CPSC 317 – Winter 1 2025 Introduction to Computer Networking

Network Performance

Module 2.1

Norm & Ibtissem

Administration

- PA1 has been released – Due Sep 28th at 23:59:59

READING

- Reading: 1.4.4

Learning Goals

Basic Definitions

- Define the terms bandwidth, throughput, goodput, latency, round-trip-time, 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
- Throughput
- Goodput
- Latency
- Round-trip-time
- Jitter

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

Units of Measurement in this Course

- For simplicity, we will use the following types of notation throughout this course:
- **Data Size**: [K/M/G][b/B], e.g. Kb, GB, KB
  - In this case, K, M, G, T follow powers of 2:
    - $K = 2^{10}$, $M = 2^{20}$, $G = 2^{30}$
- **Data Rates:** [K/M/G] bps, e.g. Kbps, Gbps
  - In this case, K, M, G, T follow powers of 10:
    - $K = 10^3$, $M = 10^6$, $G = 10^9$
- **Reminder:** 1 Byte (B) = 8 bits (b)

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%

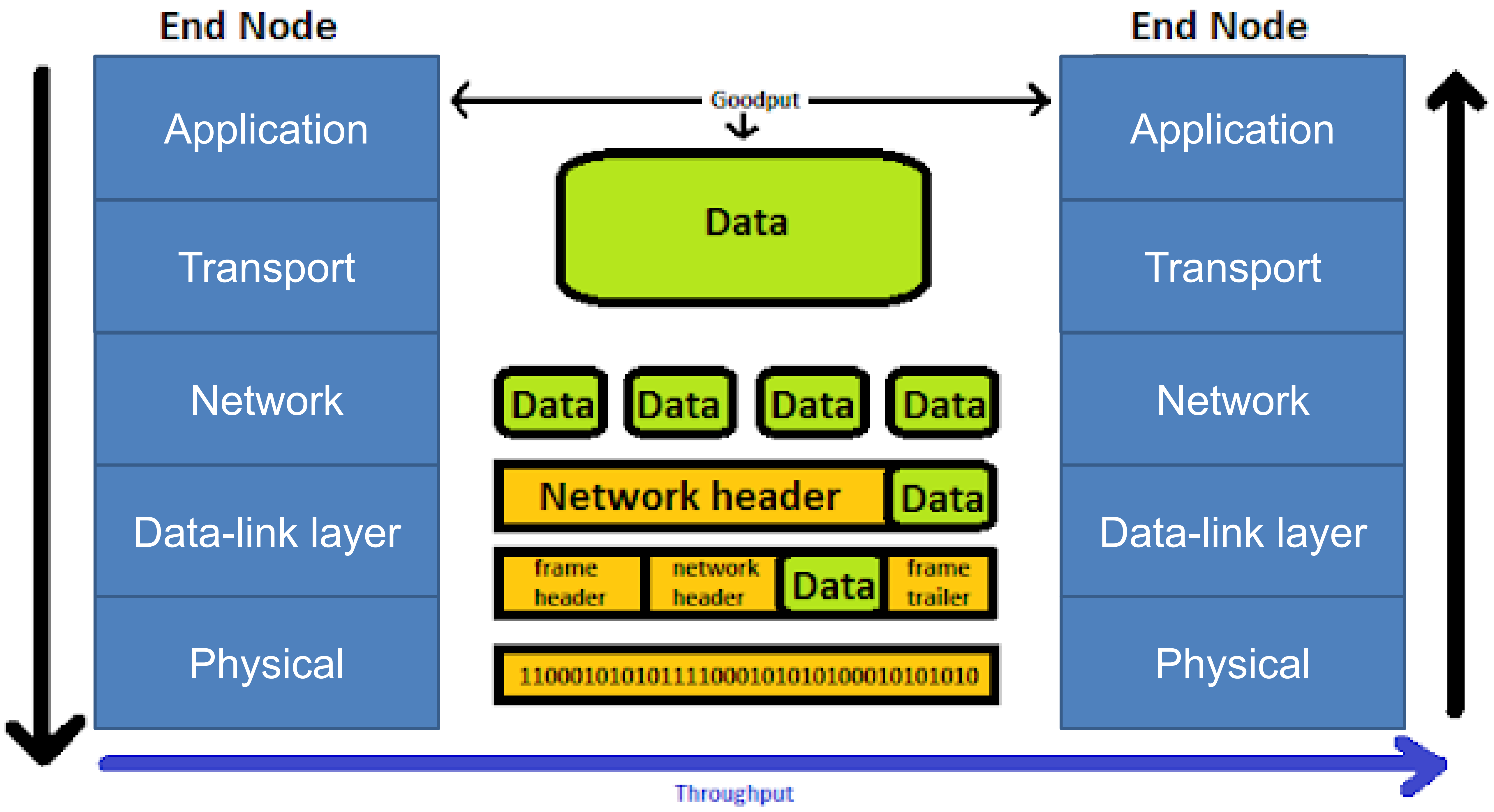
Network Metrics: Throughput

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

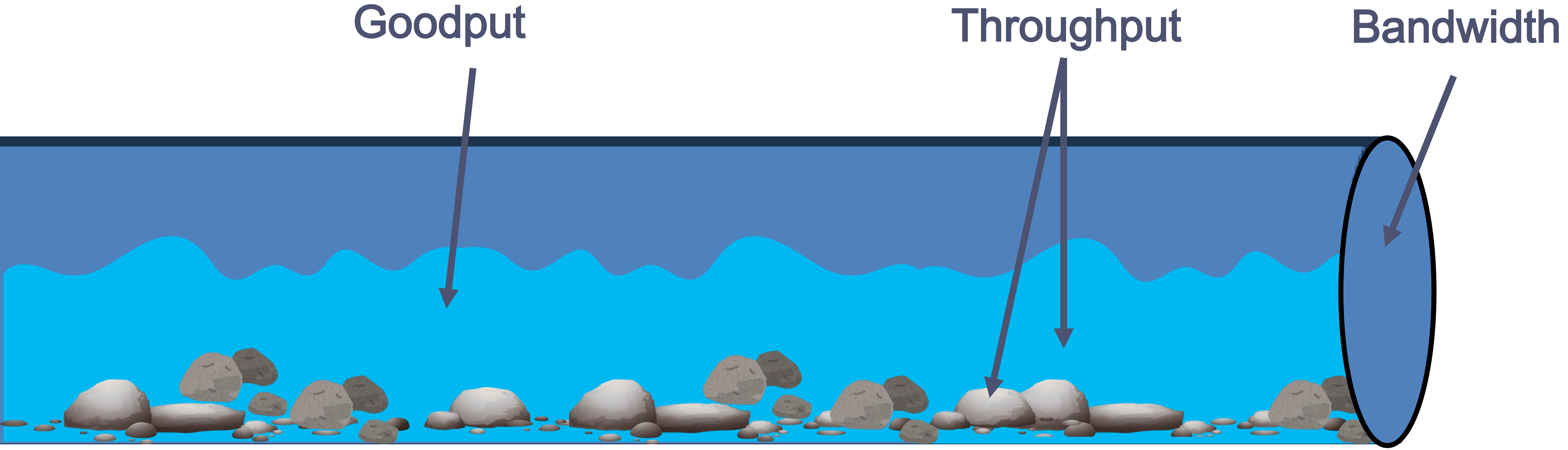
Network Metrics: Goodput

- **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



Goodput Vs Throughput Vs Bandwidth



Goodput Vs Throughput Vs Bandwidth

Clicker Question

A file of size 10 MB is being transferred over a network connection. The network operates at a data rate of 8 Mbps (Megabits per second). The total transmission time for the file is 12 seconds. During the transmission, 1 MB of the data consists of protocol overhead (headers, acknowledgments, retransmissions, etc.) is also sent.

Calculate the Throughput and Goodput in Mbps.

Clicker Answer

Throughput = Overall data sent /Time required to send data

Overall data sent = file size + overhead = 10+1 = 11 MB= 11 * 8 * 2^{20} bits

Time required to send data = 12 s

Throughput = 11 * 8 * 2^{20} / 12 = 7 689 557.33 bps = **7.6895 Mbps**

Goodput = Useful data sent /Time required to send data

Goodput = 10 * 8 * 2^{20} / 12 = 6 990 506.66 bps = **6.99 Mbps**

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**.

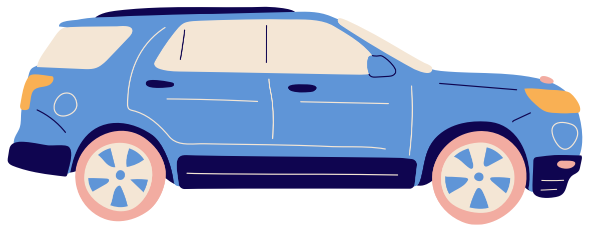
SUV vs Fiber

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 Gbps 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). Consider the 100 Gbps data connection as goodput

SUV vs Fiber

75 Km/h

3.5m³ of carrying capacity



413 Km

100 Gbps Goodput

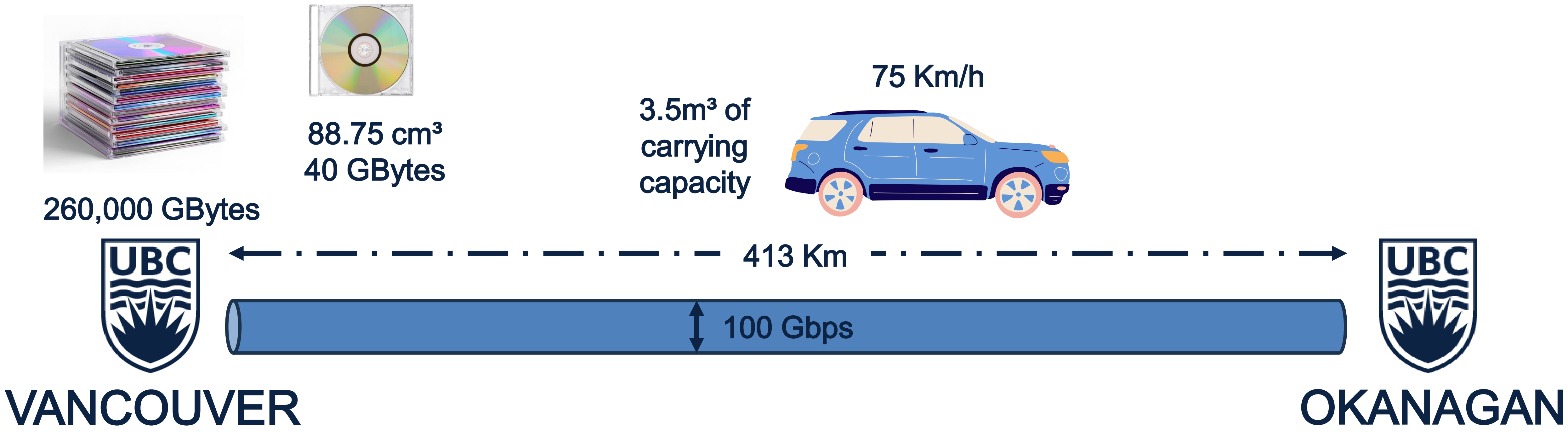
VANCOUVER

OKANAGAN

88.75 cm³
40 GBytes

260,000 GBytes

Clicker Question

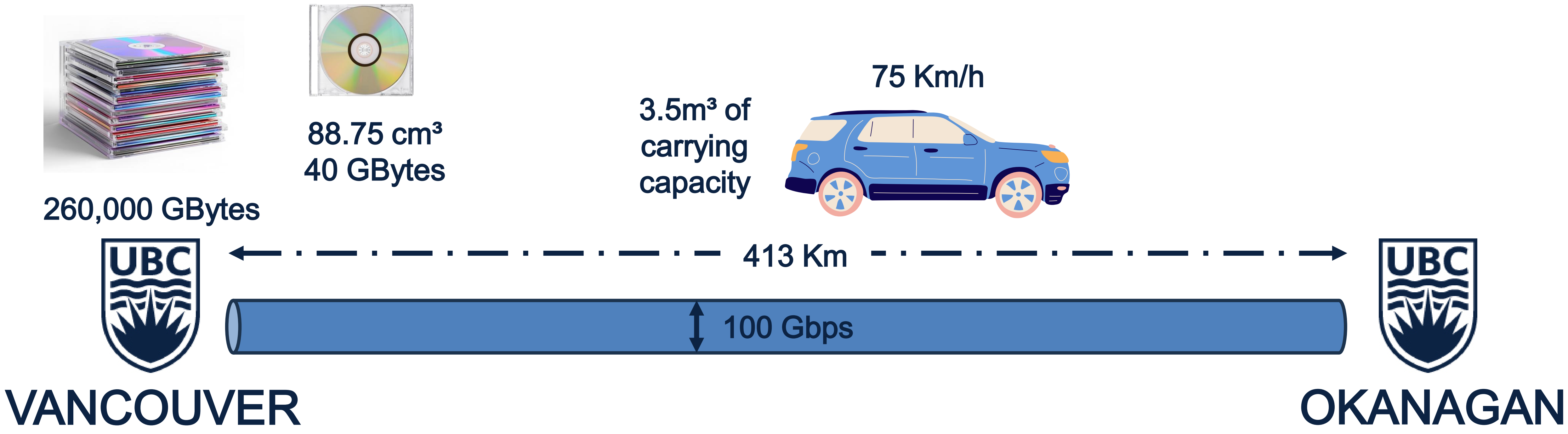


Without doing a detailed calculation, predict which will get the data to UBC-O faster?

A. SUV

B. Network connection

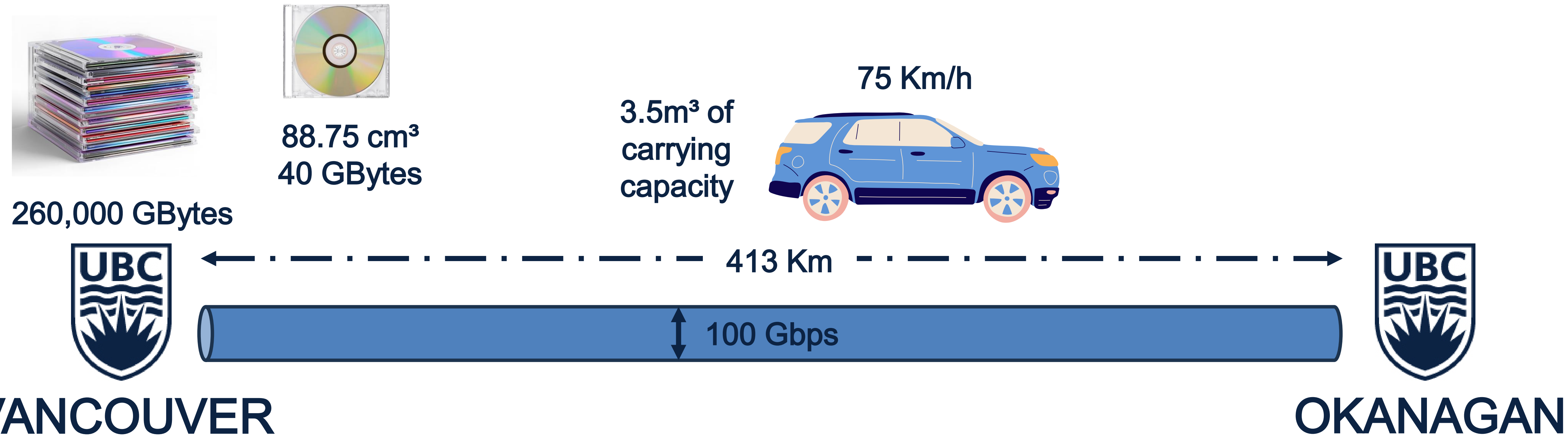
Clicker Question



After 180 minutes, how many gigabytes of data would have arrived at UBC-O by network connection ?

A. 0 GB
B. 126 000 GB
C. 1 080 000 GB

Clicker Question



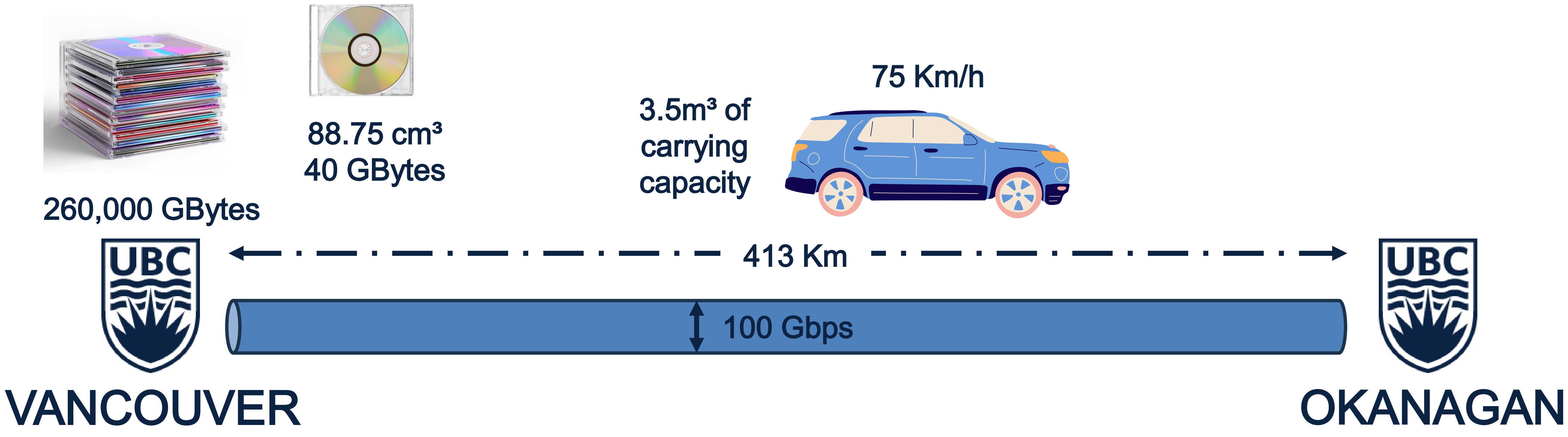
After 180 minutes, how many gigabytes of data would have arrived at UBC-O by network connection ?

A. 0 GB

B. 126 000 GB ($180*60*100*10^{9} = 1.08*10^{15}$ bits / 8= $1.35*10^{14}$ Bytes / $2^{30} \approx 126\,000$GB)

C. 1 080 000 GB

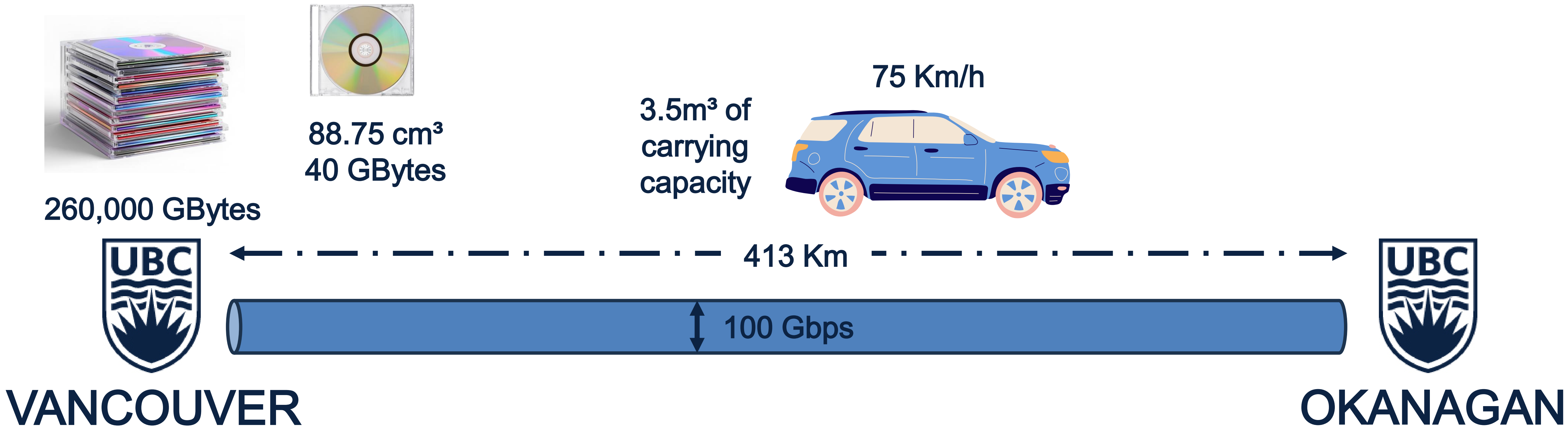
Clicker Question



After 180 minutes, how many gigabytes of data would have arrived at UBC-O by SUV?

A. 0 GB
B. 135 000 GB
C. 1 080 000 GB

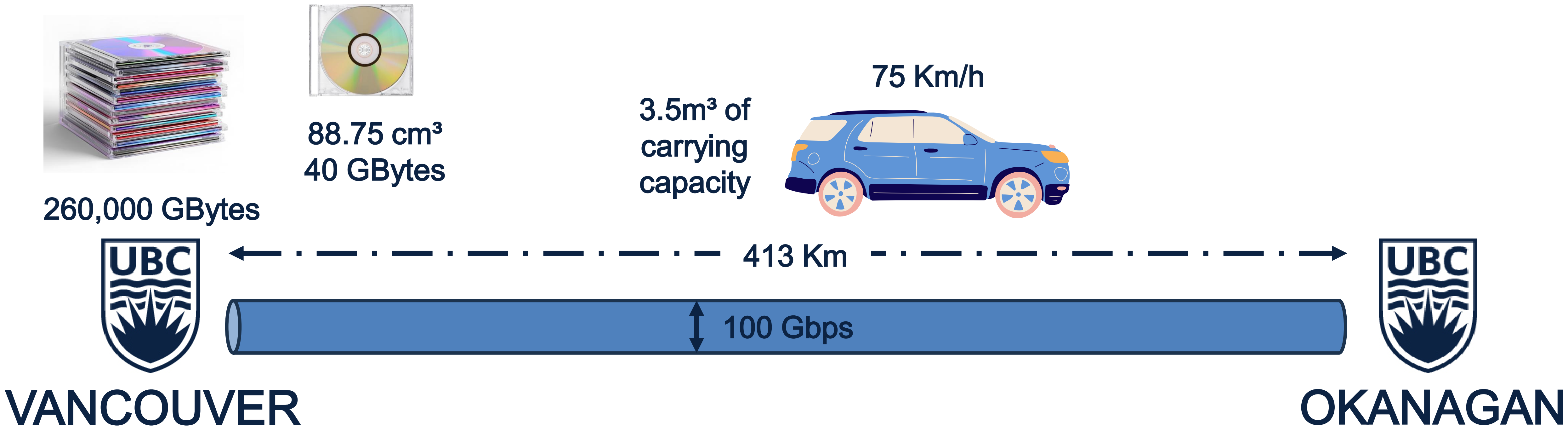
Clicker Question



After 180 minutes, how many gigabytes of data would have arrived at UBC-O by SUV?

A. 0 GB (413/75 = 5.51 hours = 330.4 min => 0 GB)
B. 135 000 GB
C. 141 646 GB

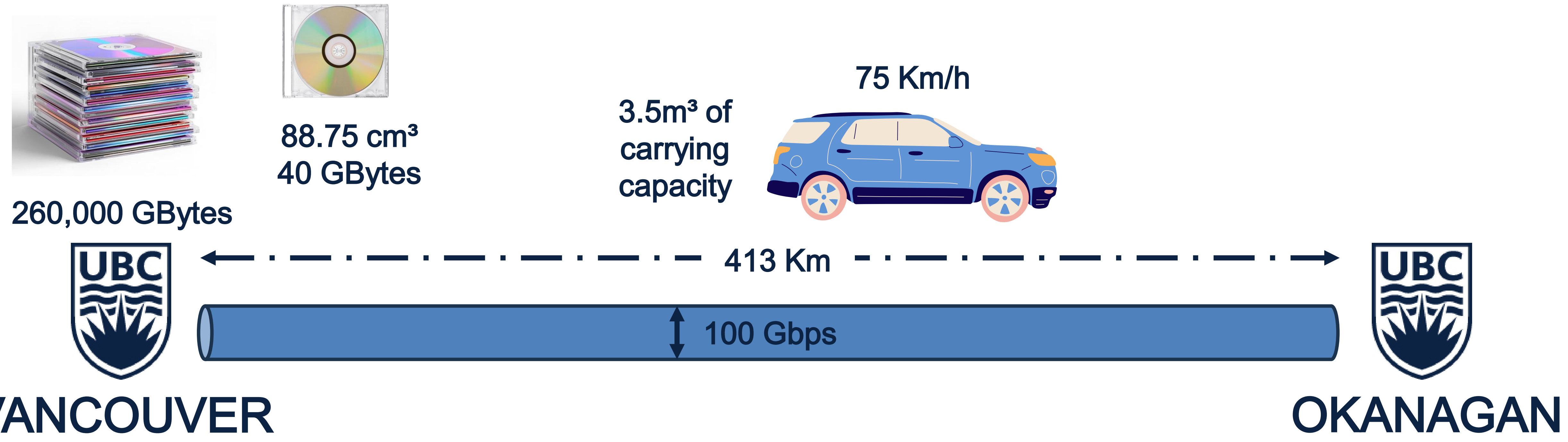
Clicker Question



Which will get **all** the data to UBC-O faster?

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

Clicker Question



Which will get **all** the data to UBC-O faster?

A. **SUV takes 413/75 = 5.51 hours = 330.4 min = 19 824 s**

B. Data size = 260000 GB = 260000 * 8 * 2^{30} bits

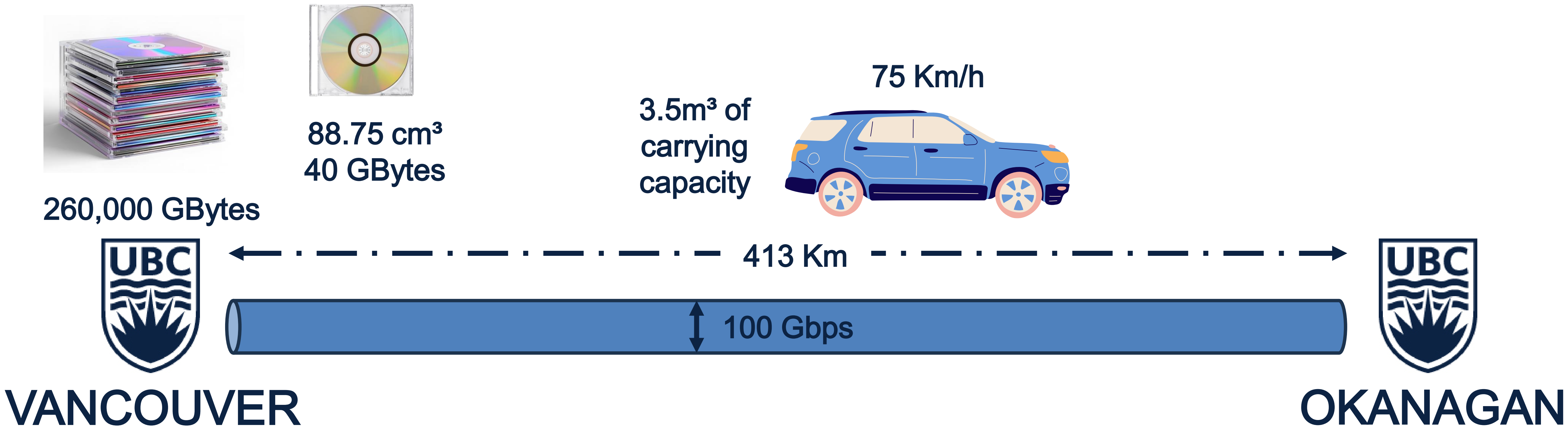
Data rate = 100 Gbps = 100 * 10^9 bps

Network takes (260000* 8 * 2^{30}) / (100 * 10^9) seconds

we divide by 36000= **6.20 hours**

C. Insufficient data to determine

Clicker Question



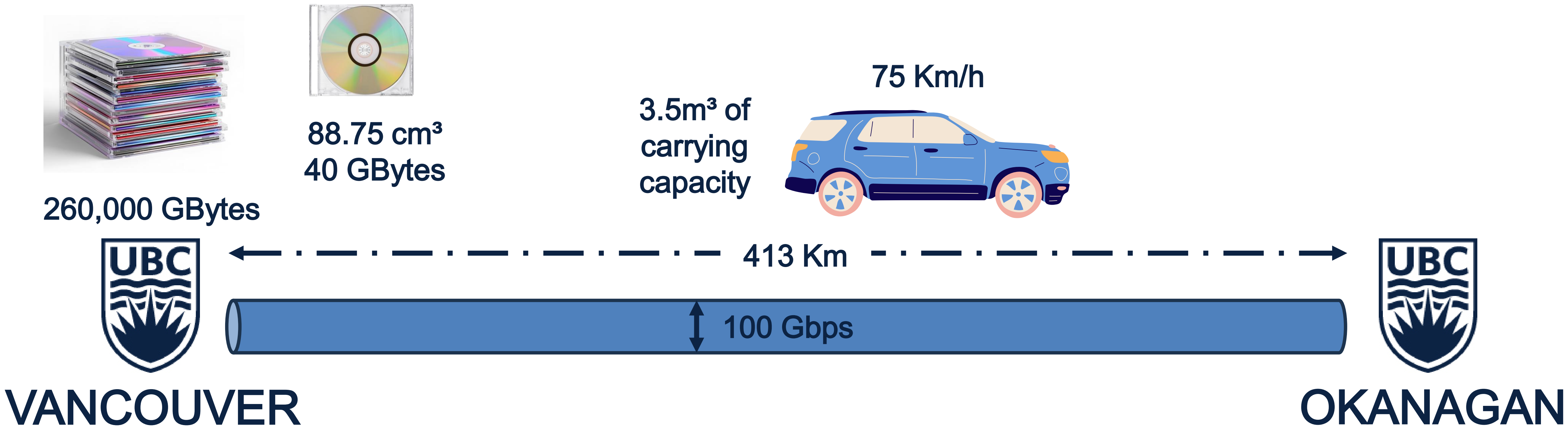
What is the effective goodput of the SUV in this scenario?

A. 104.9 Gbps

B. 112.7 Gbps

C. 683.5 Gbps

Clicker Question



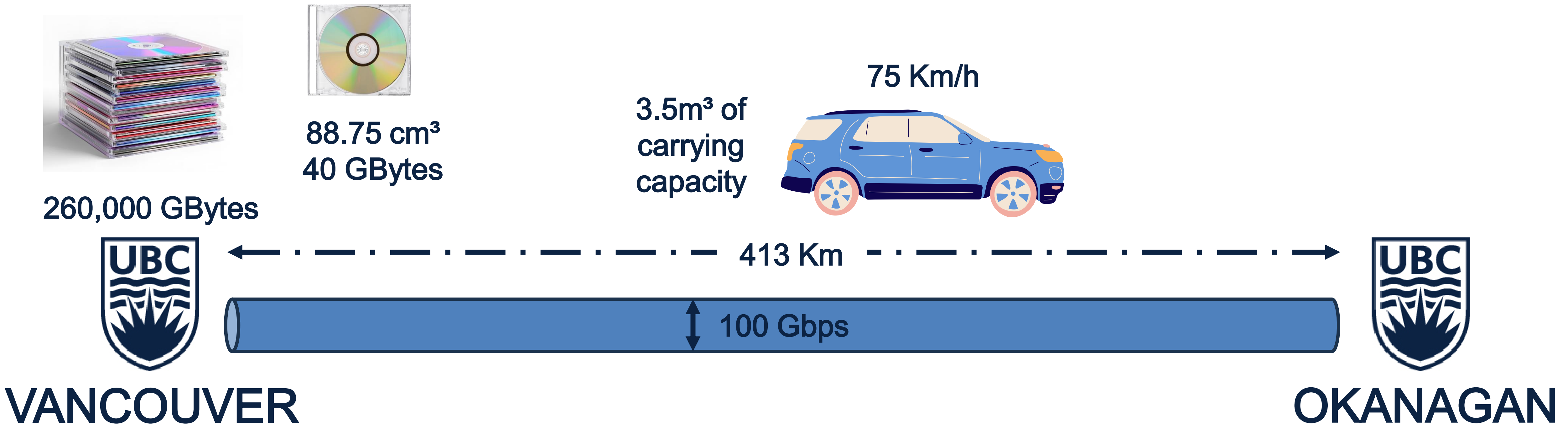
What is the effective goodput of the SUV in this scenario?

A. 104.9 Gbps

B. 112.7 Gbps ($\frac{260\,000 \times 8 \times 2^{30}}{19\,824}$ / 10^9 = 112.7 Gbps)

C. 683.5 Gbps

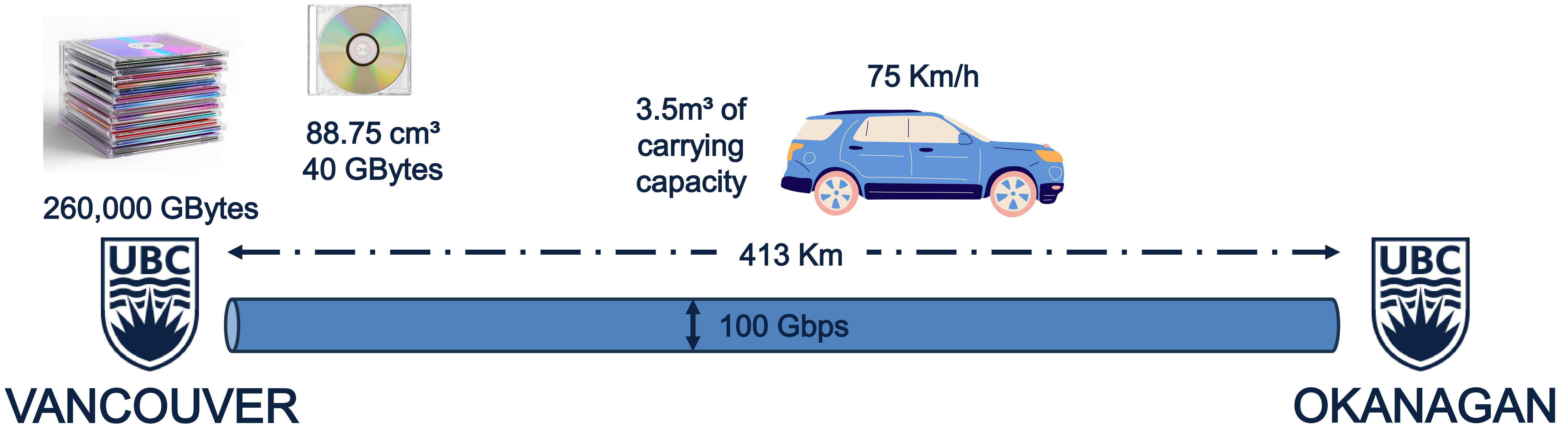
Clicker Question



Assuming the SUV's cargo area is filled with as many Blu-ray discs as possible, what is the maximum goodput of the SUV ?

A. 340.2 Gbps
B. 112.7 Gbps
C. 683.5 Gbps

Clicker Question



Assuming the SUV's cargo area is filled with as many Blu-ray discs as possible, what is the maximum goodput of the SUV ?

A. 340.2 Gbps

B. 112.7 Gbps

C. 683.5 Gbps

$$\frac{3.5 \times 10^6}{88.75} = 39\,436\ discs$$

$$\frac{39\,436 \times 40 \times 8 \times 2^{30}}{19\,824} / \times\ 10^9 = 683.5\ Gbps$$

Actually Used In Real Life

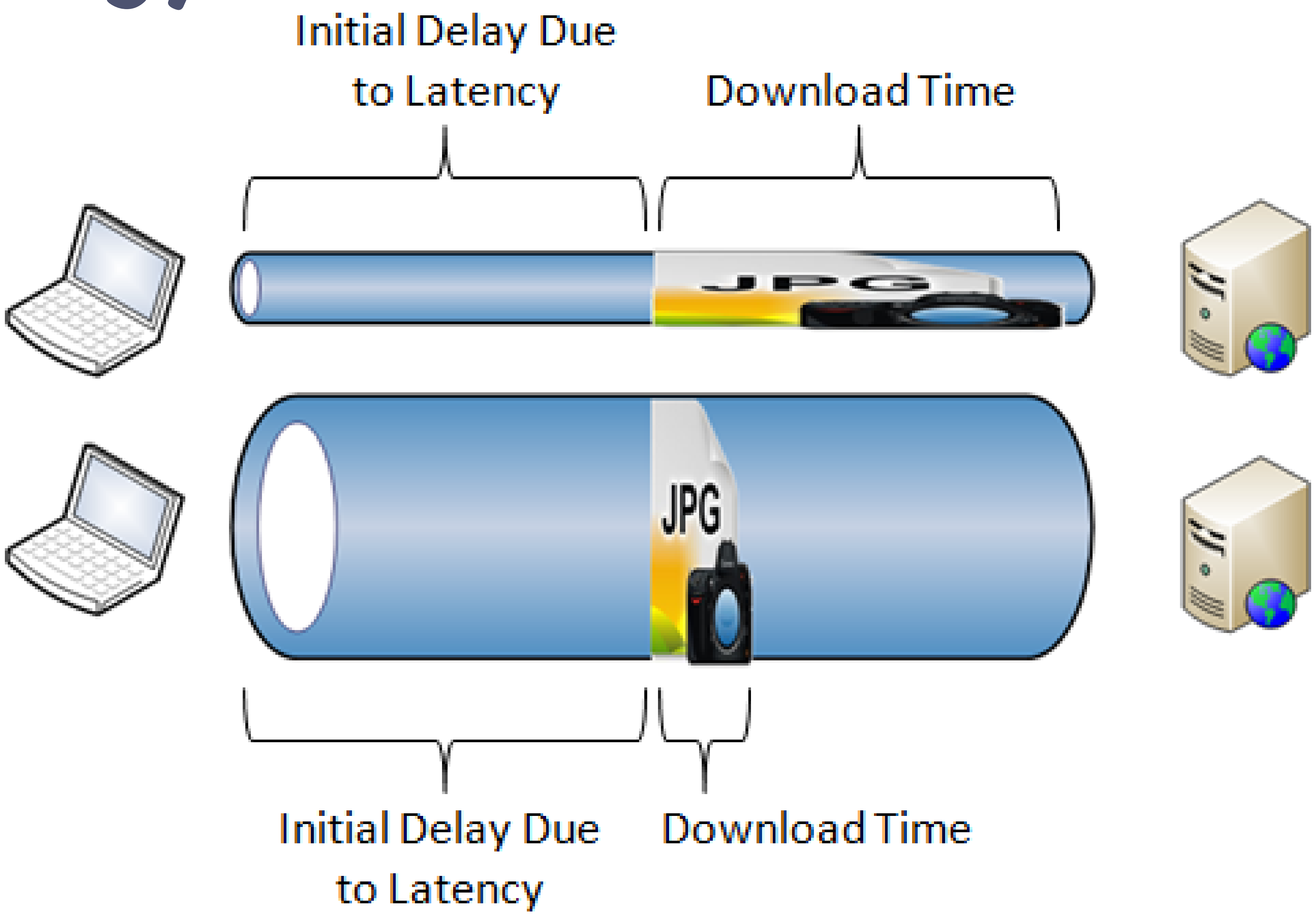
- Amazon snow family
  - Snowcone – up to 22TB – 4.5 lbs
    - https://aws.amazon.com/snowcone/
  - Snowball – up to 210TB – 50 lbs
    - https://aws.amazon.com/snowball/
  - Snowmobile – up to 100PB – 40 tons
    - https://aws.amazon.com/snowmobile/

Snowcone

Snowball

Snowmobile

Pipe Analogy



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

Some facts about latency

- Fact One: Making more bandwidth is easy
- Fact Two: Once you have bad latency you're stuck with it
- Fact Three: Current consumer devices have appallingly bad latency
- Fact Four: Making limited bandwidth go further is easy
- This is not to say bandwidth is unimportant: Bandwidth Still Matters

http://www.stuartcheshire.org/rants/latency.html

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)

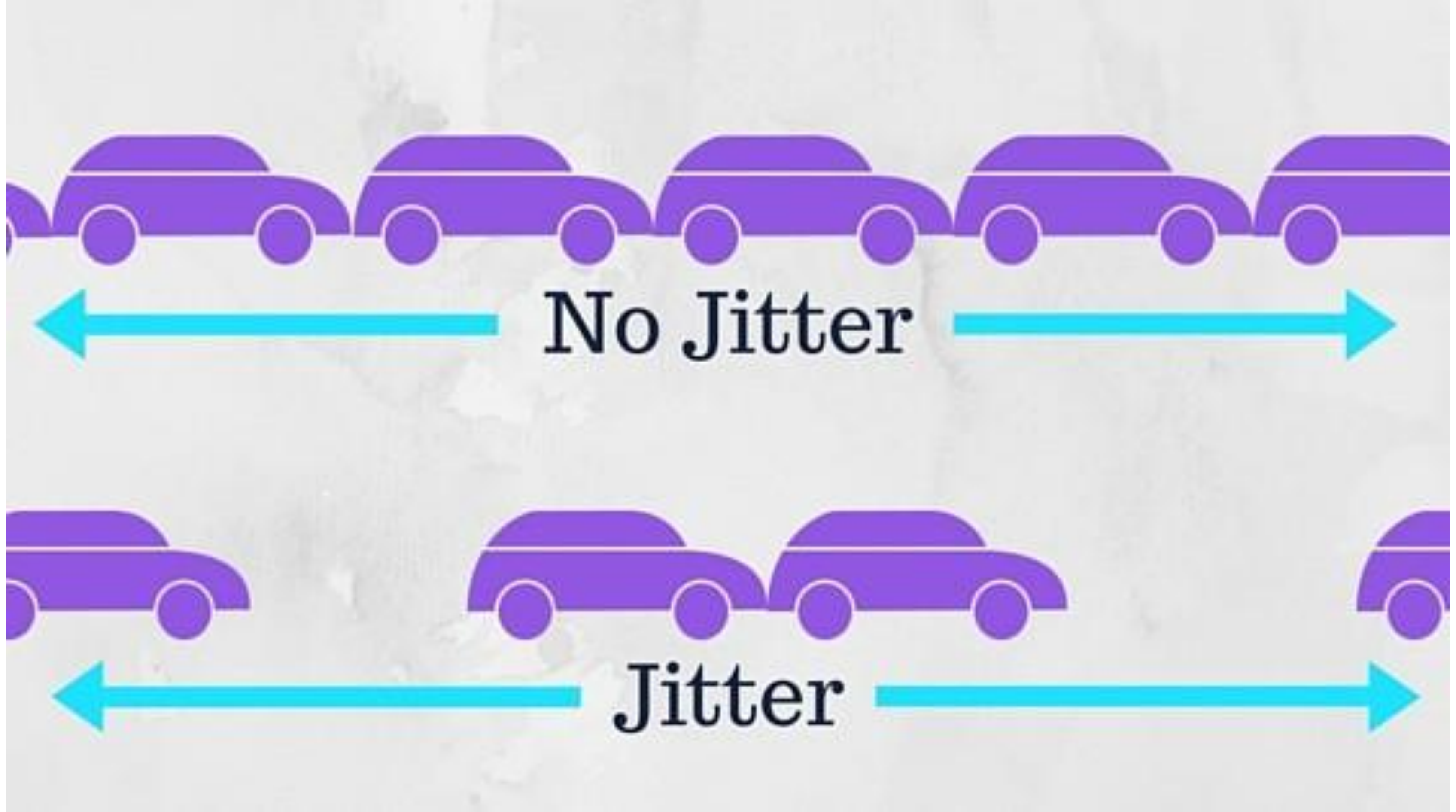
Observe that not all ping times are the same

```
$ 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)

In-class Activity

- ICA21

Next Topic:
Network Performance – Delay