CPSC 317 COMPUTER NETWORKING

Module 2: Network Performance

READING

- Reading: 1.4.4

ADMINISTRATION

- PA1 has been released – Due January 28th
- The date shown on PrairieLearn is 4 days later (because you all have 96 hours of automatic extension)
- If you submit after 23:59:59 on January 28th, you are consuming some hours of your extension quota

LEARNING GOALS

Basic Definitions

- Define the terms bandwidth, latency, round-trip-time, throughput, goodput, and jitter.
- Explain the difference between bandwidth, latency, throughput and goodput
- Perform computations with respect to bandwidth, throughput, goodput, and latency
- Calculate the protocol overheads with respect to performance (goodput vs bandwidth)
- Describe how jitter is introduced into a network

NETWORK METRICS

- Bandwidth
- Latency
- Round-trip-time
- Jitter
- Throughput
- Goodput

NETWORK METRICS: BANDWIDTH

- Bandwidth: maximum rate at which data can be sent over a link
  - When you see an advertised rate, it is almost always bandwidth
  - 1 Gbps ethernet
  - 500 Mbps or 1 Gbps “speed” from Shaw
  - 2,500 Mbps “speed” from Telus

DIGRESSION: UNITS OF MEASUREMENT

- Data sizes: KB, MB, GB, TB (in bytes)
  - K, M, G, T are multiples of 2 (2^{10}, 2^{20}, 2^{30}, 2^{40})
  - Except for disk drive manufacturers
- Rates: Kbps, Mbps, Gbps, Tbps
  - K, M, G, T are multiples of 10 (10^3, 10^6, 10^9, 10^{12})
  - If KB/s, MB/s, GB/s, TB/s, then use multiples of 2 (2^{10}, 2^{20}, 2^{30}, 2^{40})

Read the units carefully

DATA SIZE VS DATA RATE

- Discrepancy grows with size
  - 10^3 vs 2^{10} off by 2.4%
  - 10^6 vs 2^{20} off by 4.9%
  - 10^9 vs 2^{30} off by 7.4%
  - 10^{12} vs 2^{40} off by 10.0%

BANDWIDTH AND STATION-WAGONS

"Never underestimate the bandwidth of a station wagon full of tapes hurtling down the highway."
–Andrew Tanenbaum, 1981

Cisco estimates that total internet traffic currently averages 167 terabits per second. FedEx has a fleet of 654 aircraft with a lift capacity of 26.5 million pounds daily. A solid-state laptop drive weighs about 78 grams and can hold up to a terabyte.
That means FedEx is capable of transferring 150 exabytes of data per day, or 14 petabits per second—almost a hundred times the current throughput of the internet.

TOP-END LAPTOP DRIVES: 136
STORAGE: 136 TERABYTES
COST: $130,000
(PLUS $40 FOR THE SHOES)


MICROSD CARDS: 25,000
STORAGE: 1.6 PETABYTES
RETAIL COST: $1.2 MILLION

SUV VS FIBER

The distance of 413km from UBC-V to UBC-O can be covered at an average speed of 75km/hr in an SUV with 3.5m³ of carrying capacity. A Blu-Ray in a jewel case takes up 88.75 cm³. There is a 100 Gbit/s data connection between the two institutions. You have 260,000 GBytes of data, currently stored on Blu-Ray discs that you want to get to UBC-O and store on disk there. Each disc, on average, has 40 GBytes of data. Ignore van loading and unloading costs and reading/writing disc costs (i.e., the time costs of duplicating a Blu-ray Disc to send it).

CLICKER QUESTION

Which will get the data to Kelowna faster?

413km, 75km/hr, 100 Gbit/s network, 260000 GBytes

A. SUV
B. Network connection
C. Insufficient data to determine

FOLLOWUP QUESTION

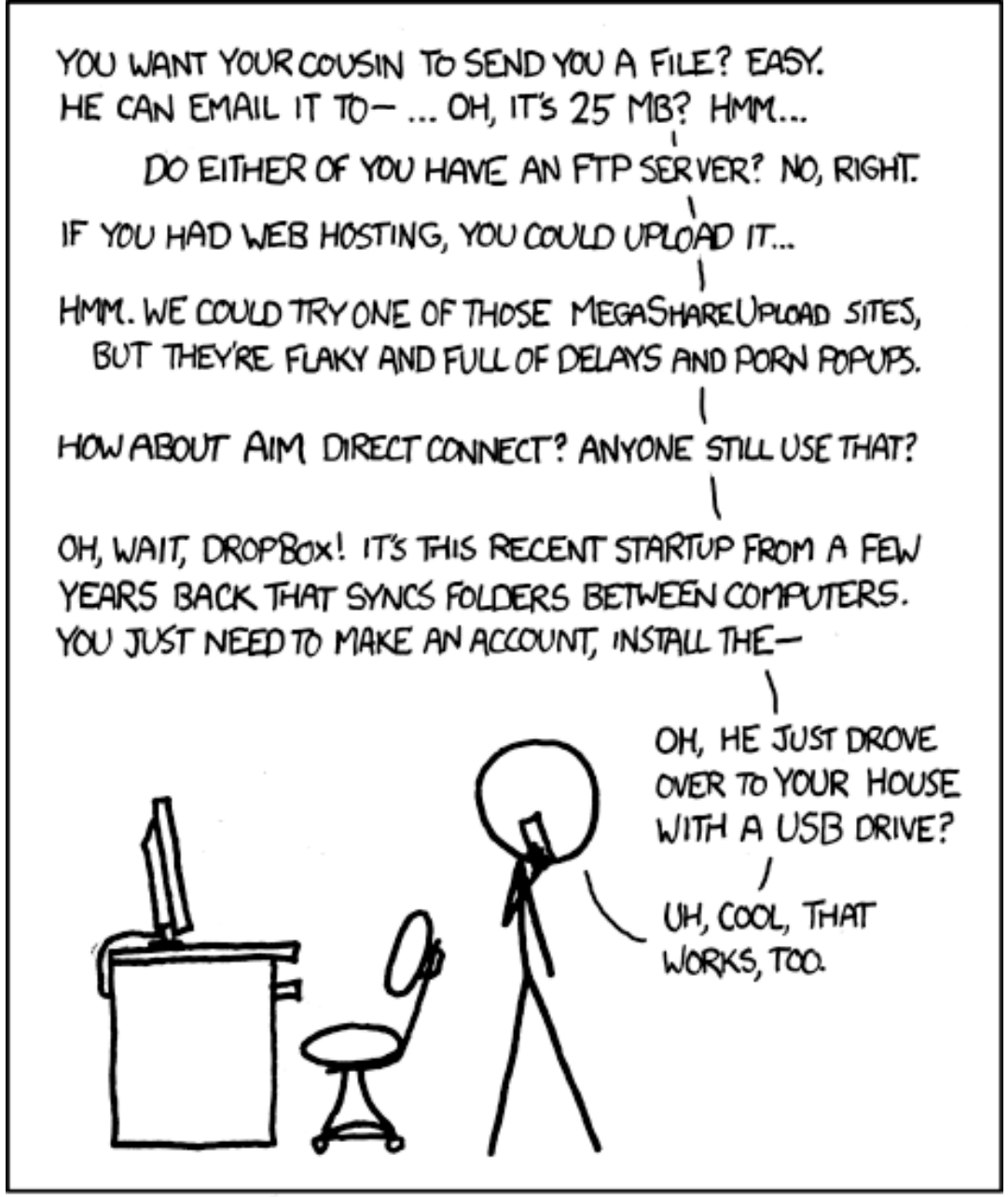
What is the bandwidth of the SUV?

413km, 75km/hr, 100 Gbit/s network, 260000 GBytes

ANOTHER FOLLOWUP QUESTION

What is the maximum bandwidth of the SUV?

413km, 75km/hr, 100 Gbit/s network, 4.3m^3 capacity, BluRay = 88.75 cm^3, 40Gbytes



I LIKE HOW WE'VE HAD THE INTERNET FOR DECADES, YET "SENDING FILES" IS SOMETHING EARLY ADOPTERS ARE STILL FIGURING OUT HOW TO DO.

FILE TRANSFER

https://xkcd.com/949

(circa 2011)

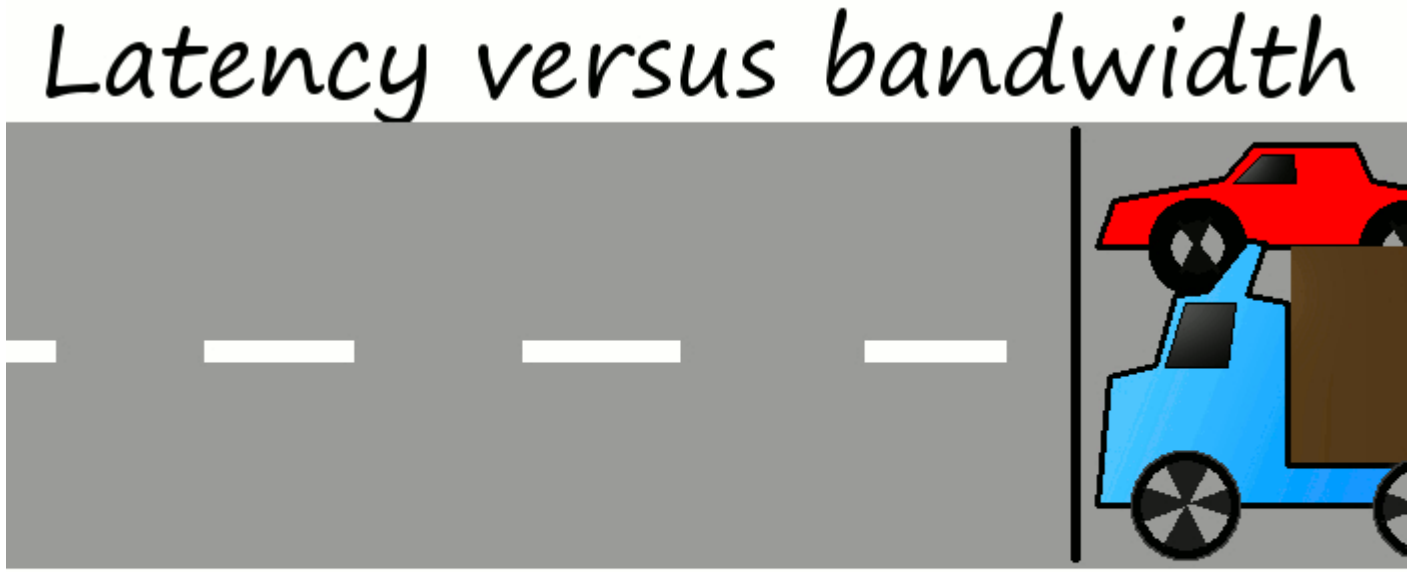
ACTUALLY USED IN REAL LIFE

- Amazon snow family
  - Snowcone – up to 22TB – 4.5 lbs
    - https://aws.amazon.com/snowcone/
  - Snowball – up to 210TB – 50 lbs
    - https://aws.amazon.com/snowball/
  - Snowmobile – up to 100PB – 40 tons??
    - https://aws.amazon.com/snowmobile/

NETWORK METRICS: LATENCY

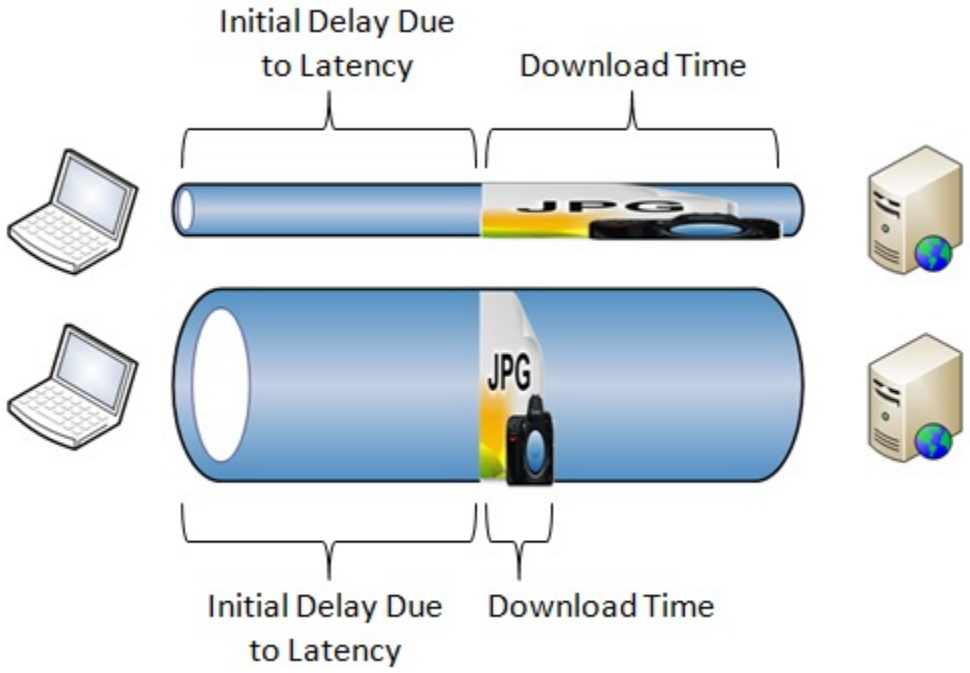
- Latency: delay from when something is sent until it is received
  - “Something” depends on context, but must be consistent
- Examples:
  - Packet latency: from start of sending packet until completely received
  - Bit/byte latency: from start of sending bit/byte until that bit/byte is completely received

VEHICLE ANALOGY



If you are doing light web browsing and want the websites to be snappy, you want low latency. Bandwidth is only important to a certain extent.
If you are downloading a large game from Steam, you want your bandwidth to be as high as possible. Latency is not really a factor in this case.

PIPE ANALOGY



NETWORK METRICS: RTT

- Round Trip Time (RTT): latency for sending something and receiving something back
  - Latency for message + latency for response + processing time
  - The RTT for a bit is not the same as the RTT for a request and a response
- Easier to compute than one-way latency (single clock)
- Reported by ping, traceroute, etc.

PING (MEASURE RTT)

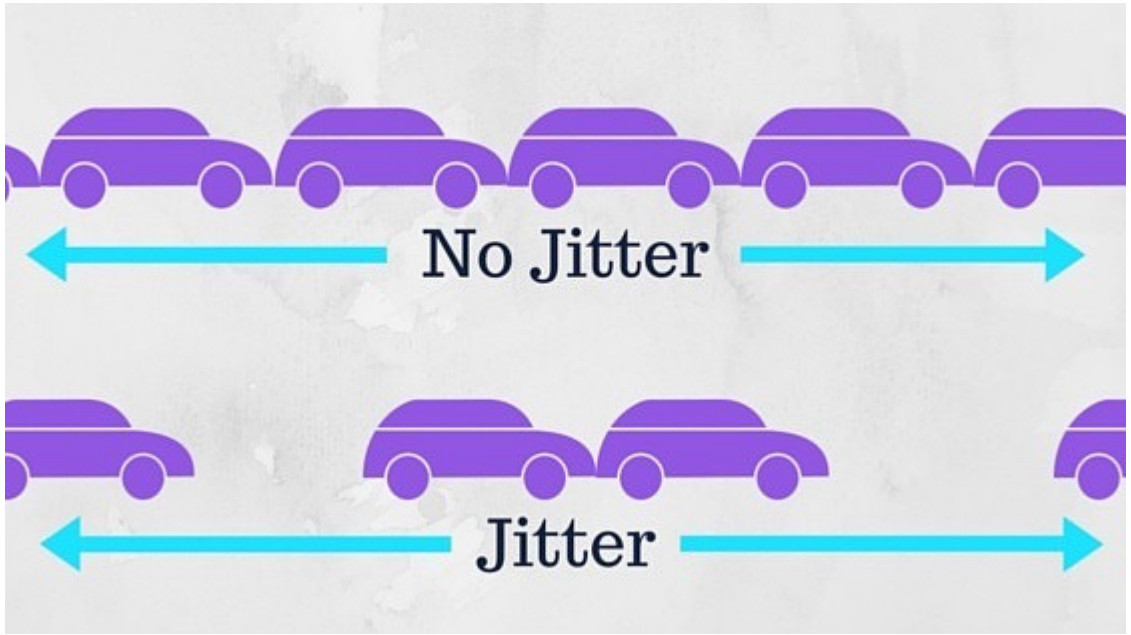
Observe that not all ping times are the same

```
$ ping -c 10 www.cs.ubc.ca
PING www.cs.ubc.ca (142.103.6.5): 56 data bytes
64 bytes from 142.103.6.5: icmp_seq=0 ttl=59 time=2.145 ms
64 bytes from 142.103.6.5: icmp_seq=1 ttl=59 time=2.177 ms
64 bytes from 142.103.6.5: icmp_seq=2 ttl=59 time=2.333 ms
64 bytes from 142.103.6.5: icmp_seq=3 ttl=59 time=2.353 ms
64 bytes from 142.103.6.5: icmp_seq=4 ttl=59 time=8.583 ms
64 bytes from 142.103.6.5: icmp_seq=5 ttl=59 time=8.446 ms
64 bytes from 142.103.6.5: icmp_seq=6 ttl=59 time=8.572 ms
64 bytes from 142.103.6.5: icmp_seq=7 ttl=59 time=8.452 ms
64 bytes from 142.103.6.5: icmp_seq=8 ttl=59 time=2.229 ms
64 bytes from 142.103.6.5: icmp_seq=9 ttl=59 time=2.221 ms

--- www.cs.ubc.ca ping statistics ---
10 packets transmitted, 10 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 2.145/4.751/8.583/3.073 ms
```

NETWORK METRICS: JITTER

- Jitter: variation in latency and/or RTT



WHAT CAUSES JITTER?

- Different paths for packets
- Network congestion
- Not implementing packet prioritization
- Poor hardware performance (old equipment)
- Wireless jitter (interference in medium)

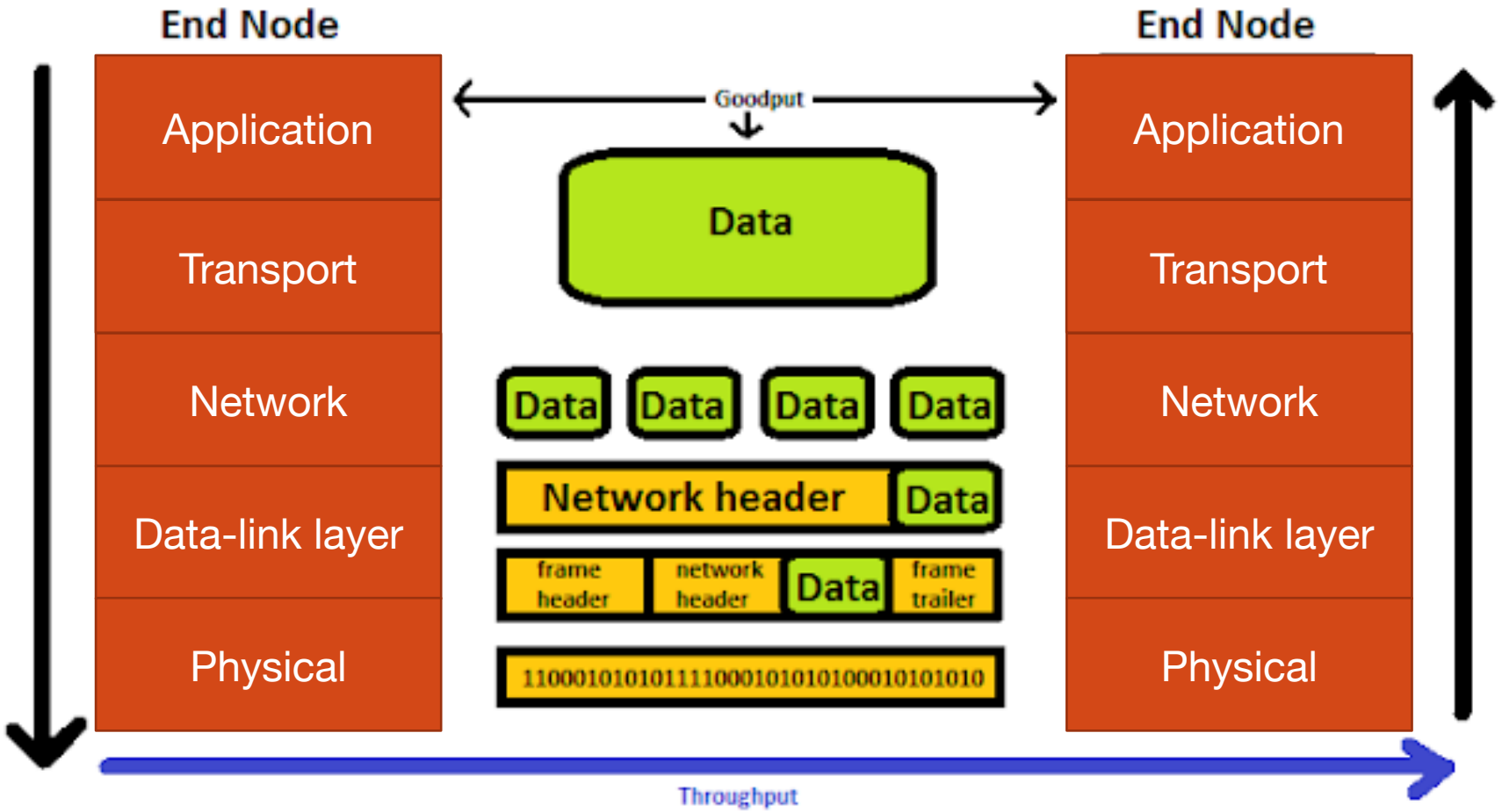
NETWORK METRICS: THROUGHPUT

- Throughput: amount of data moved from one location to another in a given time
- Usually expressed in bytes per second (B/s, MB/s, etc.) or bits per second (bps, Mbps, etc.)

NETWORK METRICS: GOODPUT

- Goodput: rate at which *useful* data arrives
  - Does not include headers and encoding costs
  - Does not include data loss and retransmissions
- May depend on context and application-layer protocol

GOODPUT VS THROUGHPUT



IN-CLASS ACTIVITY

- ICA21