



CS120: Computer Networks

Lecture 2. Course Introduction 2

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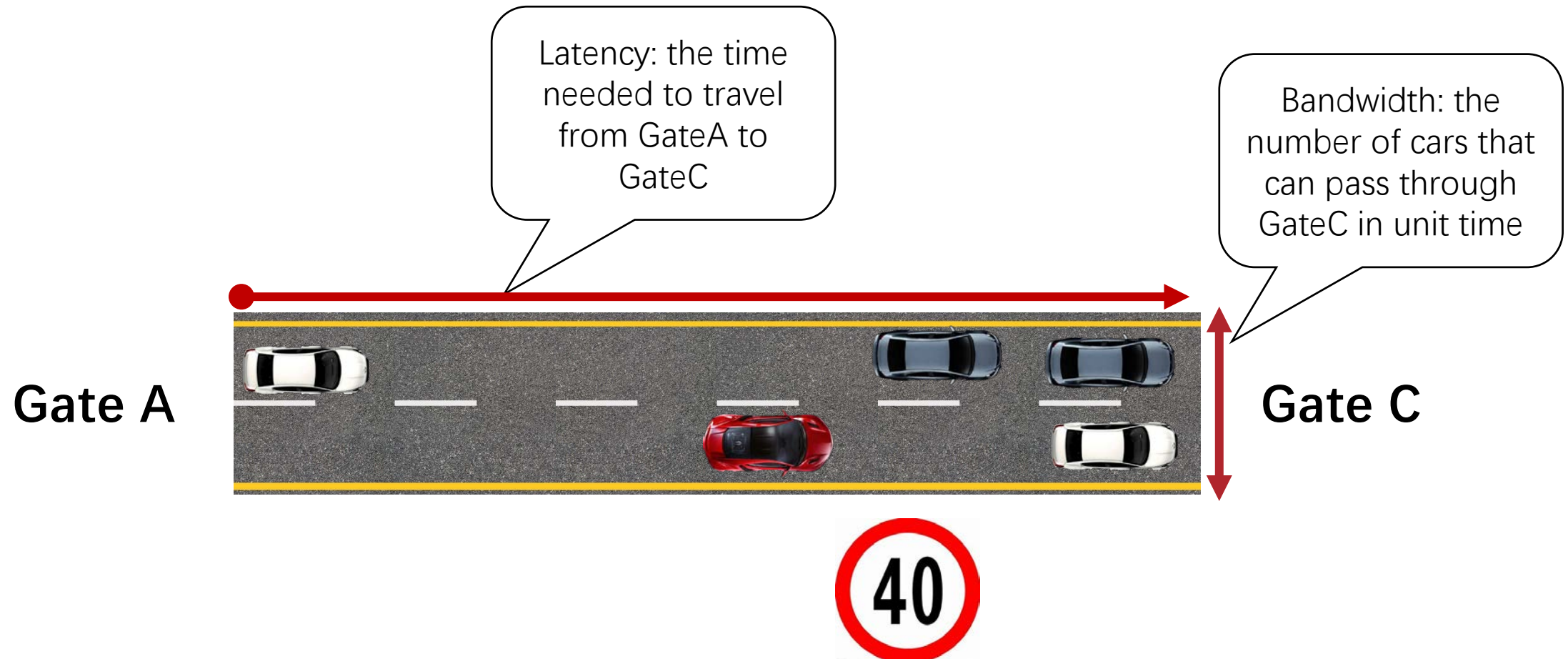
Network Performance



Network Performance

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

Example: Road



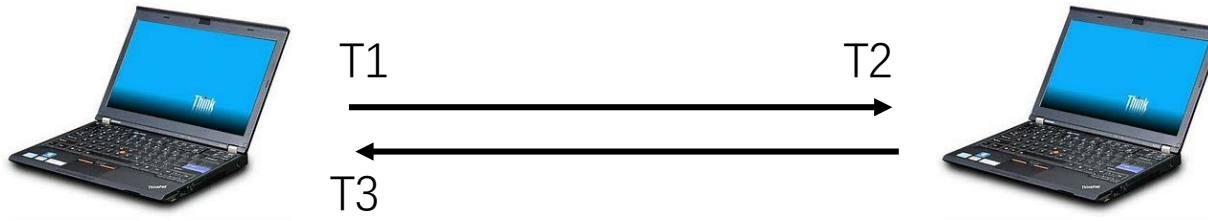
Bandwidth

- 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 $\frac{1}{100 \times 10^6}$ 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: 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

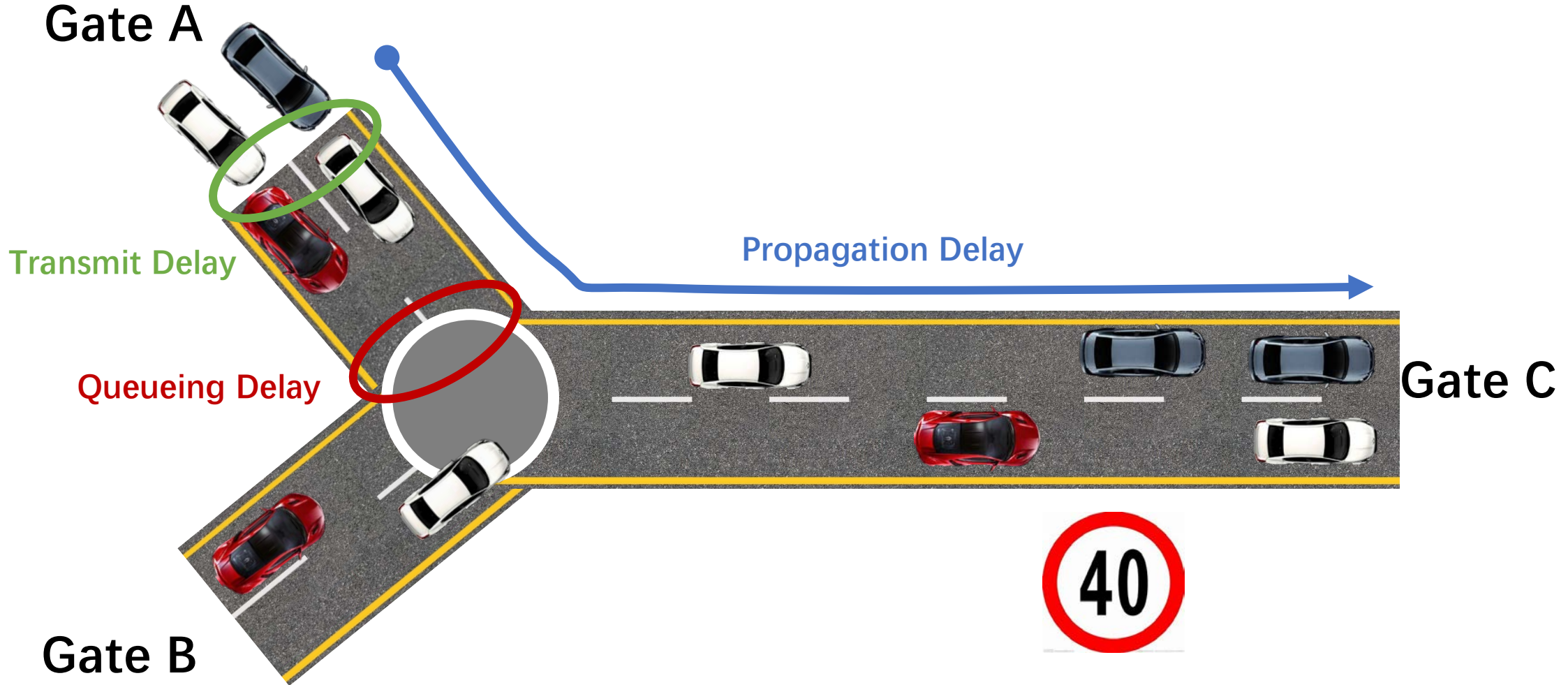
- Transmit Delay = $\text{TransferSize} / \text{Bandwidth}$

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

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

RTT/2

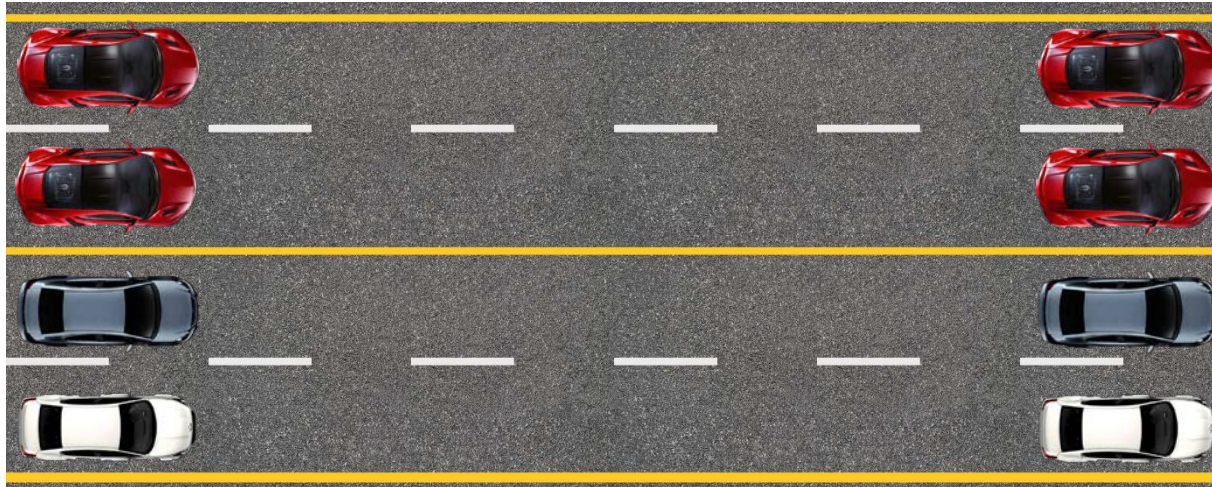
Example: Road



Bandwidth vs. Latency

High Bandwidth, Large Delay

Gate A



Gate C

1TByte/10min



100bit/10s



Low Bandwidth, Small Delay

Gate A



Gate C

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
 - For large transfer size:
 - Effective Bandwidth \rightarrow Bandwidth
- In many situations, bandwidth and throughput are used interchangeably
 - Be careful about the actual meaning

Demo

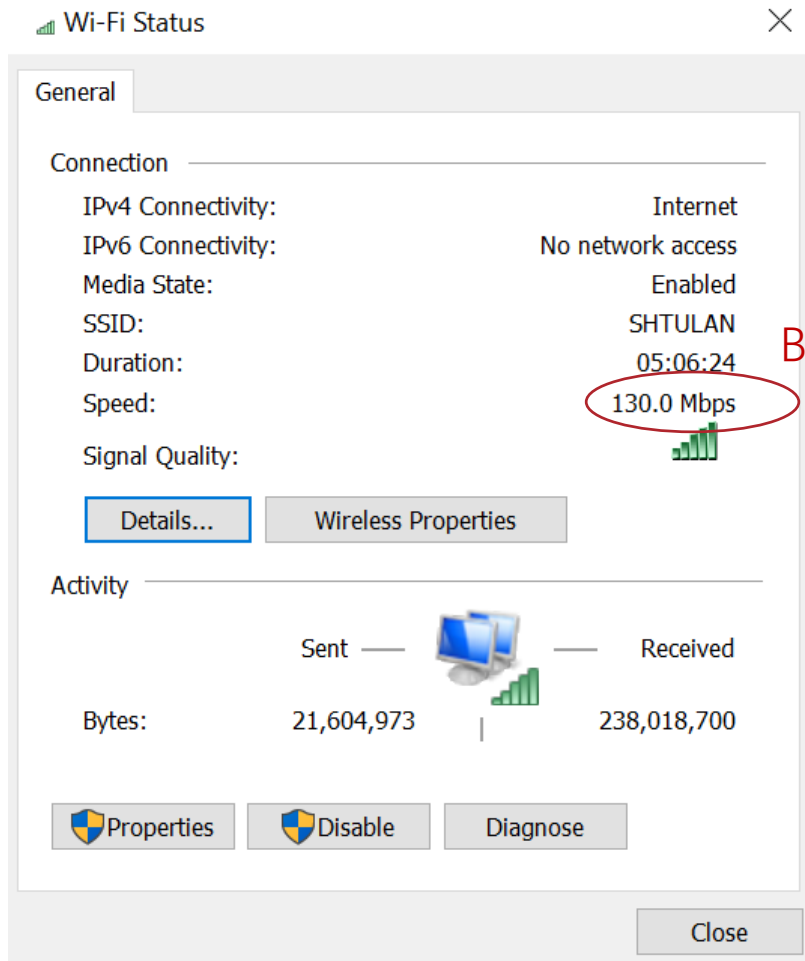
- Throughput measurement
 - iperf
 - <https://iperf.fr/iperf-servers.php>
- Latency measurement
 - ping
 - RTT

Demo

```
iperf3 -c 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
```

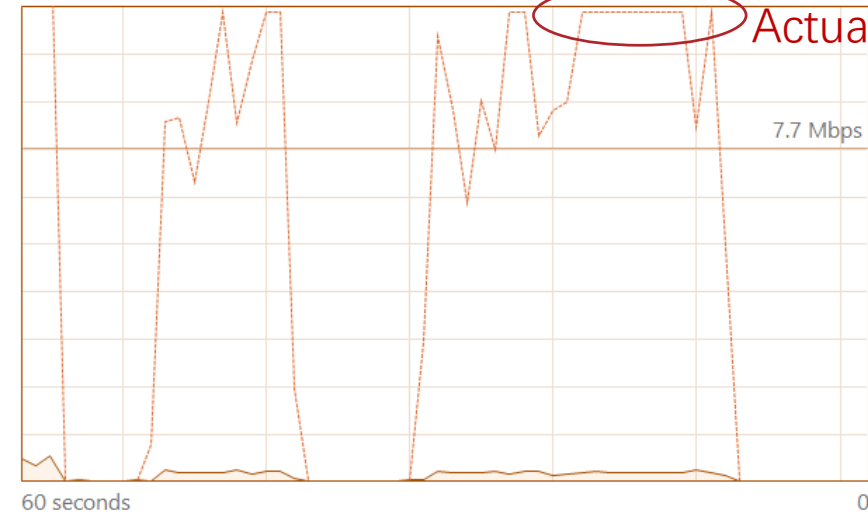
Demo



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

- Spectrum Bandwidth
- Propagation Attenuation
- Noise
- Power
- ...

Improving Latency is Even Harder

- Propagation Speed
- Contention
- Queuing
- ...

Reference

- Textbook 1.5