CS120: Computer Networks

Lecture 2. Bandwidth and Latency

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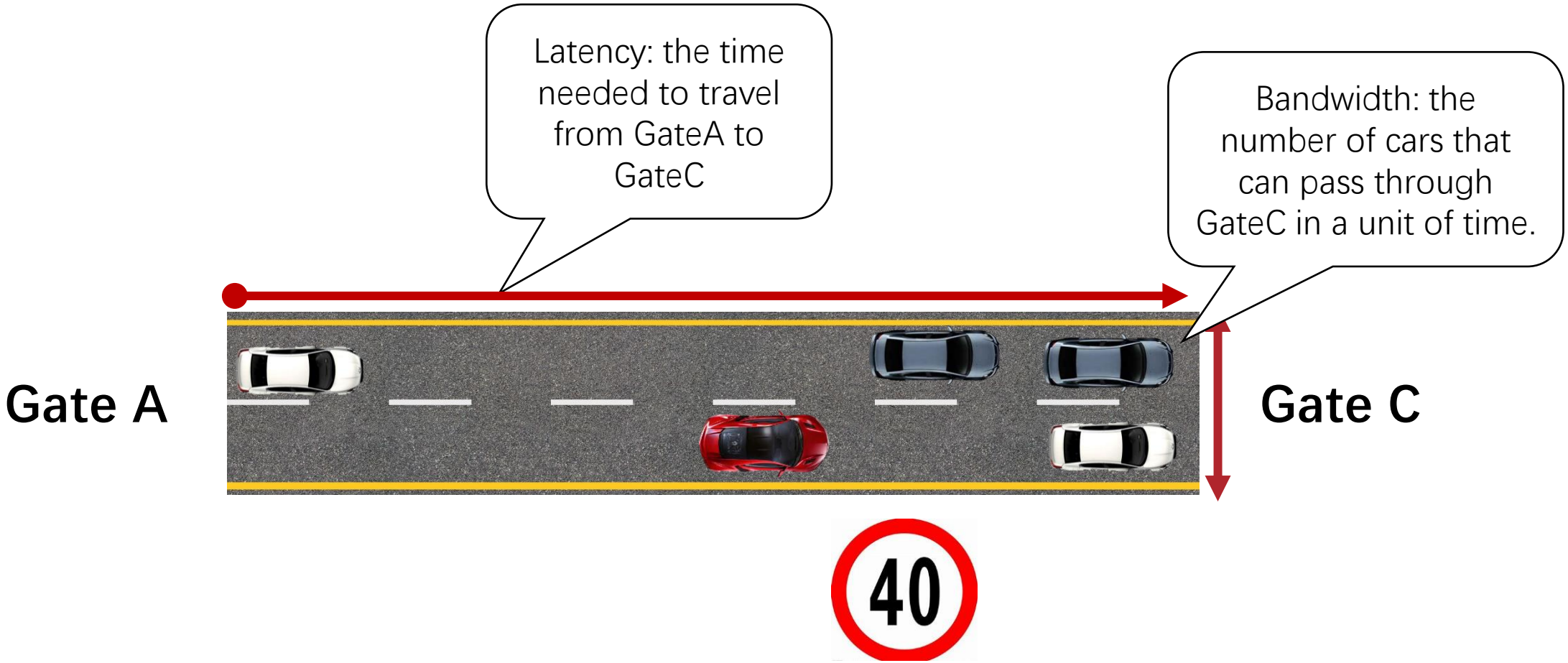
Network Performance

Network Performance

- Metrics
  - Bandwidth (Throughput)
  - Latency (Delay)

Example: Road



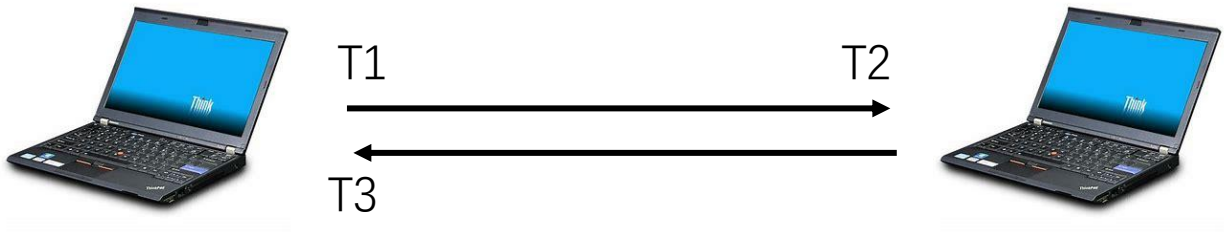
Bandwidth

- The bandwidth of a network is given by the number of bits that can be transmitted over the network in a certain period of time.
  - Unit: bps, kbps (10^3), Mbps (10^6), Gbps (10^9)
  - e.g.: a 100-Mbps Ethernet Link means it takes $\frac{1}{100\times10^6}$ seconds to transmit one bit. But it does not mean the receiver will receive that bit after $\frac{1}{100\times10^6}$ seconds

Latency

- The latency of a network is the time that takes a bit to travel from one end of a network to the other.
  - Unit: second, ms (10^{-3}), us (10^{-6}), ns (10^{-9})
  - Round-Trip Time (RTT)
    - measured with small packets

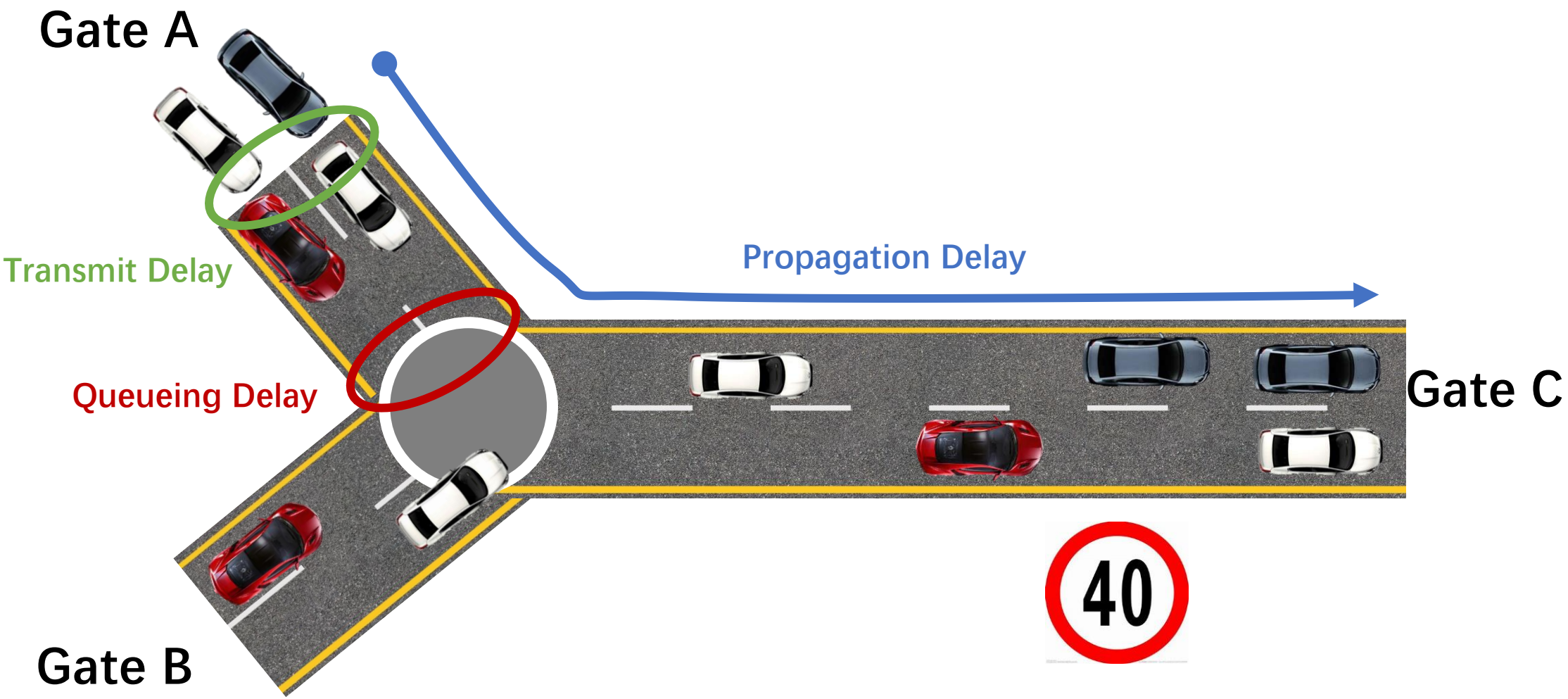
Round-Trip Time = T3 – T1
One-way Latency = T2 – T1 or T3 –T2



Latency

- Decomposing Latency
  - Latency = Transmit Delay + Propagation Delay + Queueing Delay
    - Transmit Delay = TransferSize/Bandwidth
    - Propagation Delay = Distance/SpeedofSignal
  - ➢Latency = TransferSize/Bandwidth + Distance/SpeedofSignal + Queueing Delay

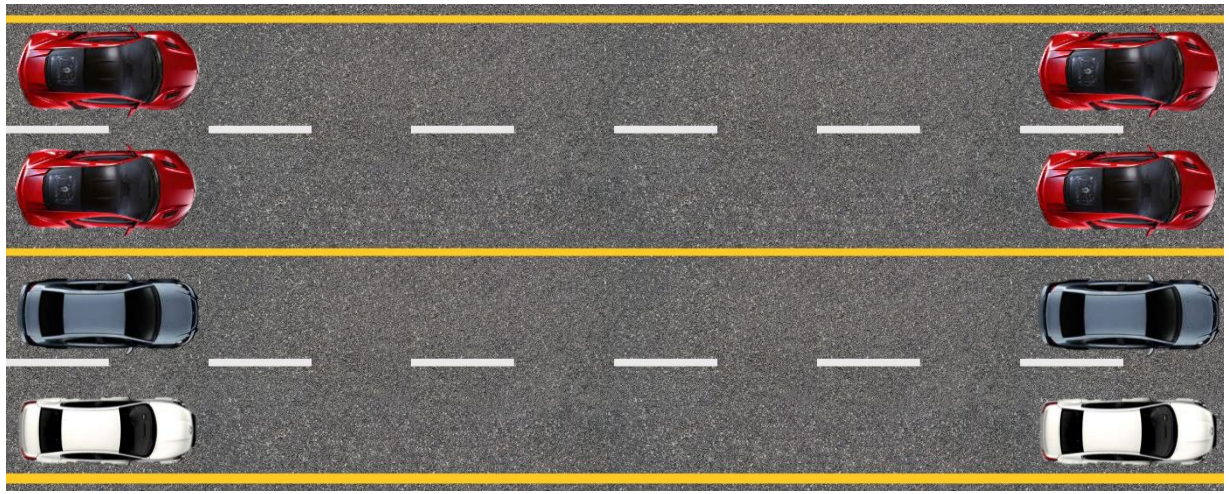
Example: Road



Bandwidth vs. Latency

High Bandwidth, Large Delay

Gate A



Gate C

1TByte/10min

Low Bandwidth, Small Delay

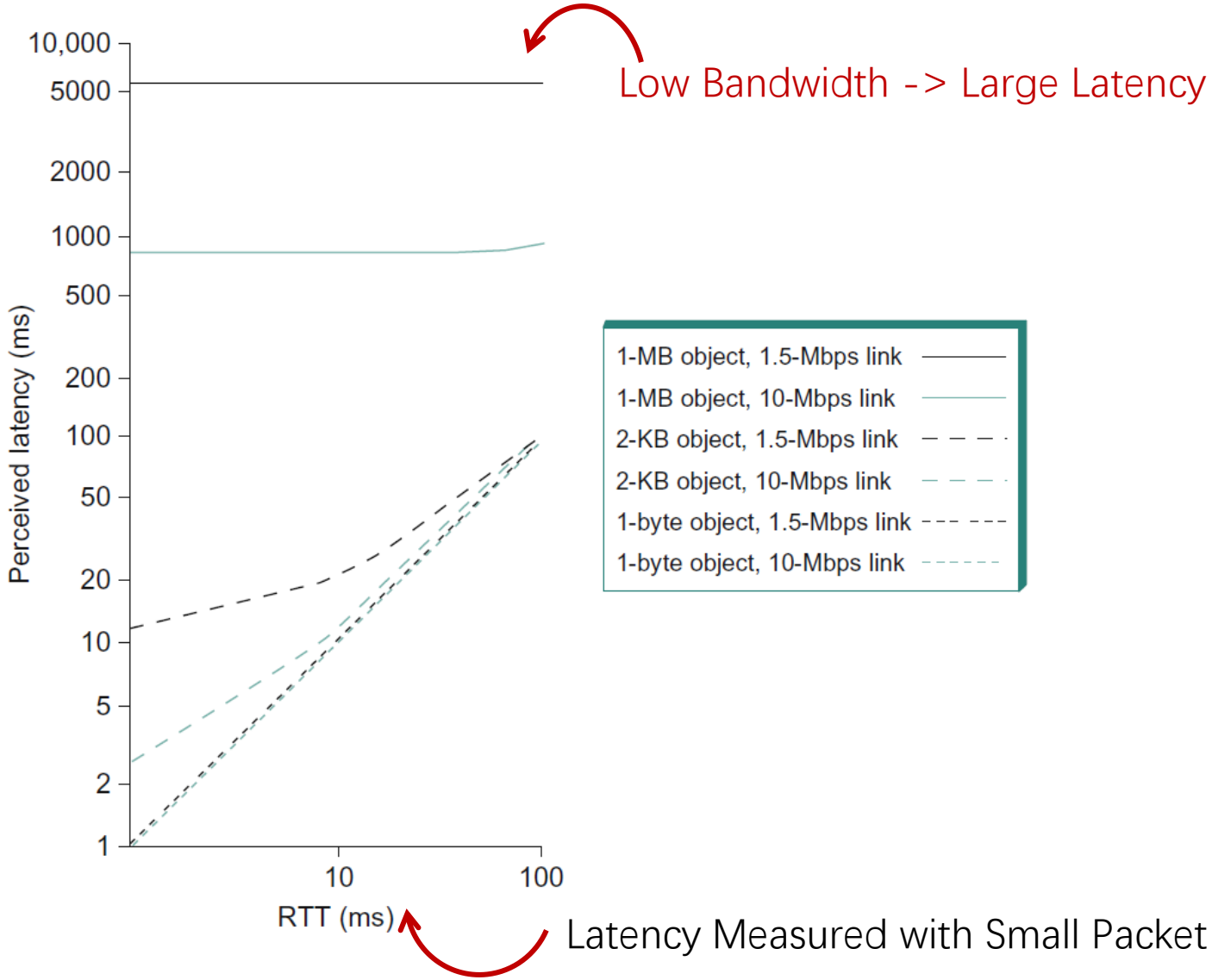
Gate A

Gate C

100bit/10ms

Bandwidth vs. Latency

Latency = TransferSize/Bandwidth + Distance/SpeedofSignal + Queueing Delay



Effective Bandwidth

Latency = TransferSize/Bandwidth + Distance/SpeedofSignal + Queueing Delay

- Effective Bandwidth = TransferSize/Latency
  - Effective bandwidth is also called throughput
  - For large transfer size:
    - Effective Bandwidth -> Bandwidth

- In many situations, bandwidth and throughput are used interchangeably
  - Be careful about the actual meaning

Demo

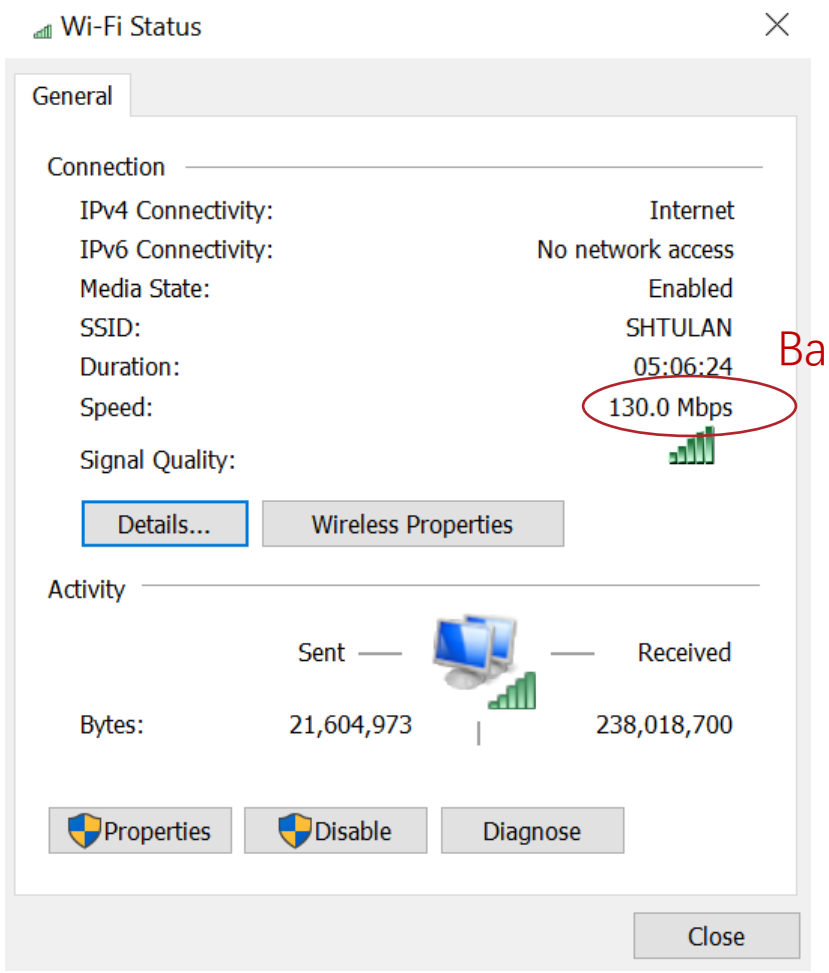
- Throughput measurement
  - iperf
    - https://iperf.fr/iperf-servers.php
- Latency measurement
  - ping
    - RTT

Demo

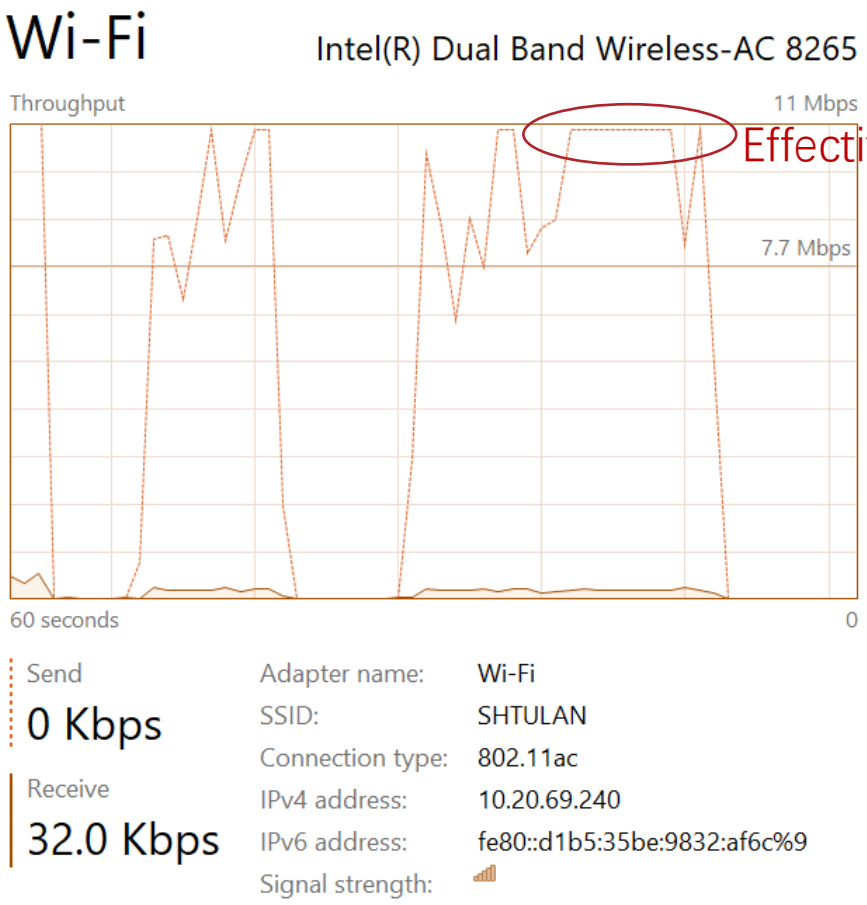
```
iperf3 -c speedtest.uztelecom.uz -p 5201 -i 1 -t 1000
```

```
C:\iperf-3.1.3-win64>iperf3 -c iperf.he.net -p 5201 -i 1 -t 1000
Connecting to host iperf.he.net, port 5201
[  4] local 10.20.69.240 port 52538 connected to 216.218.227.10 port 5201
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-1.00   sec   384 KBytes  3.14 Mbits/sec
[  4]   1.00-2.00   sec  1.12 MBytes  9.45 Mbits/sec
[  4]   2.00-3.00   sec   768 KBytes  6.28 Mbits/sec
[  4]   3.00-4.00   sec   640 KBytes  5.24 Mbits/sec
[  4]   4.00-5.00   sec   896 KBytes  7.35 Mbits/sec
[  4]   5.00-6.00   sec  1.12 MBytes  9.44 Mbits/sec
[  4]   6.00-7.00   sec  1.00 MBytes  8.39 Mbits/sec
[  4]   7.00-8.00   sec  1.25 MBytes  10.5 Mbits/sec
[  4]   8.00-9.00   sec  1.12 MBytes  9.44 Mbits/sec
[  4]   9.00-10.00  sec   768 KBytes  6.29 Mbits/sec
[  4]  10.00-11.00  sec  1.12 MBytes  9.44 Mbits/sec
[  4]  11.00-12.00  sec  1.25 MBytes  10.5 Mbits/sec
[  4]  12.00-13.00  sec  1.12 MBytes  9.45 Mbits/sec
```

Demo



Bandwidth



Effective Bandwidth

Demo

```
ping www.baidu.com -n 1000
```

```
C:\iperf-3.1.3-win64>ping www.baidu.com -n 1000

Pinging www.a.shifen.com [119.75.213.61] with 32 bytes of data:
Reply from 119.75.213.61: bytes=32 time=29ms TTL=51
Reply from 119.75.213.61: bytes=32 time=29ms TTL=51
Reply from 119.75.213.61: bytes=32 time=31ms TTL=51
Reply from 119.75.213.61: bytes=32 time=29ms TTL=51
Reply from 119.75.213.61: bytes=32 time=29ms TTL=51
Reply from 119.75.213.61: bytes=32 time=29ms TTL=51
Reply from 119.75.213.61: bytes=32 time=29ms TTL=51
```

```
ping www.shanghaitech.edu.cn -n 1000
```

```
C:\iperf-3.1.3-win64>ping shanghaitech.edu.cn -n 1000

Pinging shanghaitech.edu.cn [10.10.11.203] with 32 bytes of data:
Reply from 10.10.11.203: bytes=32 time=1ms TTL=126
Reply from 10.10.11.203: bytes=32 time=1ms TTL=126
Reply from 10.10.11.203: bytes=32 time=1ms TTL=126
Reply from 10.10.11.203: bytes=32 time=1ms TTL=126
Reply from 10.10.11.203: bytes=32 time=1ms TTL=126
Reply from 10.10.11.203: bytes=32 time=2ms TTL=126
Reply from 10.10.11.203: bytes=32 time=2ms TTL=126
```

Demo

`tracert www.baidu.com`

```
Tracing route to www.a.shifen.com [61.135.169.125]
over a maximum of 30 hops:

  1     2 ms     1 ms     1 ms  10.20.64.1
  2     1 ms     1 ms    <1 ms  10.13.7.25
  3     *        *        *     Request timed out.
  4     *        *        *     Request timed out.
  5     *        *        *     Request timed out.
  6     *        *        *     Request timed out.
  7     *        *        *     Request timed out.
  8     *        *        *     Request timed out.
  9     *        *        *     Request timed out.
 10     *        *        *     Request timed out.
 11     *        *        *     Request timed out.
 12     *        *        *     Request timed out.
 13     *        *        *     Request timed out.
 14     *        *        *     Request timed out.
 15     *        *        *     Request timed out.
 16     *        *        *     Request timed out.
 17     *        *        *     Request timed out.
 18    32 ms    32 ms    31 ms  61.135.169.125
```

`tracert www.shanghaitech.edu.cn`

```
Tracing route to www.shanghaitech.edu.cn [10.15.44.12]
over a maximum of 30 hops:

  1     3 ms     1 ms     1 ms  10.20.64.1
  2     1 ms     1 ms     1 ms  10.13.7.61
  3     2 ms     1 ms     1 ms  10.15.44.12

Trace complete.
```

More Hops -> More Latency

Increasing Bandwidth is Hard

- Spectrum
- Propagation Attenuation
- Noise
- Power
- …

Reducing Latency is Even Harder

- Propagation Speed
- Contention
- Queuing
- …

Reference

- Textbook 1.5