| 9   | 3.015247707 | 192.168.64.1 | 192.168.64.2 | ICMP     | 100    | Echo (ping) request |
| 10  | 3.015368248 | 192.168.64.2 | 192.168.64.1 | ICMP     | 100    | Echo (ping) reply   |
| 11  | 4.018014163 | 192.168.64.1 | 192.168.64.2 | ICMP     | 100    | Echo (ping) request |
| 12  | 4.018123455 | 192.168.64.2 | 192.168.64.1 | ICMP     | 100    | Echo (ping) reply   |

```

shakibaanarakifirooz@shakibas-MacBook-Pro:~
➔ ~ ping 192.168.64.2
PING 192.168.64.2 (192.168.64.2): 56 data bytes
64 bytes from 192.168.64.2: icmp_seq=0 ttl=64 time=1.595 ms
64 bytes from 192.168.64.2: icmp_seq=1 ttl=64 time=0.759 ms
64 bytes from 192.168.64.2: icmp_seq=2 ttl=64 time=0.986 ms
^C
--- 192.168.64.2 ping statistics ---
3 packets transmitted, 3 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 0.759/1.113/1.595/0.353 ms
➔ ~ ping -c 5 192.168.64.2
PING 192.168.64.2 (192.168.64.2): 56 data bytes
64 bytes from 192.168.64.2: icmp_seq=0 ttl=64 time=1.179 ms
64 bytes from 192.168.64.2: icmp_seq=1 ttl=64 time=1.206 ms
64 bytes from 192.168.64.2: icmp_seq=2 ttl=64 time=1.026 ms
64 bytes from 192.168.64.2: icmp_seq=3 ttl=64 time=1.236 ms
64 bytes from 192.168.64.2: icmp_seq=4 ttl=64 time=0.975 ms
--- 192.168.64.2 ping statistics ---
5 packets transmitted, 5 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 0.975/1.124/1.236/0.104 ms
➔ ~
  
```

ارسال بسته از VM به Host:

The image shows a terminal window displaying network configuration for an Ethernet adapter and a Wireshark packet capture. The terminal output shows the configuration for the Ethernet adapter, including the IP address, subnet mask, and default gateway. The Wireshark capture shows ICMP Echo (ping) requests and replies between 192.168.56.1 and 192.168.56.1.

```

bahareh@bahareh:~$ ping -c 5 192.168.56.1
PING 192.168.56.1 (192.168.56.1) 56(84) bytes of data:
64 bytes from 192.168.56.1: icmp_seq=1 ttl=127 time=1.20 ms
64 bytes from 192.168.56.1: icmp_seq=2 ttl=127 time=0.785 ms
64 bytes from 192.168.56.1: icmp_seq=3 ttl=127 time=1.12 ms
64 bytes from 192.168.56.1: icmp_seq=4 ttl=127 time=1.39 ms
64 bytes from 192.168.56.1: icmp_seq=5 ttl=127 time=0.803 ms
--- 192.168.56.1 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4019ms
rtt min/avg/max/mdev = 0.785/1.058/1.390/0.233 ms
bahareh@bahareh:~$
  
```

```

Select Command Prompt
Ethernet adapter Ethernet:
Media State . . . . . : Media disconnected
Connection-specific DNS Suffix . :
Ethernet adapter Ethernet 2:
Connection-specific DNS Suffix . :
Link-local IPv6 Address . . . . . : fe80::2e1-bd7:3460:7a16%5
IPv4 Address. . . . . : 192.168.56.1
Subnet Mask . . . . . : 255.255.255.0
Default Gateway . . . . . :
Wireless LAN adapter Local Area Connection* 1:
Media State . . . . . : Media disconnected
Connection-specific DNS Suffix . :
Wireless LAN adapter Local Area Connection* 10:
Media State . . . . . : Media disconnected
Connection-specific DNS Suffix . :
Wireless LAN adapter Wi-Fi:
Connection-specific DNS Suffix . :
IPv6 Address. . . . . : 2001:14e8:4:308:66e5:d6f0:ef73:31b0
Temporary IPv6 Address. . . . . : 2001:14e8:4:308:9170:aa5:44ff:e33b
Link-local IPv6 Address . . . . . : fe80:b822:688d:c3ab:25a4%13
IPv4 Address. . . . . : 172.17.0.103
  
```

| No. | Time        | Source       | Destination  | Protocol | Length | Info                     |
|-----|-------------|--------------|--------------|----------|--------|--------------------------|
| 1   | 0.000000000 | 192.168.56.1 | 192.168.56.1 | ICMP     | 100    | Echo (ping) request id 0 |
| 2   | 0.000250792 | 192.168.56.1 | 192.168.56.1 | ICMP     | 100    | Echo (ping) reply id 0   |
| 3   | 1.005282583 | 192.168.56.1 | 192.168.56.1 | ICMP     | 100    | Echo (ping) request id 1 |
| 4   | 1.005395417 | 192.168.56.1 | 192.168.56.1 | ICMP     | 100    | Echo (ping) reply id 1   |
| 5   | 2.010387083 | 192.168.56.1 | 192.168.56.1 | ICMP     | 100    | Echo (ping) request id 2 |
| 6   | 2.010485833 | 192.168.56.1 | 192.168.56.1 | ICMP     | 100    | Echo (ping) reply id 2   |
| 7   | 3.015247707 | 192.168.56.1 | 192.168.56.1 | ICMP     | 100    | Echo (ping) request id 3 |
| 8   | 3.015368248 | 192.168.56.1 | 192.168.56.1 | ICMP     | 100    | Echo (ping) reply id 3   |
| 9   | 4.018014163 | 192.168.56.1 | 192.168.56.1 | ICMP     | 100    | Echo (ping) request id 4 |
| 10  | 4.018123455 | 192.168.56.1 | 192.168.56.1 | ICMP     | 100    | Echo (ping) reply id 4   |

```

bahareh@bahareh:~$ sudo mn --topo single,2 --switch ovsk --controller ref
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(h1, s1) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ...
*** Starting CLI:
mininet> net
h1 h1-eth0:s1-eth1
h2 h2-eth0:s1-eth2
s1 lo: s1-eth1:h1-eth0 s1-eth2:h2-eth0
c0
mininet>

```

```

bahareh@bahareh:~$ sudo mn --topo linear,2,2
*** Creating network
*** Adding controller
*** Adding hosts:
h1s1 h1s2 h2s1 h2s2
*** Adding switches:
s1 s2
*** Adding links:
(h1s1, s1) (h1s2, s2) (h2s1, s1) (h2s2, s2) (s2, s1)
*** Configuring hosts
h1s1 h1s2 h2s1 h2s2
*** Starting controller
c0
*** Starting 2 switches
s1 s2 ...
*** Starting CLI:
mininet> net
h1s1 h1s1-eth0:s1-eth1
h1s2 h1s2-eth0:s2-eth1
h2s1 h2s1-eth0:s1-eth2
h2s2 h2s2-eth0:s2-eth2
s1 lo: s1-eth1:h1s1-eth0 s1-eth2:h2s1-eth0 s1-eth3:s2-eth3
s2 lo: s2-eth1:h1s2-eth0 s2-eth2:h2s2-eth0 s2-eth3:s1-eth3
c0
mininet>

```



```

bahareh@bahareh:~$ sudo mn --topo tree,depth=2,fanout=3
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2 h3 h4 h5 h6 h7 h8 h9
*** Adding switches:
s1 s2 s3 s4
*** Adding links:
(s1, s2) (s1, s3) (s1, s4) (s2, h1) (s2, h2) (s2, h3) (s3, h4) (s3, h5) (s3, h6) (s4, h7) (s4, h8) (s4, h9)
*** Configuring hosts
h1 h2 h3 h4 h5 h6 h7 h8 h9
*** Starting controller
c0
*** Starting 4 switches
s1 s2 s3 s4 ...
*** Starting CLI:
mininet> net
h1 h1-eth0:s2-eth1
h2 h2-eth0:s2-eth2
h3 h3-eth0:s2-eth3
h4 h4-eth0:s3-eth1
h5 h5-eth0:s3-eth2
h6 h6-eth0:s3-eth3
h7 h7-eth0:s4-eth1
h8 h8-eth0:s4-eth2
h9 h9-eth0:s4-eth3
s1 lo: s1-eth1:s2-eth4 s1-eth2:s3-eth4 s1-eth3:s4-eth4
s2 lo: s2-eth1:h1-eth0 s2-eth2:h2-eth0 s2-eth3:h3-eth0 s2-eth4:s1-eth1
s3 lo: s3-eth1:h4-eth0 s3-eth2:h5-eth0 s3-eth3:h6-eth0 s3-eth4:s1-eth2
s4 lo: s4-eth1:h7-eth0 s4-eth2:h8-eth0 s4-eth3:h9-eth0 s4-eth4:s1-eth3
c0
mininet>

```

#### 4- الف) پهنای باند ثابت (100Mbps):

هنگامی که پهنای باند ثابت است، تفاوت چندانی در ستون Measured Bandwidth مشاهده نمی‌شود (به جز سطر آخر). اما در مورد RTT می‌توان گفت که دارای یک رابطه مستقیم با Delay است و با افزایش تاخیر مقدار RTT نیز افزایش می‌یابد.

| Delay (ms) | RTT(ms)   | Measured Bandwidth |
|------------|---|--------------------|
| 0.01       | min/avg/max/mdev = 0.150/0.636/3.050/0.833          | 89.0 Mbits/sec     |
| 0.05       | min/avg/max/mdev = 0.150/0.582/3.415/0.950          | 91.1 Mbits/sec     |
| 0.1        | min/avg/max/mdev = 0.181/3.354/31.218/9.288         | 87.0 Mbits/sec     |
| 0.5        | min/avg/max/mdev = 0.596/3.658/15.515/5.439         | 90.8 Mbits/sec     |
| 1.0        | min/avg/max/mdev = 1.125/5.081/39.004/11.309        | 88.6 Mbits/sec     |
| 5.0        | min/avg/max/mdev = 5.122/11.633/66.573/18.315       | 91.2 Mbits/sec     |
| 10.0       | min/avg/max/mdev = 10.181/14.415/44.906/10.229      | 91.1 Mbits/sec     |
| 50.0       | min/avg/max/mdev = 50.174/56.111/105.272/16.390     | 89.5 Mbits/sec     |
| 100.0      | min/avg/max/mdev = 100.094/111.342/210.858/33.172   | 80.4 Mbits/sec     |
| 500.0      | min/avg/max/mdev = 500.126/551.358/1009.572/152.738 | 7.92 Mbits/sec     |

تصویر یک نمونه اجرا:

```
bahareh@bahareh:~$ sudo mn --topo single,2 --link tc,bw=100
[sudo] password for bahareh:
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(100.00Mbit) *** Error: Warning: sch_htb: quantum of class 50001 is big. Consider r2q change.
(100.00Mbit) *** Error: Warning: sch_htb: quantum of class 50001 is big. Consider r2q change.
(h1, s1) (100.00Mbit) *** Error: Warning: sch_htb: quantum of class 50001 is big. Consider r2q change.
(100.00Mbit) *** Error: Warning: sch_htb: quantum of class 50001 is big. Consider r2q change.
(h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ... (100.00Mbit) *** Error: Warning: sch_htb: quantum of class 50001 is big. Consider r2q change.
(100.00Mbit) *** Error: Warning: sch_htb: quantum of class 50001 is big. Consider r2q change.

*** Starting CLI:
mininet> h1 tc qdisc add dev h1-eth0 root netem delay 0.01ms
mininet> h1 ping -c 10 h2
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=3.05 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.479 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.223 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.150 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.153 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.173 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=0.758 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=0.314 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=0.301 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=0.761 ms

--- 10.0.0.2 ping statistics ---
10 packets transmitted, 10 received, 0% packet loss, time 9198ms
rtt min/avg/max/mdev = 0.150/0.636/3.050/0.833 ms
mininet> h2 iperf -s &
mininet> h1 iperf -c h2 -t 10
-----
Client connecting to 10.0.0.2, TCP port 5001
TCP window size: 85.3 KByte (default)
-----
[ 1] local 10.0.0.1 port 42974 connected with 10.0.0.2 port 5001
[ ID] Interval      Transfer      Bandwidth
```



ب) تاخیر ثابت (1ms):

با افزایش پهنای باند، مقدار Measured Bandwidth افزایش می‌یابد و مقدار میانگین RTT کاهش می‌یابد.

چند تصویر از مراحل انجام شده:

```
shakiba@shakiba-server:~$ sudo mn --topo single,2 --link tc,bw=0.01,delay=1ms
*** No default OpenFlow controller found for default switch!
*** Falling back to OVS Bridge
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(0.01Mbit 1ms delay) (0.01Mbit 1ms delay) (h1, s1) (0.01Mbit 1ms delay) (0.01Mbit 1ms d
elay) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller

*** Starting 1 switches
s1 ...(0.01Mbit 1ms delay) (0.01Mbit 1ms delay)
*** Starting CLI:
mininet> h1 ping -c h2
ping: invalid argument: '10.0.0.2'
mininet> h1 ping -c 2 h2
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=9.05 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=4.46 ms

--- 10.0.0.2 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1001ms
rtt min/avg/max/mdev = 4.458/6.753/9.049/2.295 ms
mininet> h2 iperf -s &
mininet> h1 iperf -c h2 -t 5

-----
Client connecting to 10.0.0.2, TCP port 5001
TCP window size: 85.3 KByte (default)
-----
[ 1] local 10.0.0.1 port 41624 connected with 10.0.0.2 port 5001
[ ID] Interval      Transfer    Bandwidth
[ 1] 0.0000-10.2884 sec   140 KBytes  112 Kbits/sec
mininet> █
```

```

shakiba@shakiba-server:~$ sudo mn --topo single,2 --link tc,bw=0.05,delay=1ms
*** No default OpenFlow controller found for default switch!
*** Falling back to OVS Bridge
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(0.05Mbit 1ms delay) (0.05Mbit 1ms delay) (h1, s1) (0.05Mbit 1ms delay) (0.05Mbit 1ms delay) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller

*** Starting 1 switches
s1 ... (0.05Mbit 1ms delay) (0.05Mbit 1ms delay)
*** Starting CLI:
mininet> h1 ping -c 2 h2
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=9.25 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=4.26 ms

--- 10.0.0.2 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1003ms
rtt min/avg/max/mdev = 4.257/6.755/9.253/2.498 ms
mininet> h2 iperf -s &
mininet> h1 iperf -c h2 -t 5
-----
Client connecting to 10.0.0.2, TCP port 5001
TCP window size: 85.3 KByte (default)
-----
[ 1] local 10.0.0.1 port 37202 connected with 10.0.0.2 port 5001
[ ID] Interval      Transfer    Bandwidth
[ 1] 0.0000-10.3627 sec  246 KBytes  195 Kbits/sec
mininet> █

```

```

shakiba@shakiba-server:~$ sudo mn --topo single,2 --link tc,bw=0.1,delay=1ms
*** No default OpenFlow controller found for default switch!
*** Falling back to OVS Bridge
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(0.10Mbit 1ms delay) (0.10Mbit 1ms delay) (h1, s1) (0.10Mbit 1ms delay) (0.10Mbit 1ms d
elay) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller

*** Starting 1 switches
s1 ...(0.10Mbit 1ms delay) (0.10Mbit 1ms delay)
*** Starting CLI:
mininet> h1 ping -c 2 h2
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=10.1 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=4.33 ms

--- 10.0.0.2 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1001ms
rtt min/avg/max/mdev = 4.334/7.232/10.131/2.898 ms
mininet> h2 iperf -s &
mininet> h1 iperf -c h2 -t 2
-----
Client connecting to 10.0.0.2, TCP port 5001
TCP window size: 85.3 KByte (default)
-----
[ 1] local 10.0.0.1 port 47316 connected with 10.0.0.2 port 5001
[ ID] Interval      Transfer    Bandwidth
[ 1] 0.0000-4.0686 sec  182 KBytes  367 Kbits/sec
mininet>

```

| <b>Bandwidth</b> | <b>RTT<br/>min/avg/max/mdev ms</b> | <b>Measured Bandwidth</b> |
|------------------|------------------------------------|---------------------------|
| <b>0.01</b>      | 4.458/6.753/9.049/2.295            | 112 Kbits/sec             |
| <b>0.05</b>      | 4.257/6.755/9.253/2.498            | 195 Kbits/sec             |
| <b>0.1</b>       | 4.334/7.232/10.131/2.898           | 367 Kbits/sec             |
| <b>0.5</b>       | 4.369/4.394/4.419/0.025            | 935 Kbits/sec             |
| <b>1.0</b>       | 4.342/6.976/9.610/2.634            | 1.17Mbits/sec             |
| <b>5.0</b>       | 4.267/6.505/8.744/2.238            | 4.77Mbits/sec             |
| <b>10.0</b>      | 4.291/4.817/5.343/0.526            | 9.52 Mbits/sec            |
| <b>50.0</b>      | 4.237/6.750/9.264/2.513            | 47.6 Mbits/sec            |
| <b>100.0</b>     | 4.437/7.144/9.851/2.707            | 94.9 Mbits/sec            |
| <b>500.0</b>     | 4.332/6.731/9.130/2.399            | 473 Mbits/sec             |