Low-Earth-Orbit (LEO) Satellite Networks

Jinwei Zhao
2024/04/03
About me

• MSc in Computer Science at UVic, 2021/09 – 2023/12
• First year PhD student since 2024/01
• https://pan.uvic.ca/~clarkzjw/

• Current research interests:
  • Network measurement in LEO satellite networks
  • Adaptive video streaming
  • QUIC and its extensions
In CSC361

- HTTP/1.1 → HTTP/2
- DNS
- TCP/UDP
- Congestion control (Cubic, Reno, ...)
- Error control
- Routing
- NAT
- IPv4/IPv6

- Wireshark/tshark/tcpdump
- nslookup/dig
- ip
- ping
- traceroute/mtr
- iperf
- arp

- socket programming
Today’s Topics

What’s beyond CSC361 and what you can do in future graduate studies

Introduction to

• **Measuring the performance of Starlink**
  • Mapping the Starlink global backbone topology
  • A multi-faceted look at Starlink performance globally

• **Cloud gaming over Starlink**
  • VKURA internship project by a first-year undergraduate student last summer

• **Adaptive video streaming over Starlink**
  • My MSc research project
Satellite Internet Access and LEO Constellations

- **Lower latency**
  - RTT < 50 ms

- **Lower launch costs**

- **Achieve higher throughput using mass-produced small satellites**

**O3b mPOWER**
- 8,062 km
- RTT ~125 ms

**Geostationary Orbit**
- GEO
- 35,786 km

**Medium-Earth-Orbit**
- MEO

**Low-Earth-Orbit**
- LEO
- < 2,000 km

**High latency**
- RTT > 800 ms

Figure 1: Schematic of orbital altitudes and coverage areas
Starlink: a new dimension for networking

[3] https://www.reddit.com/r/Starlink/comments/pbfpvs/starlink_is_coming_to_turkey_these_are_starlink/
Starlink: a new dimension for networking

- User dish, satellite, ground station, point-of-presence, exchange point, etc.
  - Mostly "bent-pipe": less delay than GEO satellites but highly dynamic, 20, 40 to 80 ms RTT
  - Inter-satellite links (ISLs) in some regions: longer and more staged delay, 100, 200 and 400 ms RTT
  - Dynamic user-satellite-ground association every 15 seconds
  - User public IP addresses highly reused with carrier-grade NAT (CGNAT) and coarsely geolocated at PoP level
"Bent-pipe" vs ISLs

--- Inter-Satellite Links
--- Satellite-to-Ground Links

UT: User Terminal (Dish)
GS: Ground Station
PoP: Point of Presence

Starlink UT

Starlink GS A
Starlink PoP A

Internet

Starlink PoP B
Starlink GS B
Starlink User Terminal models and hardware revisions
January 2024

REV1 - Original Starlink "Dishy"
- rev1_pre_production
- rev1_production
- rev_rev1_proto3
Years in production: 2020 - 2021

High Performance
- rev_hp1_proto0
- rev_hp1_proto1
Years in production: 2022 -

REV2 - Mass production "Dishy"
- rev2_proto1
- rev2_proto2
- rev2_proto3
- rev2_proto4
Years in production: 2021 - 2022

Flat High Performance
- rev_hp1_proto0
- rev_hp1_proto1
Years in production: 2022 -

REV3 - Standard Actuated
- rev3_proto0
- rev3_proto1
- rev3_proto2
Years in production: 2022 -

REV4 - Standard
- rev4_proto3
- rev4_proto4
- rev4_prod1
Years in production: Q4 2023 -
Mapping the Starlink global backbone topology

Starlink GeoIP database: [https://geoip.starlinkisp.net/feed.csv](https://geoip.starlinkisp.net/feed.csv)

Example:
98.97.32.0/24,US,US-WA,Seattle
170.203.201.0/24,CA,CA-BC,Vancouver

```bash
~ curl -4 ipconfig.io
170.203.201.12

~ curl -6 ipconfig.io
2605:59c8:5da:a000::55e

~ nslookup 170.203.201.12
12.201.203.170.in-addr.arpa name = customer.sttlwax1.pop.starlinkisp.net.

~ nslookup 2605:59c8:5da:a000::55e
e.e.5.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.a.d.5.0.8.c.9.5.5.0.6.2.ip6.arpa
name = customer.sttlwax1.pop.starlinkisp.net.
```

- Normal customers on a Standard plan get a IPv4 address with CGNAT
- Business customers get a public IPv4 address, reachable from the Internet
- With proper configuration, customers can have end-to-end IPv6 connectivity
## Mapping the Starlink global backbone topology

Starlink GeoIP database: [https://geoip.starlinkisp.net/feed.csv](https://geoip.starlinkisp.net/feed.csv)

Example `mtr` result from a device connected to a Starlink dish at UVic to Cloudflare

<table>
<thead>
<tr>
<th>Host</th>
<th>Loss%</th>
<th>Snt</th>
<th>Last</th>
<th>Avg</th>
<th>Best</th>
<th>Wrst</th>
<th>StDev</th>
</tr>
</thead>
<tbody>
<tr>
<td>192.168.1.1 (192.168.1.1)</td>
<td>0.0%</td>
<td>104</td>
<td>0.3</td>
<td>0.4</td>
<td>0.3</td>
<td>0.9</td>
<td>0.1</td>
</tr>
<tr>
<td>100.64.0.1 (100.64.0.1)</td>
<td>0.0%</td>
<td>104</td>
<td>18.0</td>
<td>29.8</td>
<td>16.9</td>
<td>52.3</td>
<td>7.2</td>
</tr>
<tr>
<td>172.16.251.66 (172.16.251.66)</td>
<td>0.0%</td>
<td>104</td>
<td>23.7</td>
<td>29.7</td>
<td>17.8</td>
<td>56.5</td>
<td>8.0</td>
</tr>
<tr>
<td>undefined.hostname.localhost (206.224.64.22)</td>
<td>0.0%</td>
<td>104</td>
<td>26.1</td>
<td>35.4</td>
<td>18.5</td>
<td>110.3</td>
<td>16.5</td>
</tr>
<tr>
<td>undefined.hostname.localhost (206.224.66.143)</td>
<td>0.0%</td>
<td>103</td>
<td>22.6</td>
<td>30.2</td>
<td>17.8</td>
<td>56.4</td>
<td>7.7</td>
</tr>
<tr>
<td>149.19.109.25 (149.19.109.25)</td>
<td>0.0%</td>
<td>103</td>
<td>28.9</td>
<td>35.0</td>
<td>19.8</td>
<td>135.4</td>
<td>15.4</td>
</tr>
<tr>
<td>172.71.144.3 (172.71.144.3)</td>
<td>1.9%</td>
<td>103</td>
<td>23.2</td>
<td>35.3</td>
<td>16.6</td>
<td>98.2</td>
<td>13.3</td>
</tr>
<tr>
<td>one.one.one.one (1.1.1.1)</td>
<td>0.0%</td>
<td>103</td>
<td>25.8</td>
<td>29.6</td>
<td>17.3</td>
<td>50.1</td>
<td>6.9</td>
</tr>
</tbody>
</table>
Mapping the Starlink global backbone topology

In comparison, a mtr result from UVic network to Cloudflare

192.168.0.124 -> 1.1.1.1 (1.1.1.1)

<table>
<thead>
<tr>
<th>Host</th>
<th>Loss%</th>
<th>Snt</th>
<th>Last</th>
<th>Avg</th>
<th>Best</th>
<th>Wrst</th>
<th>StDev</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. _gateway (192.168.0.254)</td>
<td>0.0%</td>
<td>21</td>
<td>0.5</td>
<td>0.5</td>
<td>0.3</td>
<td>0.6</td>
<td>0.1</td>
</tr>
<tr>
<td>2. 142.104.68.1 (142.104.68.1)</td>
<td>0.0%</td>
<td>21</td>
<td>1.2</td>
<td>1.3</td>
<td>0.6</td>
<td>6.4</td>
<td>1.6</td>
</tr>
<tr>
<td>3. 142.104.124.105 (142.104.124.105)</td>
<td>0.0%</td>
<td>20</td>
<td>33.3</td>
<td>4.8</td>
<td>0.7</td>
<td>46.0</td>
<td>12.1</td>
</tr>
<tr>
<td>4. 142.104.100.241 (142.104.100.241)</td>
<td>0.0%</td>
<td>20</td>
<td>1.1</td>
<td>3.1</td>
<td>0.7</td>
<td>44.1</td>
<td>9.7</td>
</tr>
<tr>
<td>5. cle-core-edge.bb.uvic.ca (142.104.100.189)</td>
<td>0.0%</td>
<td>20</td>
<td>1.5</td>
<td>1.4</td>
<td>1.2</td>
<td>1.9</td>
<td>0.2</td>
</tr>
<tr>
<td>6. 207.23.244.233 (207.23.244.233)</td>
<td>0.0%</td>
<td>20</td>
<td>1.7</td>
<td>1.8</td>
<td>1.4</td>
<td>3.5</td>
<td>0.5</td>
</tr>
<tr>
<td>7. 206.12.3.41 (206.12.3.41)</td>
<td>0.0%</td>
<td>20</td>
<td>4.0</td>
<td>3.5</td>
<td>2.9</td>
<td>5.1</td>
<td>0.6</td>
</tr>
<tr>
<td>8. as13335.vanix.ca (206.41.104.52)</td>
<td>0.0%</td>
<td>20</td>
<td>37.7</td>
<td>13.9</td>
<td>4.0</td>
<td>41.6</td>
<td>11.1</td>
</tr>
<tr>
<td>9. one.one.one.one (1.1.1.1)</td>
<td>0.0%</td>
<td>20</td>
<td>3.5</td>
<td>3.3</td>
<td>3.0</td>
<td>3.6</td>
<td>0.2</td>
</tr>
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</table>
Mapping the Starlink global backbone topology

Starlink GeoIP database: https://geoip.starlinkisp.net/feed.csv

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192.168.1.144 -> 1.1.1.1 (1.1.1.1)

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<td>0.0%</td>
<td>104</td>
<td>26.1</td>
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<td>110.3</td>
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</tr>
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</table>

How do we understand these results?
How to correlate them with actual geolocations of routers/switches?
How does Starlink terrestrial backbone connect with the rest of the Internet, globally?
Mapping the Starlink global backbone topology

- Utilize traceroute/mtr
  - “Inside-out”
  - Locally
  - Remote access to other Starlink dishes through global collaborations
- Looking glass servers provided by different ISPs (Known locations)
- RIPE Atlas network probes (User-claimed known locations)
  - “Outside-in”
  - Public reachable customer IPv4/IPv6 addresses
- BGP peering databases
  - Backbone topology
Measuring a Low-Earth-Orbit Satellite Network

Jianping Pan, Jinwei Zhao, Lin Cai

2023 IEEE 34th Annual International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC’23)
Correlate customer GeoIP with PoPs

https://tinyurl.com/starlinkgeoip
A multi-faceted look at Starlink performance globally

If we decrease the packet interval for ping, e.g., 10ms
A multi-faceted look at Starlink performance globally

Averaged RTT at every second:

Latency spikes happen at 12, 27, 42, 57 second of each minute, synchronized globally
## A global Starlink testbed

<table>
<thead>
<tr>
<th>Dish</th>
<th>Location</th>
<th>Hardware Version</th>
<th>Point of Presence (PoP)</th>
<th>Service Tier</th>
</tr>
</thead>
<tbody>
<tr>
<td>victoria</td>
<td>Victoria, BC, CA</td>
<td>rev3_proto2</td>
<td>Seattle</td>
<td>Standard</td>
</tr>
<tr>
<td>victoria_inactive</td>
<td>Victoria, BC, CA</td>
<td>rev3_proto2</td>
<td>Seattle</td>
<td>Inactive</td>
</tr>
<tr>
<td>vancouver</td>
<td>Vancouver, BC, CA</td>
<td>rev2_proto3</td>
<td>Seattle</td>
<td>Standard</td>
</tr>
<tr>
<td>seattle</td>
<td>Seattle, WA, USA</td>
<td>rev3_proto2</td>
<td>Seattle</td>
<td>Standard</td>
</tr>
<tr>
<td>seattle_hp</td>
<td>Seattle, WA, USA</td>
<td>hp1_proto1</td>
<td>Seattle</td>
<td>Priority</td>
</tr>
<tr>
<td>ottawa</td>
<td>Ottawa, ON, USA</td>
<td>rev3_proto2</td>
<td>New York</td>
<td>Standard</td>
</tr>
<tr>
<td>iowa</td>
<td>Iowa City, IA, USA</td>
<td>rev_1_pre_production</td>
<td>Chicago</td>
<td>Standard</td>
</tr>
<tr>
<td>denver</td>
<td>Denver, CO, USA</td>
<td>rev3_proto2</td>
<td>Denver</td>
<td>Mobile, Roam</td>
</tr>
<tr>
<td>louvain</td>
<td>Louvain, Belgium</td>
<td>rev3_proto2</td>
<td>Frankfurt</td>
<td>Standard</td>
</tr>
<tr>
<td>seychelles</td>
<td>Seychelles</td>
<td>rev3_proto2</td>
<td>Lagos / Frankfurt</td>
<td>Mobile, Roam</td>
</tr>
<tr>
<td>alaska</td>
<td>Anchorage, AK, USA</td>
<td>rev3_proto2</td>
<td>Seattle</td>
<td>Mobile</td>
</tr>
<tr>
<td>calgary</td>
<td>Calgary, AB, CA</td>
<td>rev3_proto2</td>
<td>Seattle</td>
<td>Inactive</td>
</tr>
<tr>
<td>dallas</td>
<td>Oxford, MS, USA</td>
<td>rev3_proto2</td>
<td>Dallas</td>
<td>Inactive</td>
</tr>
<tr>
<td>edinburgh</td>
<td>Edinburgh, UK</td>
<td>rev3_proto2</td>
<td>London</td>
<td>Standard</td>
</tr>
<tr>
<td>wroughton</td>
<td>Wroughton, UK</td>
<td>rev2_proto2</td>
<td>London</td>
<td>Standard</td>
</tr>
</tbody>
</table>
LENS: A LEO Satellite Network Measurement Dataset

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Jianping Pan
University of Victoria
Victoria, BC, Canada
pan@uvic.ca

https://github.com/clarkzjw/LENS

Legend:
- Red: Obstruction
- Black: No data
- White: Unobstructed
Latency performance

Utilization of ISLs

Fewer satellites in orbits above 53° inclination
Side-by-side dishes
Side-by-side dishes
Starlink vs OneWeb

- **Starlink**
  - Initially target consumer users
  - Mostly 53-degree inclination
  - Mostly 550km above the Earth
  - Spotting beams for individual dishes
    - Ku for UT and Ka for GS
  - Currently >5000 active satellites
    - All launched by SpaceX
  - Currently >100 ground stations
  - Many PoPs around the world
  - Lower but relatively fluctuating RTT
    - Due to Spotting beams
    - UT-Sat-GS shuffling every 15 seconds

- **OneWeb**
  - Currently target enterprise users
  - Polar orbits
  - Above 1000km in altitude
  - Sweeping beams for community dishes
    - Similarly Ku and Ka
  - Currently ~600 active satellites
    - Limited 3rd-party launch capacity
  - Currently ~10 ground stations
  - Very few customer PoPs now
  - High but relatively stable RTT to PoP
Starlink vs OneWeb
Applications

(a) E2E Latency

(b) Downlink Throughput

Figure 3.4: Time synchronized RTT and downlink throughput

(a) Uplink OWD

(b) Downlink OWD

Figure 3.5: Time synchronized One-Way Delay (OWD)
Applications

• Starlink employs a time synchronized scheduler across the globe to perform satellite handover events **every 15 seconds**.
• The handover timestamps are fixed at 12-27-42-57 seconds of every minute.
• There are latency spikes and packet losses when satellite handover events happen.
• The TCP throughput performance is affected and goes through slow-start pattern after handover events.
Applications - Cloud gaming

Analyzing the Performance of Cloud Gaming over Low-Earth Orbit Satellite Networks

By Pouria Tolouei

Supervised by Dr. Jianping Pan
Mentored by Jinwei Zhao
Supported by the Valerie Kuehne Undergraduate Research Awards (VKURA)
Applications - Cloud gaming

Methods (Measurements)

- Collected (GFN Network Stats Overlay)
  - Ping (ms)
  - Packet Loss (# of packets)
  - Used and Available Bandwidth (Mbps)
  - Resolution
  - Stream FPS

- Measured
  - Input latency (ms)
  - * Approximated using screenshots
Applications - Cloud gaming

Methods (Measurements)

- Method for measuring input latency
  - Press the key (virtually) to boost the car forward every 1 second
  - Record the keystroke timestamp (input time)
  - Observe a pixel in the car exhaust and look for a red color change
    - Using screenshots
    - Each screenshot has an average latency of 53 ms
  - Record the color change timestamp (action time)
  - Subtract the two timestamps to get input latency
## Applications - Cloud gaming

<table>
<thead>
<tr>
<th>Applications</th>
<th>Ping (ms) (mean)</th>
<th>Input Latency (ms) (mean)</th>
<th>Round Packet Loss (mean)</th>
<th>Round Packet Loss (%) (mean)</th>
<th>Available Bandwidth (Mbps) (mean)</th>
<th>Used Bandwidth (Mbps) (mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Victoria Telus vs. Victoria Telus (Same)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Victoria Telus 1</td>
<td>31.42</td>
<td>72.99</td>
<td>62.27</td>
<td>0.025%</td>
<td>82.33</td>
<td>19.18</td>
</tr>
<tr>
<td>Victoria Telus 2</td>
<td>31.21</td>
<td>74.61</td>
<td>62.10</td>
<td>0.025%</td>
<td>81.86</td>
<td>19.34</td>
</tr>
<tr>
<td><strong>Victoria Telus vs. Victoria Telus (Different)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Victoria Telus 1</td>
<td>31.51</td>
<td>72.00</td>
<td>0.40</td>
<td>0.000%</td>
<td>83.75</td>
<td>19.27</td>
</tr>
<tr>
<td>Victoria Telus 2</td>
<td>42.65</td>
<td>91.72</td>
<td>447.125</td>
<td>0.179%</td>
<td>57.95</td>
<td>18.03</td>
</tr>
<tr>
<td><strong>Victoria Starlink vs. Victoria Telus</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Victoria Starlink</td>
<td>67.04</td>
<td>116.92</td>
<td>460.04</td>
<td>0.184%</td>
<td>56.87</td>
<td>15.89</td>
</tr>
<tr>
<td>Victoria Telus</td>
<td>31.41</td>
<td>74.64</td>
<td>16.88</td>
<td>0.007%</td>
<td>82.80</td>
<td>19.22</td>
</tr>
<tr>
<td><strong>Victoria Starlink vs. Victoria Starlink</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Victoria Starlink 1</td>
<td>70.26</td>
<td>121.68</td>
<td>730.75</td>
<td>0.292%</td>
<td>46.75</td>
<td>15.17</td>
</tr>
<tr>
<td>Victoria Starlink 2</td>
<td>70.41</td>
<td>121.56</td>
<td>862.04</td>
<td>0.345%</td>
<td>46.54</td>
<td>15.19</td>
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<td><strong>Victoria Starlink vs. Vancouver Starlink</strong></td>
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<tr>
<td>Victoria Starlink</td>
<td>67.44</td>
<td>116.95</td>
<td>608.60</td>
<td>0.243%</td>
<td>57.30</td>
<td>16.02</td>
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<tr>
<td>Vancouver Starlink</td>
<td>65.88</td>
<td>118.32</td>
<td>727.04</td>
<td>0.291%</td>
<td>61.60</td>
<td>16.29</td>
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<td><strong>Victoria Starlink vs. Ottawa Starlink</strong></td>
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<tr>
<td>Victoria Starlink</td>
<td>65.29</td>
<td>117.24</td>
<td>745.54</td>
<td>0.298%</td>
<td>59.78</td>
<td>17.43</td>
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<tr>
<td>Ottawa Starlink</td>
<td>60.57</td>
<td>106.84</td>
<td>597.60</td>
<td>0.239%</td>
<td>51.49</td>
<td>13.85</td>
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</table>
## Applications - Cloud gaming

<table>
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<tr>
<th></th>
<th>Ping (ms) (SD)</th>
<th>Input Latency (ms) (SD)</th>
<th>Round Packet Loss (SD)</th>
<th>Round Packet Loss (%) (SD)</th>
<th>Available Bandwidth (Mbps) (SD)</th>
<th>Used Bandwidth (Mbps) (SD)</th>
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<tbody>
<tr>
<td><strong>Victoria Telus vs. Victoria Telus (Same)</strong></td>
<td></td>
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<tr>
<td>Victoria Telus 1</td>
<td>1.53</td>
<td>25.50</td>
<td>177.72</td>
<td>0.071%</td>
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<td>1.73</td>
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<td>12.54</td>
<td>1.69</td>
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<td><strong>Victoria Telus vs. Victoria Telus (Different)</strong></td>
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<td>Victoria Telus 1</td>
<td>1.40</td>
<td>20.09</td>
<td>2.60</td>
<td>0.001%</td>
<td>12.16</td>
<td>1.55</td>
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<tr>
<td>Victoria Telus 2</td>
<td>8.87</td>
<td>39.37</td>
<td>107.91</td>
<td>0.043%</td>
<td>12.82</td>
<td>3.03</td>
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<td><strong>Victoria Starlink vs. Victoria Telus</strong></td>
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<tr>
<td>Victoria Starlink</td>
<td>26.50</td>
<td>84.68</td>
<td>435.34</td>
<td>0.174%</td>
<td>18.50</td>
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<td>25.15</td>
<td>48.42</td>
<td>0.019%</td>
<td>12.85</td>
<td>1.61</td>
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<td>Victoria Starlink 1</td>
<td>27.93</td>
<td>87.10</td>
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<td>0.257%</td>
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<td>29.05</td>
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<td>925.39</td>
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<td>4.97</td>
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<td>Victoria Starlink</td>
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<td>76.52</td>
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<td>91.47</td>
<td>419.68</td>
<td>0.168%</td>
<td>21.58</td>
<td>4.91</td>
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<tr>
<td>Victoria Starlink</td>
<td>21.27</td>
<td>82.65</td>
<td>590.57</td>
<td>0.236%</td>
<td>16.09</td>
<td>4.11</td>
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<td>82.22</td>
<td>296.46</td>
<td>0.119%</td>
<td>24.37</td>
<td>5.06</td>
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Applications - Low latency live video streaming
Applications - Low latency live video streaming

(a) Emulation  
(b) Starlink  
(c) Terrestrial

Figure 6: Average live latency
Applications - Low latency live video streaming

Figure 7: Average bitrate
Applications - Low latency live video streaming

(a) Emulation

(b) Starlink

(c) Terrestrial

Figure 8: Rebuffering time ratio (%)
Applications - Low latency live video streaming

Figure 9: Number of bitrate switches
Applications - Low latency live video streaming

Figure 10: Bitrate standard deviation
Our works

- **LENS: A LEO Satellite Network Measurement Dataset**
  - Jinwei Zhao, Jianping Pan
  - *2024 ACM 15th Multimedia Systems Conference Open-Source software & Datasets track (MMSys'24 ODS)*

- **Measuring the Satellite Links of a LEO Network**
  - Jianping Pan, Jinwei Zhao
  - *2024 IEEE 59th International Conference on Communications (ICC'24)*

- **Low Latency Live Video Streaming over a Low-Earth-Orbit Satellite Network with DASH**
  - Jinwei Zhao, Jianping Pan
  - *2024 ACM 15th Multimedia Systems Conference (MMSys'24)*

- **Measuring a Low-Earth-Orbit Satellite Network**
  - Jianping Pan, Jinwei Zhao, Lin Cai
  - *2023 IEEE 34th Annual International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC'23)*
Our works - Ongoing

- Understand the satellite selection strategy with obstruction maps and inter-satellite links
- Develop new congestion control algorithms suitable for the dynamic satellite networks
- Multipath protocols
  - Evaluate and improve the multipath QUIC (MPQUIC) performance over LEO satellite networks
  - Supported by NSERC USRA Award
Interested?

Experience Starlink near ECS404

Come near ECS404 and connect to WiFi SSID @starlink.
Feel free to ping, mtr, traceroute (tracert on Windows), speedtest, etc.

Opportunities to get involved
• JKURA
• NSERC USRA
• CSC 461 (Multimedia Systems), CSC 466 (Overlay and Peer-to-Peer Networking)
• CSC 499
• Graduate programs
• ......