

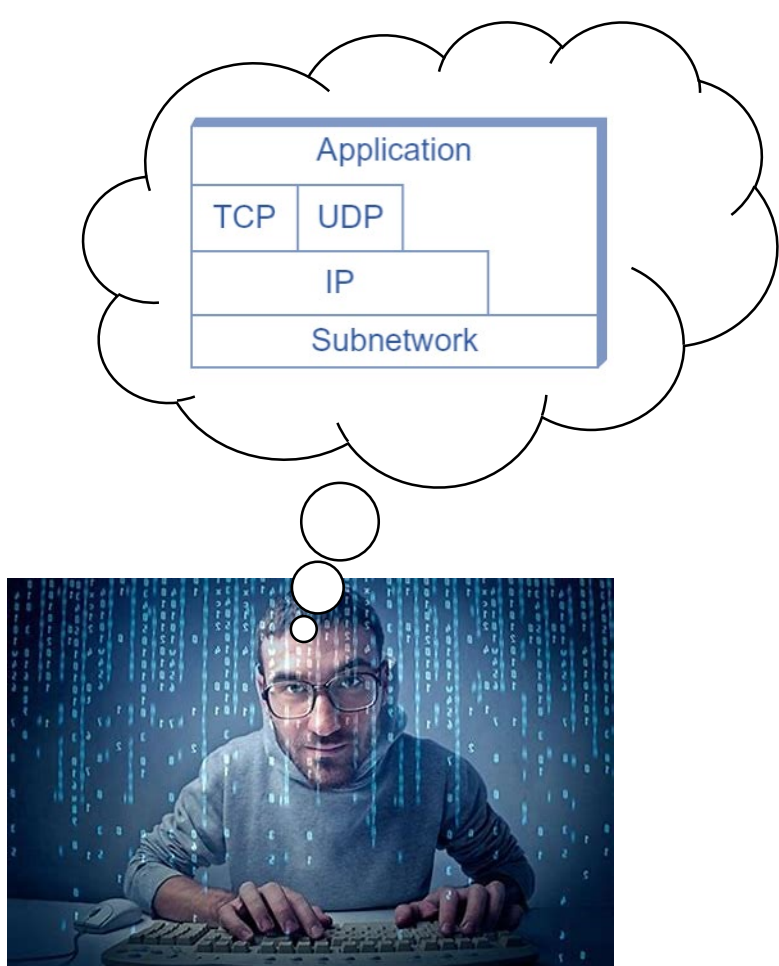


# CS120: Computer Networks

## **Lecture 2. Course Introduction 2**

Zhice Yang

# Network Performance is the Ultimate Goal



Network Designer  
(performance, management, security, etc.)

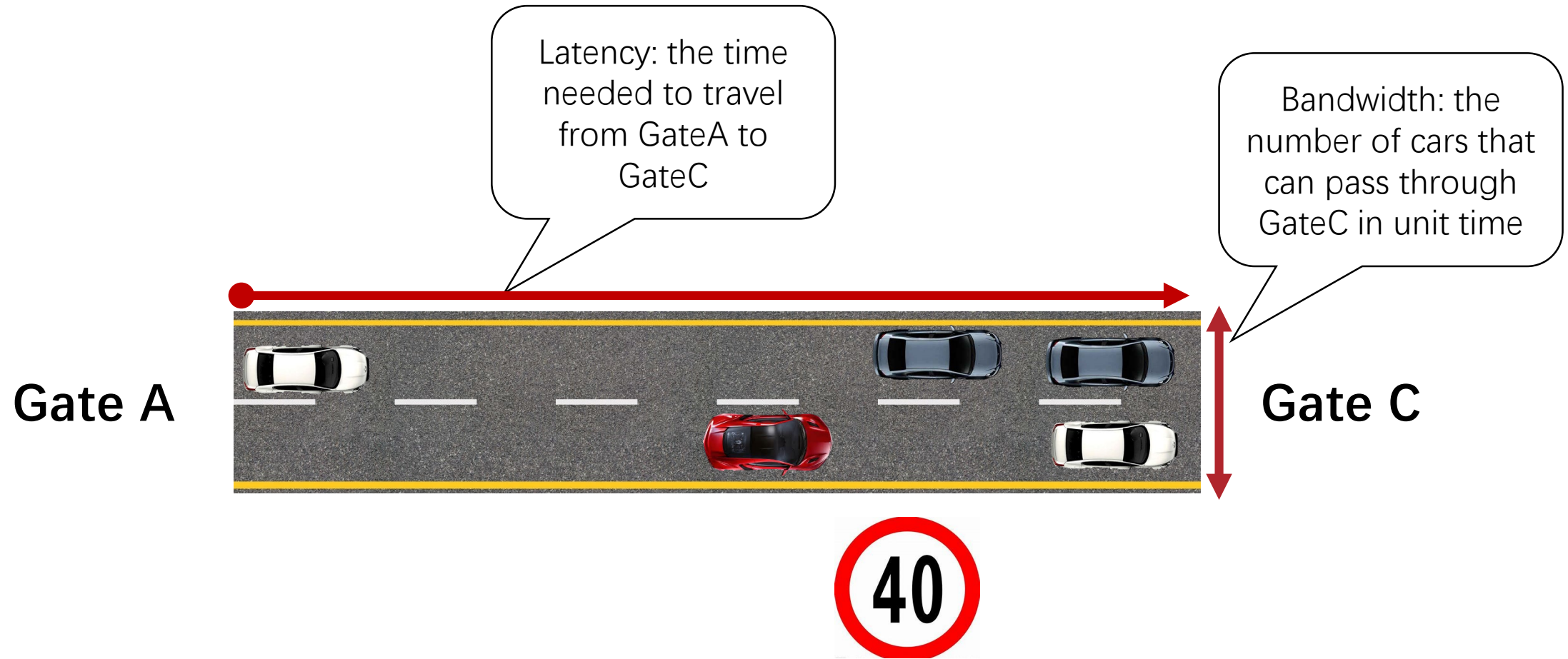


Network User

# Network Performance

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

# Example: Road



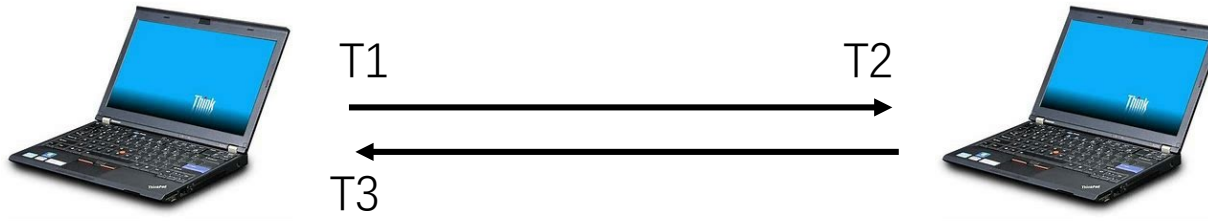
# Bandwidth

- 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 ( $10^9$ )
  - eg: a 100-Mbps Ethernet Link means it takes  $\frac{1}{100 \times 10^6}$  seconds to transmit one bit. But it does not mean the receiver will receive that bit after  $\frac{1}{100 \times 10^6}$  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: s, 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

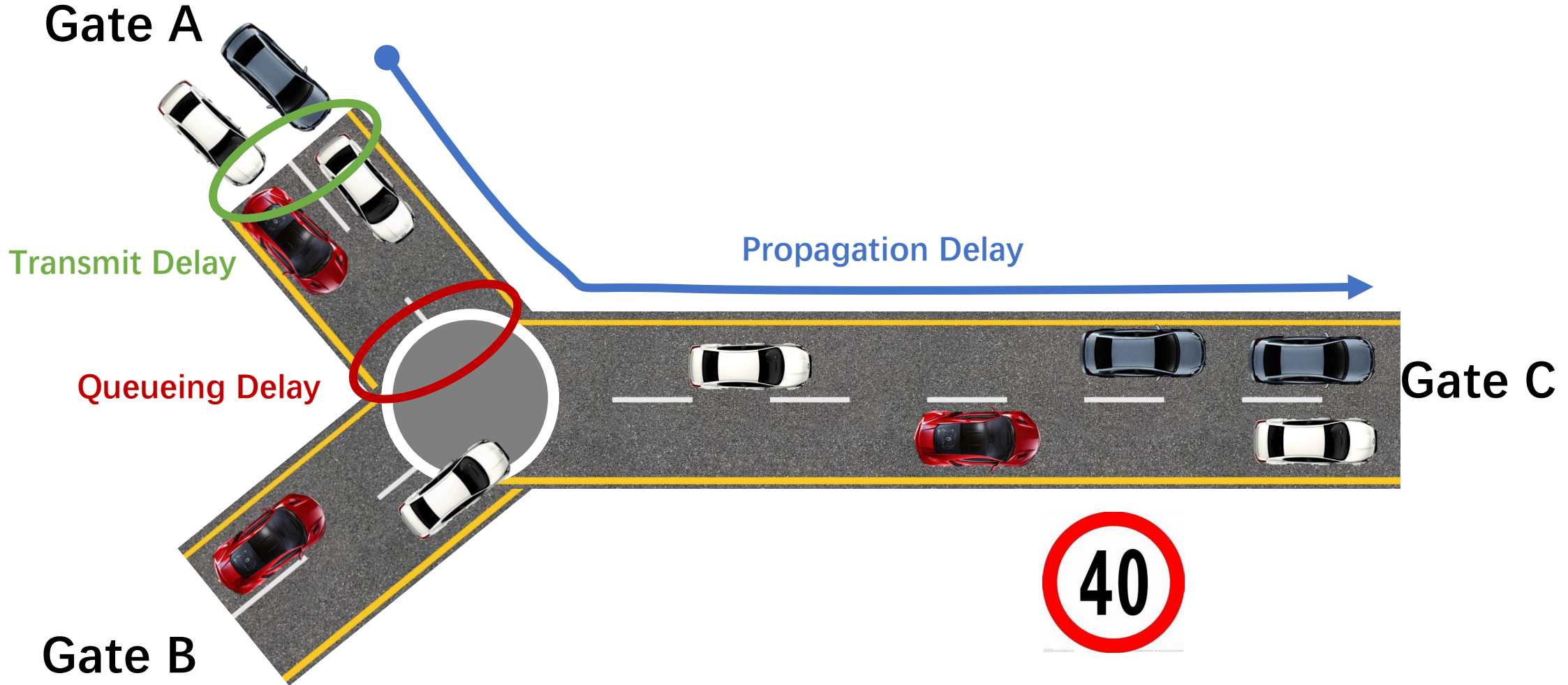
- Transmit Delay =  $\text{TransferSize} / \text{Bandwidth}$

- Propagation Delay =  $\text{Distance} / \text{SpeedofSignal}$

- **Latency** =  $\text{TransferSize} / \text{Bandwidth} + \text{Distance} / \text{SpeedofSignal} + \text{Queueing Delay}$

RTT/2

# Example: Road

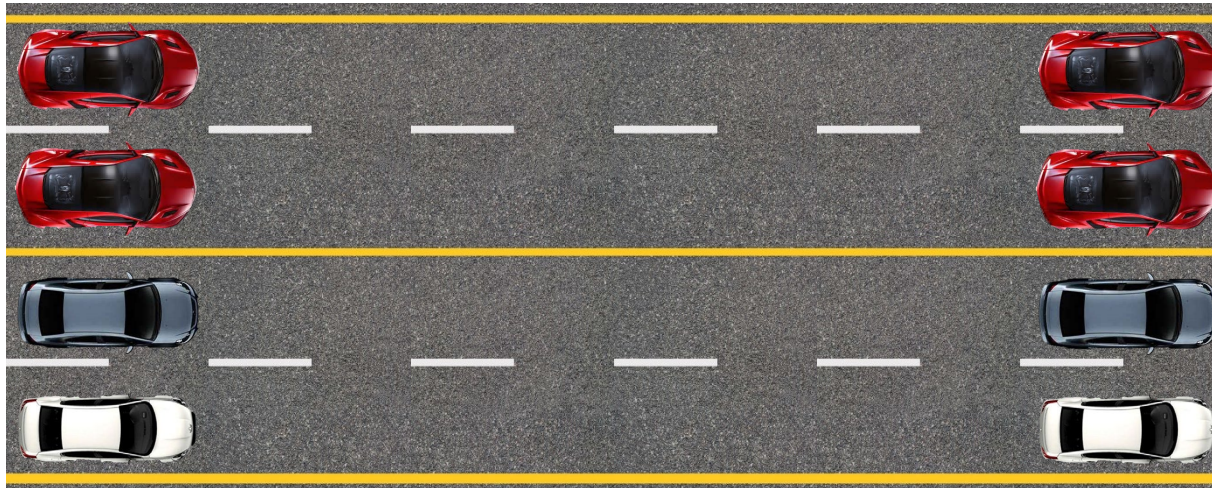




# Bandwidth vs. Latency

High Bandwidth, Large Delay

Gate A



Gate C

1TByte/10min



Low Bandwidth, Small Delay

Gate A



Gate C

100bits/10s



# Effective Bandwidth

Latency =  
 $\text{TransferSize} / \text{Bandwidth} +$   
 $\text{Distance} / \text{SpeedofSignal} +$   
Queueing Delay

- Effective Bandwidth =  $\text{TransferSize} / \text{Latency}$ 
  - Effective bandwidth is also called throughput
  - In many situations, bandwidth and throughput are used interchangeably

# Demo

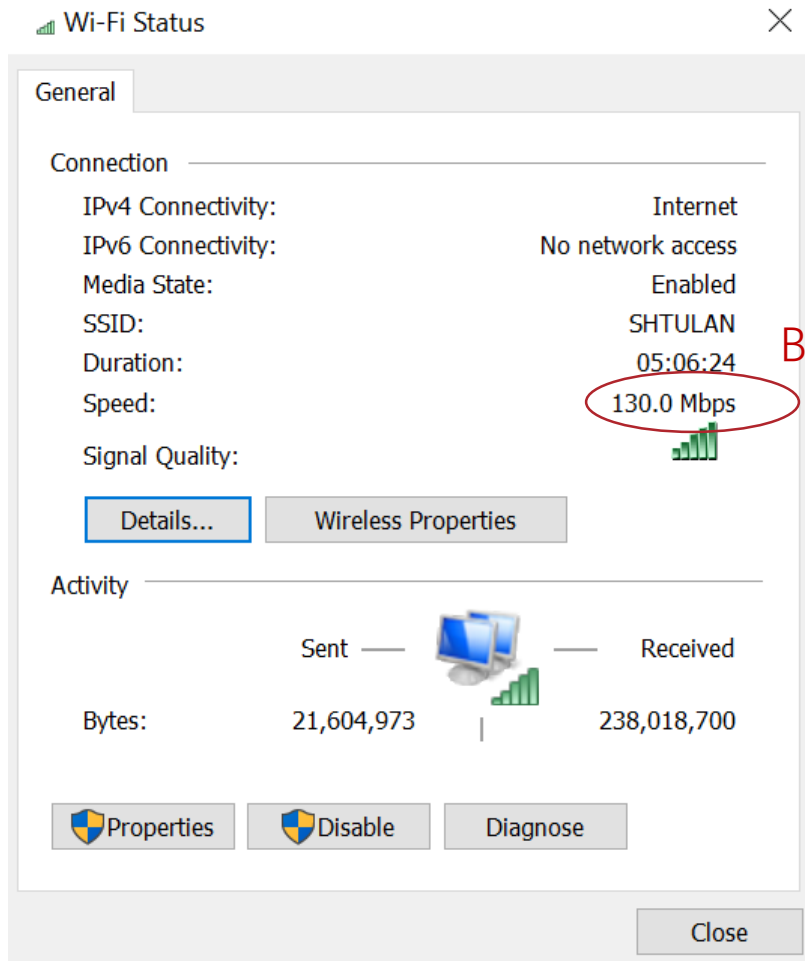
- Throughput measurement
  - iperf
    - <https://iperf.fr/iperf-servers.php>
- Latency measurement
  - ping
    - RTT

# Demo

```
iperf3 -c bouygues.iperf.fr -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

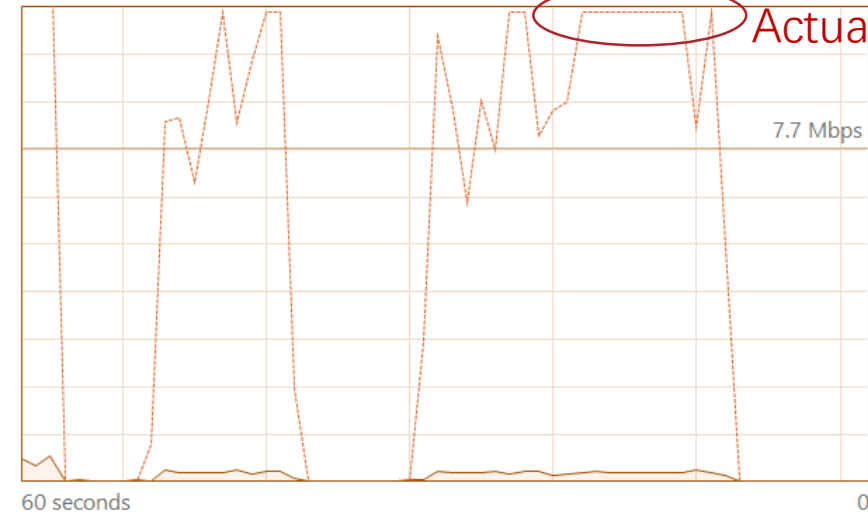


Bandwidth

## Wi-Fi

Intel(R) Dual Band Wireless-AC 8265

Throughput



Actual throughput

Send  
0 Kbps

Receive  
32.0 Kbps


Adapter name: Wi-Fi

SSID: SHTULAN

Connection type: 802.11ac

IPv4 address: 10.20.69.240

IPv6 address: fe80::d1b5:35be:9832:af6c%9

Signal strength: 

# 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

# Improving Bandwidth is Hard

- Limited Spectrum Bandwidth
- DAC/ADC Rate
- Medium Propagation Attenuation
- Noise
- Power
- ...



# Improving Latency is Even Harder

- Propagation Speed
- Processing Ability
- Interference
- Contention
- Queuing
- ...

# Reference

- Textbook 1.5