Research on Low-Earth-Orbit (LEO) Satellite Networks @PanLab

Jinwei Zhao
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PANDA
Parallel, Networking and Distributed Applications

About Me

Jinwei Zhao
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- First year PhD student in the Department of Computer Science at the University of Victoria (UVic)
- Obtained my MSc in Computer Science at UVic in December 2023
- Advised by Dr. Jianping Pan

- **Research interests**:
- Network measurement on Low-Earth-Orbit (LEO) satellite networks (Starlink/OneWeb)
- Networked multimedia systems, such as adaptive video streaming

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PanLab @UVic

Current Members

- 1 Postdoc
- 5 PhD students (including 1 visiting PhD student)
- 4 MSc students

Recent research projects

- Space-Air-Ground-Aqua (SAGA) networks:
  - UAV, HAP, GEO/MEO/LEO (e.g., Starlink, OneWeb)
- Wireless sensor networks:
  - data collection, energy replenishment, battery management, etc.
- Industrial Internet of Things (IIoT):
  - deterministic and time-sensitive networking
- Protocols for advanced networking:
  - flow/error/congestion control, scheduling, routing, (multipath) TCP/QUIC
- Performance analysis and improvement of networked systems:
  - reinforcement learning, multi-armed bandit
- Network security

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LEO Satellite Networks

https://oac.uvic.ca/starlink

Measuring Starlink access network and global backbone

Measuring the Satellite Links of a LEO Network
Jianping Pan, Jinwei Zhao, Lin Cai
2024 IEEE 59th International Conference on Communications (ICC’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)

Application adaptation and performance enhancement over LEO networks

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)
DASH-IF Excellence in DASH Award Third Place

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

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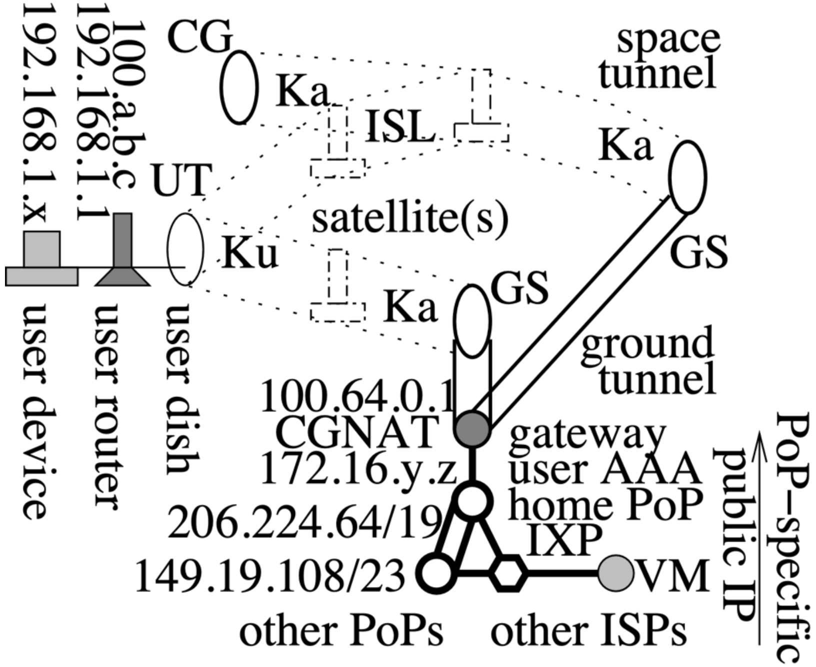
Starlink in a nutshell

- An ***outgoing*** packet's journey to the Internet (reverse for the incoming one)
  - User devices
    - 192.168.1.*x* if the default gateway is at 192.168.1.1/24
  - **User <u>router</u>** (User Terminal Router, **UTR**, provided by Starlink, can be *replaced* or *bypassed*)
    - LAN: 192.168.1.1 (by default)
    - WAN: **100.64/10** (*unique* per user dish)
  - **User dish** (Antenna, **UTA**, provided by Starlink)
    - 192.168.**100**.1 (*fixed* address as modem)
  - ***Satellite**** (inter-satellite links, ISLs, if possible)
  - Landing ground station (**GS**, transparent to IP)
  - <u>CGNAT</u> (Carrier-Grade NAT) gateway (GW)
    - **100.64.0.1** (or public IP user's gateway)
  - Home **PoP** (Point-of-Presence) entry
    - 172.16/12
  - PoP, other PoPs/ISPs, IXPs, etc: the **Internet**

1 IP hop



[1]

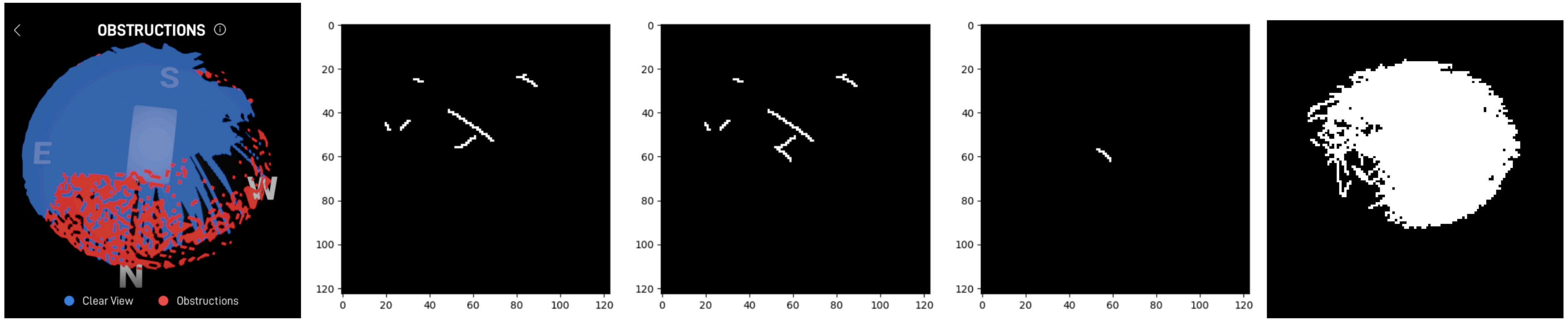
[1] Measuring the Satellite Links of a LEO Network, Jianping Pan, Jinwei Zhao, Lin Cai
2024 IEEE 59th International Conference on Communications (ICC'24)

Notable Related Work

1. Making Sense of Constellations: Methodologies for Understanding Starlink's Scheduling Algorithms

Hammas Bin Tanveer, Mike Puchol, Rachee Singh, Antonio Bianchi, and Rishab Nithyanand. CoNEXT'23. https://doi.org/10.1145/3624354.3630586

- Previously, Starlink exposes information about the connected satellite through dish's gRPC interface, but such information was later removed through firmware updates due to various reasons.
- In this paper, the authors first utilized the obstruction map data from Starlink gRPC interface and the public Two-Line Element (TLE) data for Starlink satellites to identify the current connected satellite for the dish.



(a) Starlink app. (b) gRPC($x-1$) (c) gRPC(x) (d) gRPC($x-1$) $\oplus$ gRPC(x) (e) gRPC map after 2 days.

Figure 3: Obstruction maps (a) obtained from the Starlink app, (b, c) obtained from gRPC for two consecutive 15-second slots $x-1$ and x, (d) their XOR, and (e) the gRPC map after two days without a terminal reset.

Notable Related Work

2. Democratizing LEO Satellite Network Measurement

Liz Izhikevich, Manda Tran, Katherine Izhikevich, Gautam Akiwate, and Zakir Durumeric. Proceedings of the ACM on Measurement and Analysis of Computing Systems. March 2024. https://doi.org/10.1145/3639039

- In this paper, the authors conducted the "outside-in" approach, utilizing Starlink users with public IPv4 addresses, to observe the global latency performance.
- However, most Starlink users are behind CGNAT over IPv4.
- Only Starlink users on the Priority plan with the public IP option are reachable from the Internet.

- SpaceX deploys a dual-stack network, where the IPv6 address of the user router are always reachable from the Internet.
- Utilizing IPv6 with the "outside-in" approach can significantly increase the measurement capabilities.

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Measuring Starlink Access Network and Global Backbone

Addressing and naming information we can obtain

- **Starlink ISP AS number**
  - 14593 (in all regions except Indonesia)
  - 45700 (Indonesia)

- **Starlink IP address allocation**
  - e.g., https://bgp.he.net/AS14593#_prefixes
    - 102.215.59.0/24 Starlink Internet Services Nigeria Ltd

- **Starlink GeoIP feed**
  - at https://geoip.starlinkisp.net
    - e.g., 102.215.57.0/24,NG,NG-LA,Lagos

- **Starlink authoritative DNS PTR record**
  - Reflect Point-of-Presence (PoP) info, e.g., nslookup 102.215.57.10
    - 10.57.215.102.in-addr.arpa name = customer.lgosnga1.pop.starlinkisp.net.
    - i.e., a customer associated with the Lagos PoP, Nigeria, Africa
    - customer.xxx.pop.starlinkisp.net, xxx: user's PoP association

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Peering and routing information we can obtain

- Peering DB https://www.peeringdb.com/asn/14593
  - Public peering exchange points
    - IXPN Lagos 14593 100G RS PEER BFD Support 196.216.148.128 2001:43f8:bb1::128
    - IXPN Lagos 14593 100G RS PEER BFD Support 196.216.148.129 2001:43f8:bb1::129
  - Interconnection facilities
    - MainOne MDXi Lagos 14593 Nigeria Lagos

- More about peering and routing
  - AS info: https://bgp.he.net/AS14593#_asinfo
  - Route propagation: https://bgp.he.net/AS14593#_graph4 (and IPv6 too)
  - Address prefixes: https://bgp.he.net/AS14593#_prefixes (and IPv6 too)
  - Peers info: https://bgp.he.net/AS14593#_peers (and IPv6 too)
  - WHOIS info: https://bgp.he.net/AS14593#_whois
  - Internet routing registry (IRR) info: https://bgp.he.net/AS14593#_irr
  - Internet exchange point (IXP) info: https://bgp.he.net/AS14593#_ix

Measurement we can do (without a Starlink dish)

- https://bgp.he.net/AS14593#_traceroute
  - Probes mostly from RIPE Atlas hosted by Starlink users (also GlobalPing and perfSONAR)
    - currently about 77 active probes on Starlink
    - in AU (2), BE (2), BJ(1), CA (8, including ours), DE (5), ES (2), FR (10), GB (5), GR (1), GU (1), HN (1), HT (2), IT (1), KI (1), PH (1), PL (2), US (30), and VI (1)
    - way behind Starlink's global availability for 3M+ users in 100+ countries and regions

- More systematically at RIPE Atlas
  - http://tinyurl.com/starlinkatlas
    - including some non-public probes: CA (+1), FR (+1), GU (+1), HN (1), SE (1), US (+3)
  - RIPE Atlas has CLI interface for easy automation
    - measurement credits needed
  - Limited by sparse time and space granularity
    - e.g., Ping interval and count, etc
    - no mtr alike capability, etc

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Measurement we can do (with a Starlink dish)

- Anything ethically
  - Ping to CGNAT (100.64.0.1) or public IP user's gateway
  - Ping to any Starlink or Internet destination
    - might be filtered out on the Internet
    - also affected by Internet traffic
  - Traceroute or mtr to any Starlink or Internet destination
    - hop-by-hop interface IP and latency
    - Starlink uses MPLS for user traffic, so RTT might be inflated
      - backbone destination not affected
  - IRTT, iPerf3 and many others with a time-sync'ed VM near the Starlink PoP

- With Starlink's known backbone address space (probed in [1])
  - Mostly 149.19.108/23 and increasingly 206.224.64/19
  - Systematic traceroute and mtr for minimal/best RTT
  - We created the first Starlink backbone map published in 2023

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[1] Measuring the Satellite Links of a LEO Network, Jianping Pan, Jinwei Zhao, Lin Cai
2024 IEEE 59th International Conference on Communications (ICC'24)

Measurement we can do (with inactive Starlink dishes)

- Inactive dish == no active service subscription (service canceled or paused)
  - Dish must be powered on
    - to receive firmware update
    - another Internet connection for remote access if needed
  - IPv4 gateway
    - reachable by ARPing
  - IPv6 gateway (`fe80::200:5eff:fe00:101`)
    - reachable by Ping
  - Certain Starlink Internet destinations
    - reachable by (HTTP)ing
    - e.g., connect.starlink.com
    - to be able to resume the service
- Greatly increase the measurement capability
  - Especially for satellite access network performance published in 2024
  - https://api.starlink.com/public-files/StarlinkLatency.pdf

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Measurement we can do (without any Starlink dishes)

- Outside-in ethically
  - Public IPv4 address at the user router
    - however, most Starlink users are behind CGNAT
  - Public IPv6 address always available at the user router
    - massive IPv6 address space makes it much slower
    - Starlink IPv6 address allocation and structure might help
  - Better from a VM near the Starlink PoP
    - focus on the satellite hop, not affected by the Internet
  - Some hosted “public” services
    - e.g., https://search.censys.io/
    - 19,000 hosts: 6,361 in US; 1,817 CA; 1,339 AU; 1,144 Chile; 943 Mexico; 859 Germany, etc.
    - 4,100 Fortinet, 3,089 SonicWall, 2,615 nginx; 2,146 Peplink; 2,060 Microsoft, etc.
    - SSL certificates: organization name, location, business, etc.
  - More sophisticated measurements possible

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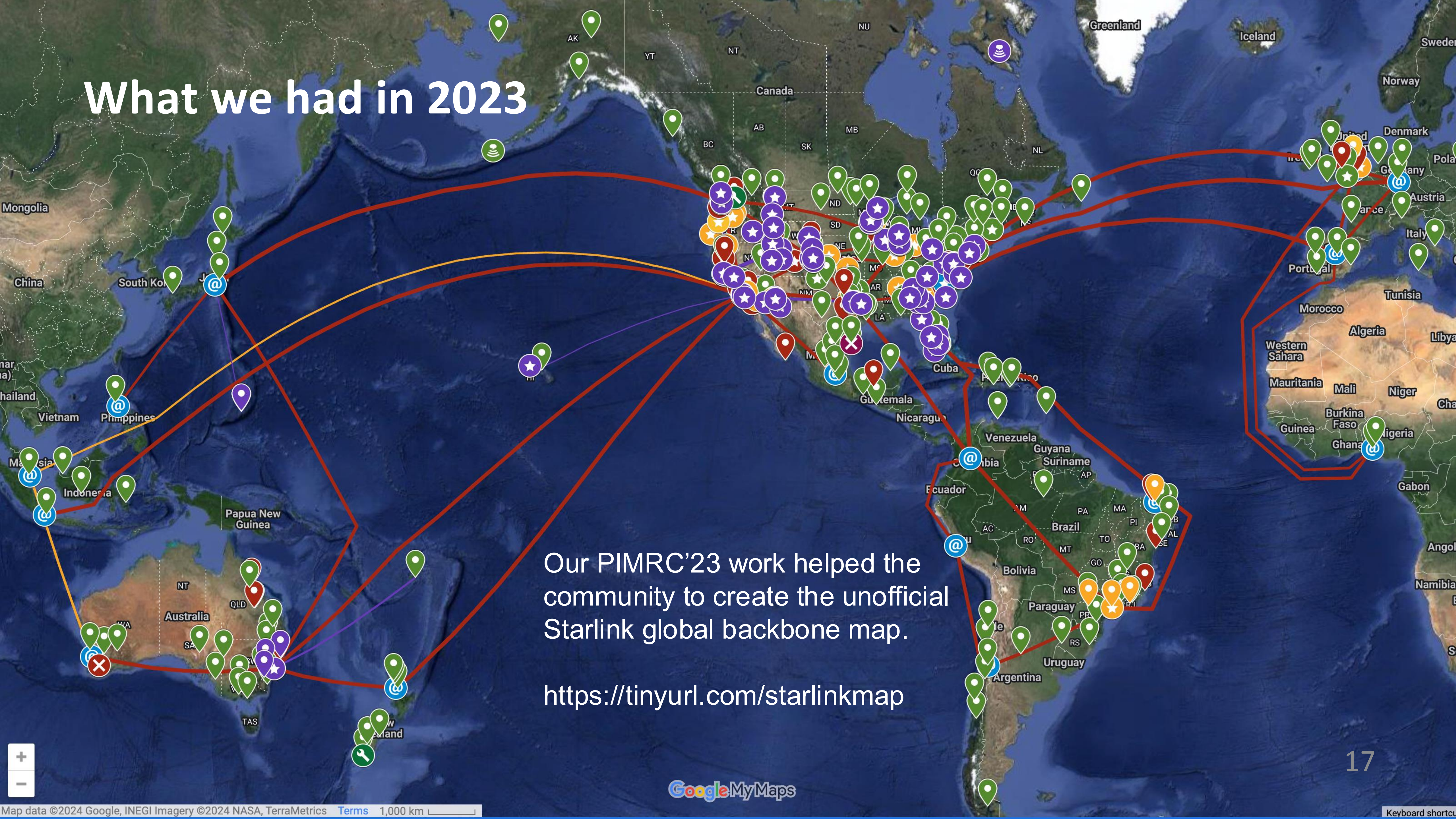
What we had in 2023



Our PIMRC’23 work helped the community to create the unofficial Starlink global backbone map.

https://tinyurl.com/starlinkmap

What’s changed in 2024?

- 6 new PoPs in the US
  - Previously: Seattle, Chicago, Denver, Los Angeles, Dallas, Atlanta, New York City
  - New: San Jose, Salt Lake City, Phoenix, Minneapolis, Ashburn, Miami
- New PoPs in Asian Pacific
  - Previously: Tokyo, Sydney, Auckland
  - New: Perth, Manila, Singapore, Jakarta
  - Upcoming: Mumbai, Karachi
- Others around the world
  - Previously: Mexico City, Bogota, Fortaleza, São Paulo, Santiago, Lima; London, Frankfurt, Madrid; Lagos
  - Upcoming: Amsterdam, Papua New Guinea (?), Sofia (Bulgaria) (?)
  - Community gateways: Dutch Harbor (Alaska), Iqaluit (Canada) (?)
- An updated backbone map is needed, possibly mapped to the fiber layer

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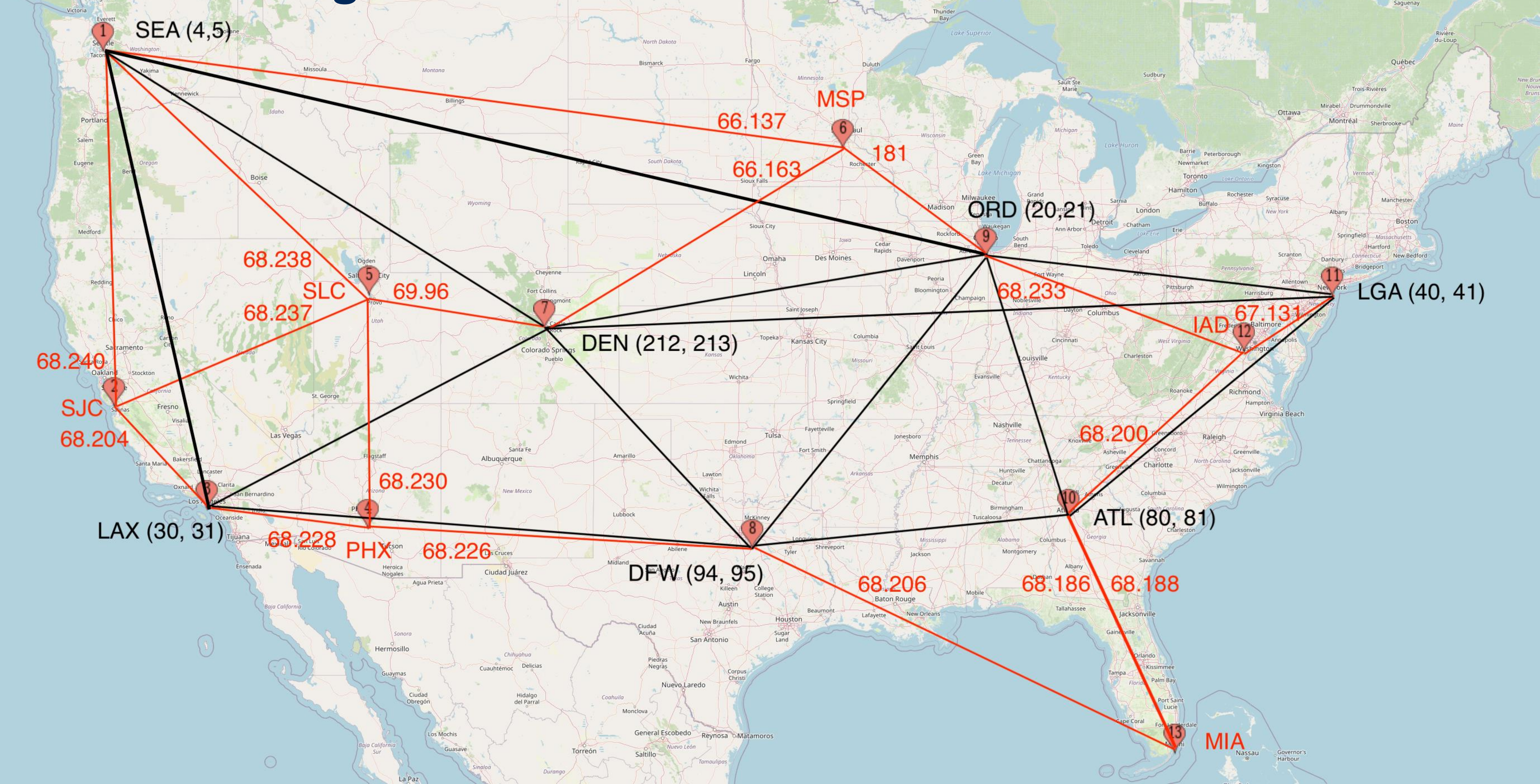
What’s changed in 2024?



Our global Starlink testbed

Thanks to our alumni and external collaborators!

Dish	Location	Hardware Version	PoP
victoria	Victoria, BC, CA	rev3_proto2	Seattle
vancouver	Vancouver, BC, CA	rev2_proto3	Seattle
calgary	Calgary, AB, CA	rev3_proto2	Seattle
ottawa	Ottawa, ON, CA	rev3_proto2	New York
ulukhaktok	Ulukhaktok, NT, CA	rev3_proto2	Seattle
seattle	Seattle, WA, USA	rev3_proto2	Seattle
seattle_hp	Seattle, WA, USA	hp1_proto1	Seattle
alaska	Anchorage, AK, USA	rev3_proto2	Seattle
denver	Denver, CO, USA	rev3_proto2	Denver
slc	Salt Lake City, UT, USA	rev_1_pre_production	Salt Lake City / Seattle
iowa	Iowa City, IA, USA	rev_1_pre_production	Chicago
dallas	Oxford, MS, USA	rev3_proto2	Dallas
stanford	Stanford, CA, USA	rev3_proto2	San Jose
louvain	Louvain, Belgium	rev3_proto2	Frankfurt / London
bruhl	Brühl, Germany	rev4_prod2	Frankfurt
kanazawa	Kanazawa, Japan	rev3_proto2	Tokyo
brisbane	Brisbane, Australia	rev3_proto2	Sydney
seychelles	Victoria, Seychelles	rev3_proto2	Lagos / Frankfurt

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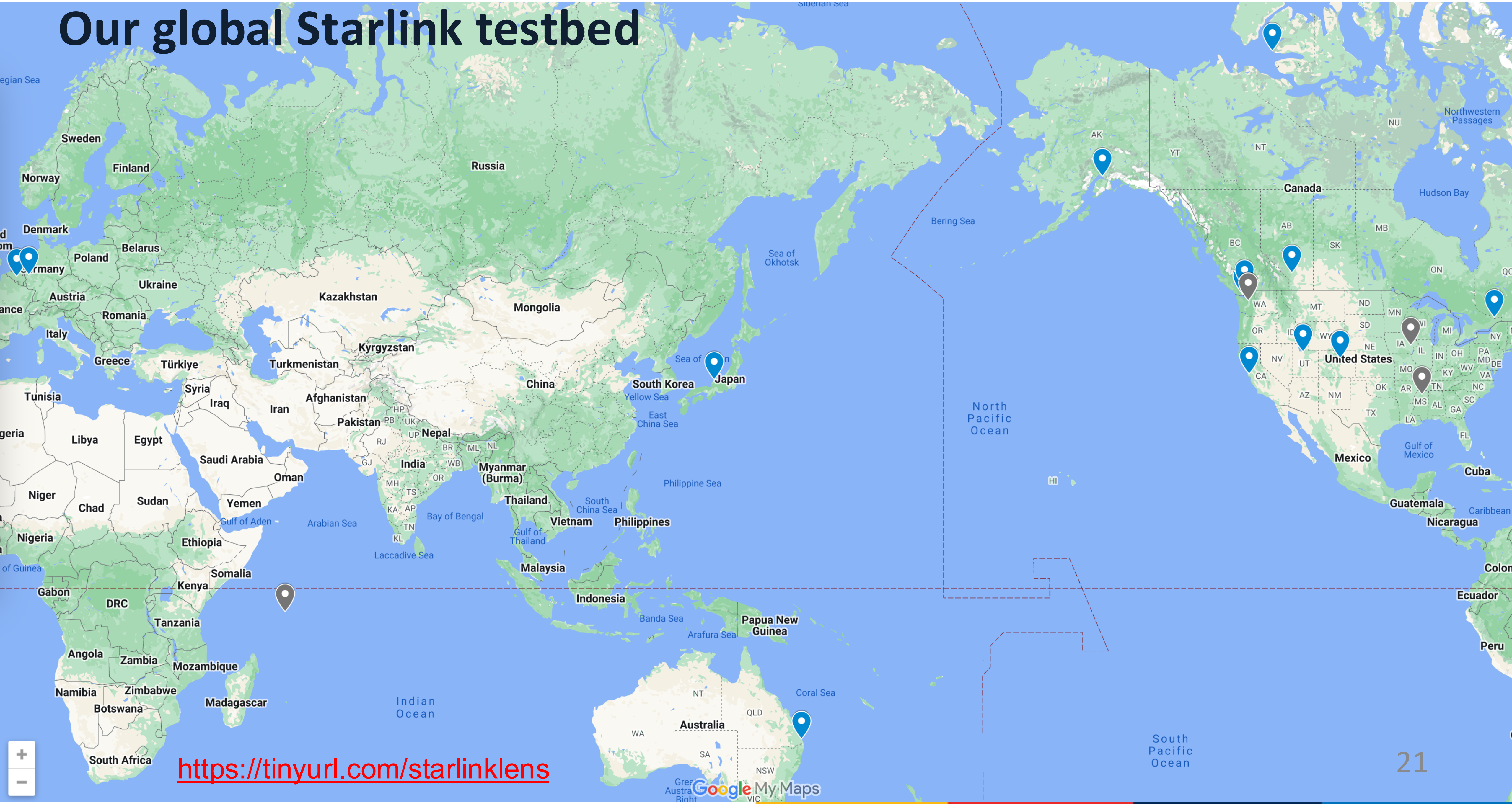
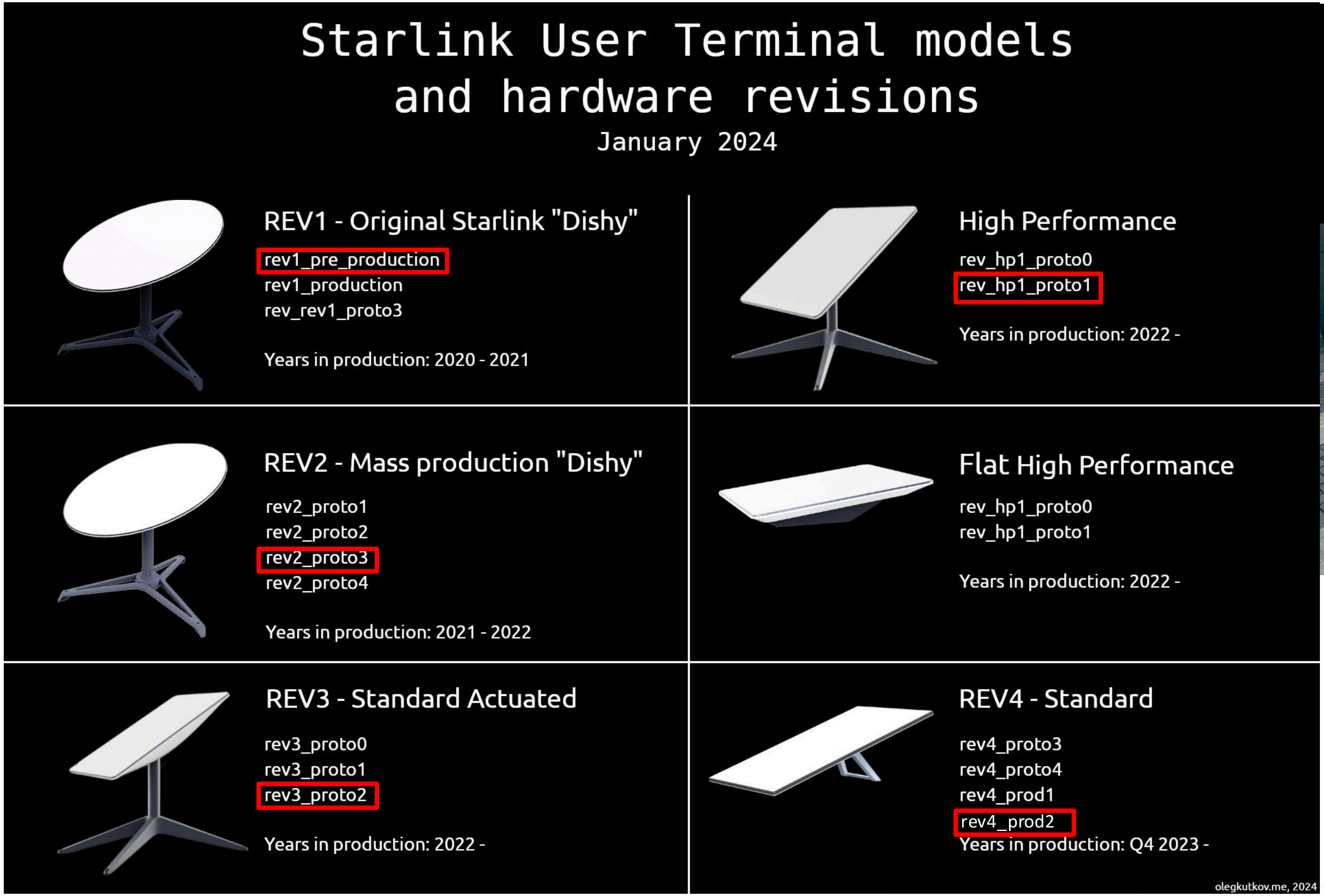
Our global Starlink testbed



https://tinyurl.com/starlinklens

Our global Starlink testbed



New in July 2024
Starlink Mini

Our testbed covers all Starlink dish hardware models

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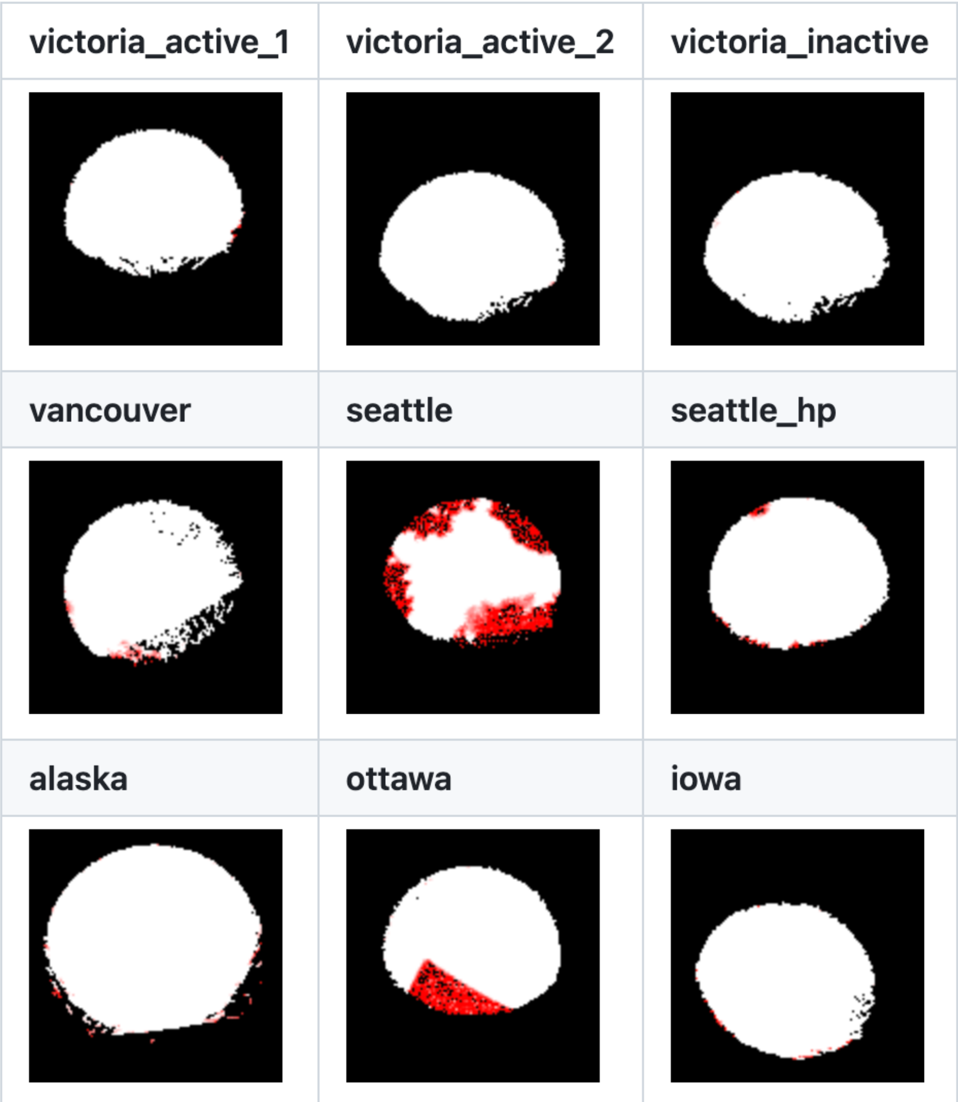
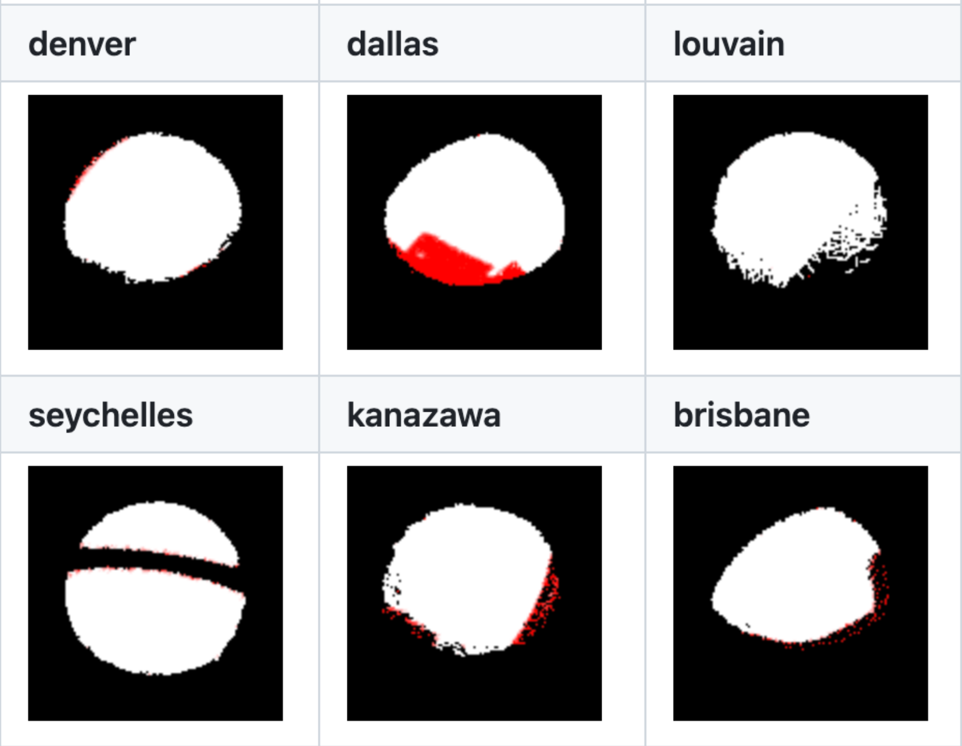
https://twitter.com/olegkutkov/status/1742322178320670753/

Our global Starlink testbed and dataset https://github.com/clarkzjw/LENS





Different alignment and obstruction parameters

Continuous measurements since 2023/11 and monthly snapshots are regularly released.

Our datasets on Zenodo.org have been downloaded over 400 times in total, and the number continues to grow.

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[3] LENS: A LEO Satellite Network Measurement Dataset. Jinwei Zhao, Jianping Pan. 2024 ACM 15th Multimedia Systems Conference (MMSys'24)

We also contribute to the research community

starlink-mobility in denver now

RIPE Atlas

General | Network | Built-ins | UDMs

IPv4

Internet Address	216.147.124.21
Prefix	216.147.120.0/21
ASN	14593 (SPACEX-STARLINK)

IPv6

Addresses	fd3e:324f:7dac:10:da58:d7ff:fe03:a37/64 2605:59c8:5002:f810:da58:d7ff:fe03:a37/64
Prefix	2605:59c8:5000::/38
ASN	14593 (SPACEX-STARLINK)

Connection Information https://atlas.ripe.net/probes/60287

Probe's birthday: 2023-06-25

starlink-victoria

General | Network | Built-ins | UDMs

IPv4

Internet Address	170.203.205.18
Prefix	170.203.200.0/21
ASN	14593 (SPACEX-STARLINK)

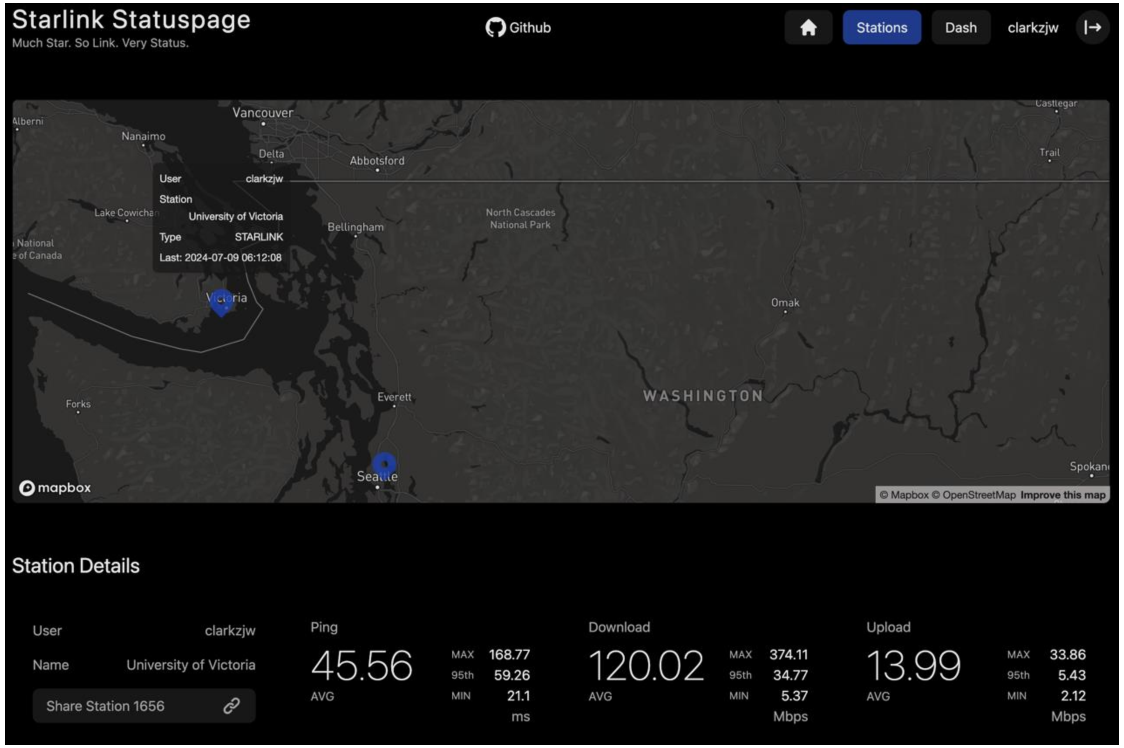
IPv6

Addresses	fd4e:acf6:ad8a:0:da58:d7ff:fe03:4d1/64 2605:59c8:2fc:da00:da58:d7ff:fe03:4d1/64
Prefix	2605:59c8::/38
ASN	14593 (SPACEX-STARLINK)

Connection Information https://atlas.ripe.net/probes/62390/

Probe's birthday: 2023-06-24

LEOScope



starlinkstatus.space

Nodes for the testbed have been donated/contributed by:

Node Contributors

University of Surrey (London, Wrexham, and Nigeria)

Edinburgh (Edinburgh Node)

Telefonica (Madrid Node)

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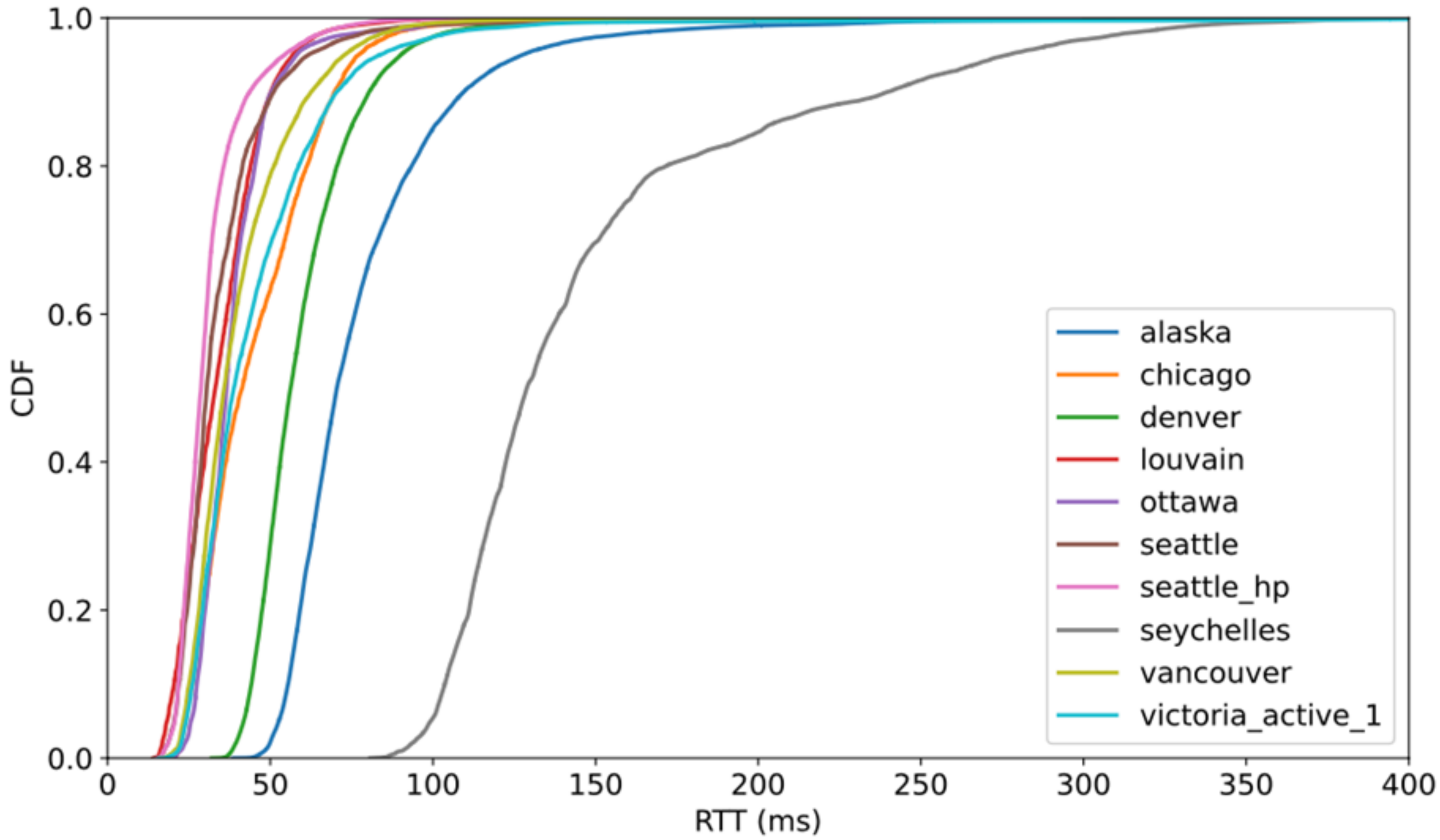
Latency performance



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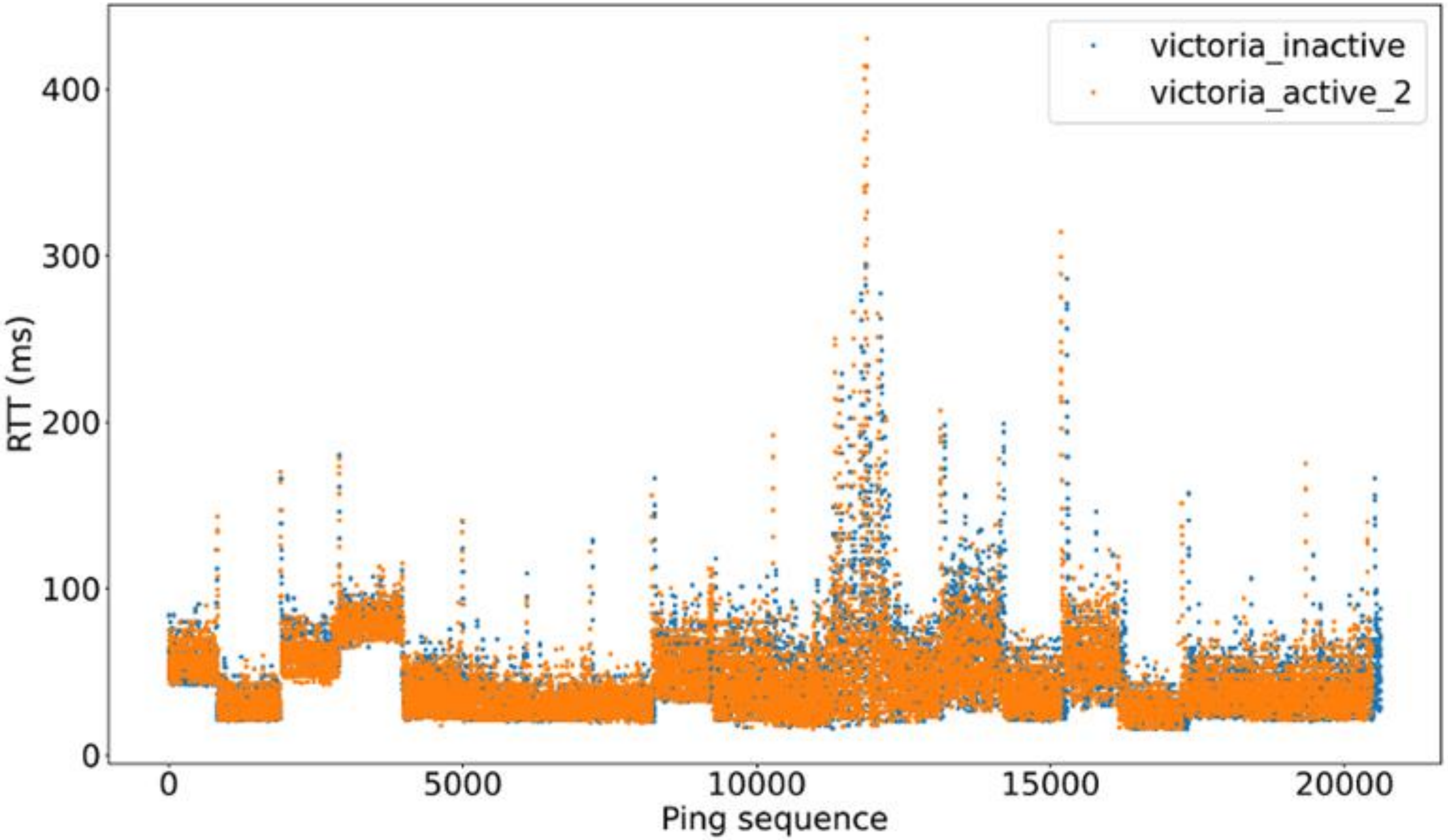
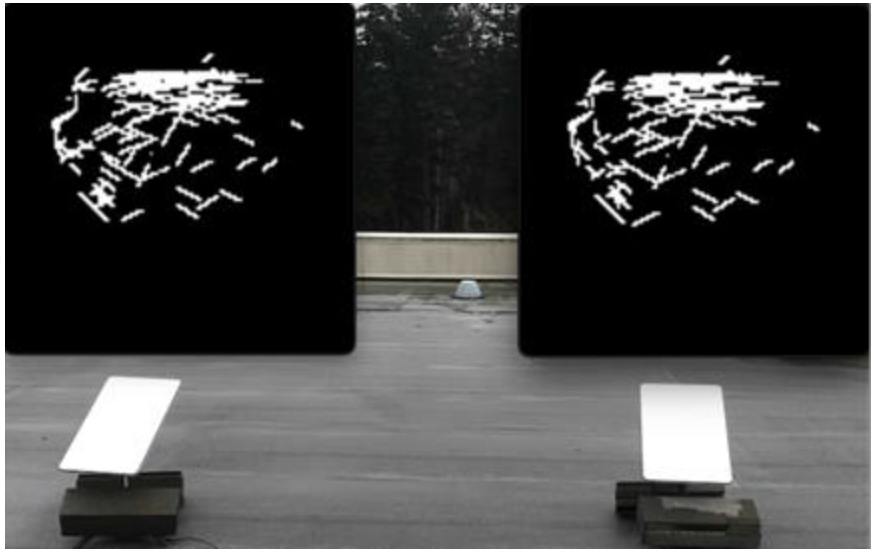
[3] LENS: A LEO Satellite Network Measurement Dataset. Jinwei Zhao, Jianping Pan. 2024 ACM 15th Multimedia Systems Conference (MMSys'24)

Side-by-side dishes





Same satellite selection strategy for dishes within the same cell.
Hence similar performance

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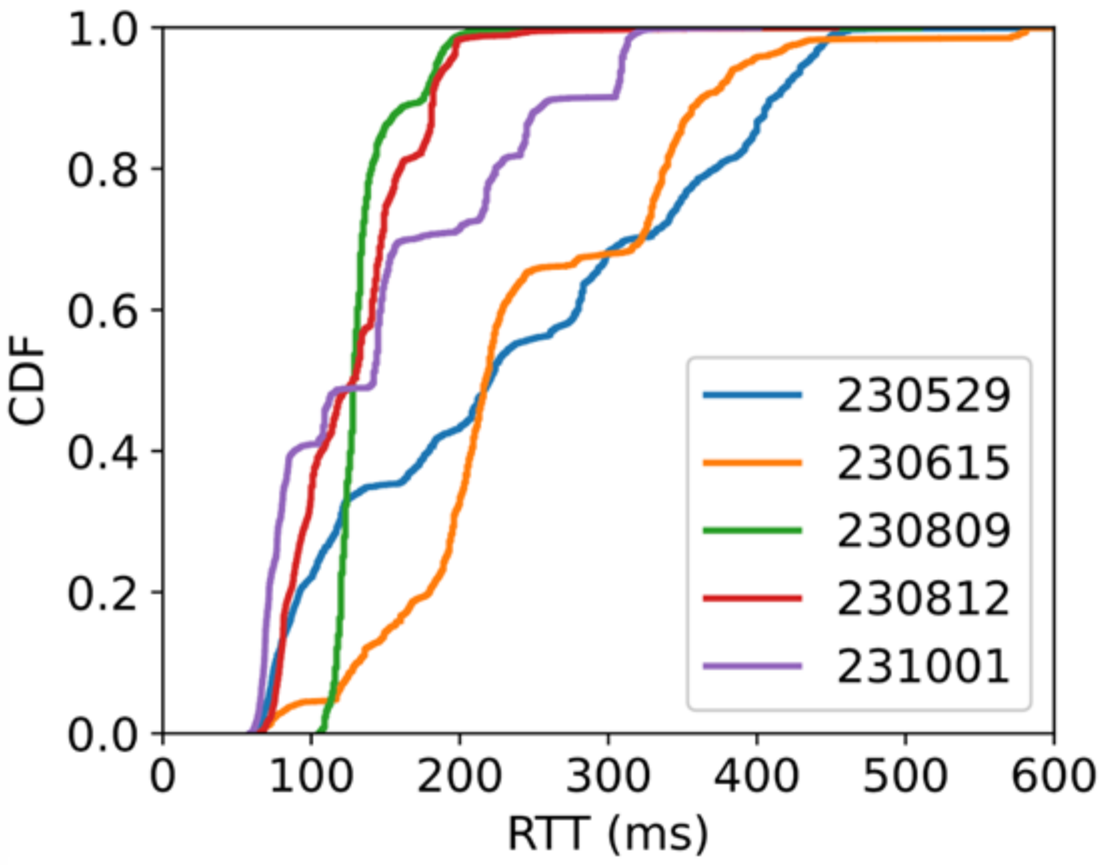
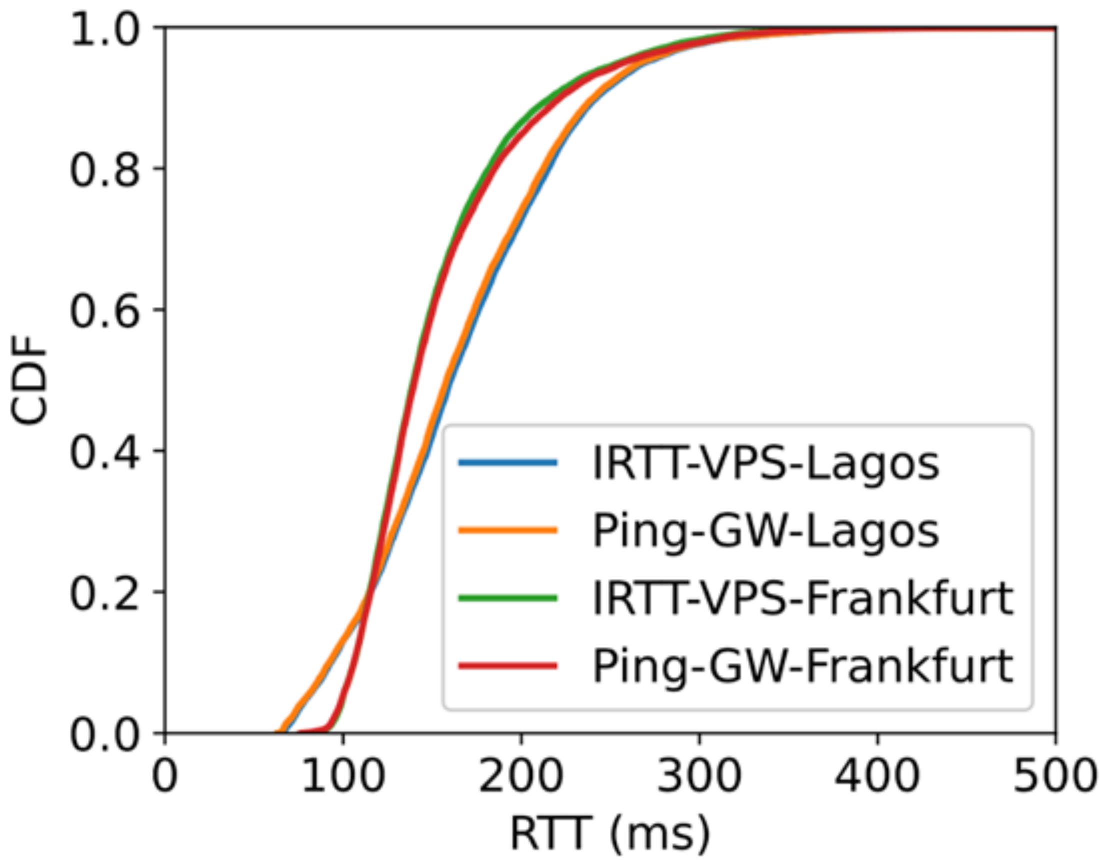
[3] LENS: A LEO Satellite Network Measurement Dataset. Jinwei Zhao, Jianping Pan. 2024 ACM 15th Multimedia Systems Conference (MMSys'24)

Inter-satellite links (in Seychelles)





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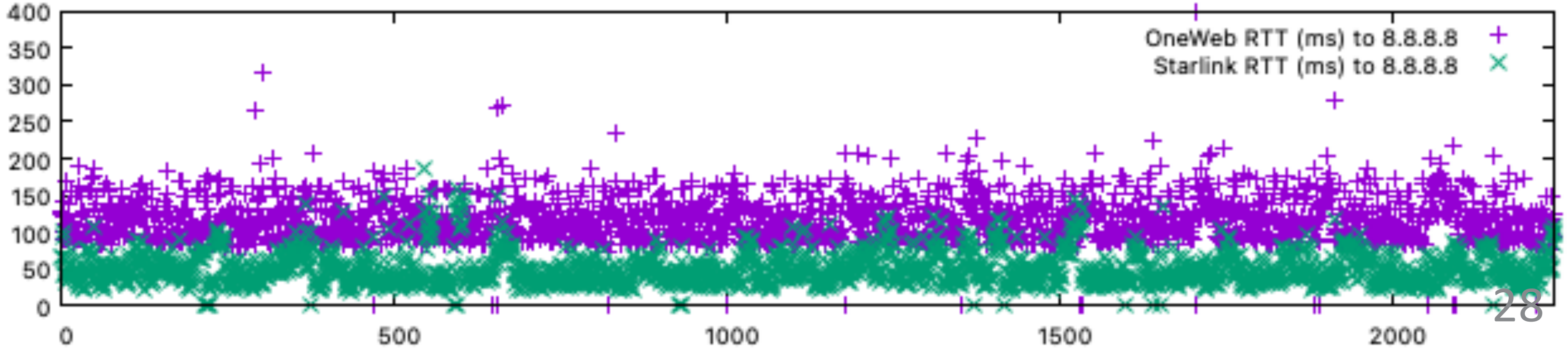
[3] LENS: A LEO Satellite Network Measurement Dataset. Jinwei Zhao, Jianping Pan. 2024 ACM 15th Multimedia Systems Conference (MMSys'24)

Starlink vs OneWeb

- Starlink
  - Initially target *consumer* users
  - Mostly 53° inclination
  - Mostly 550km above the Earth
  - **Spotting** beams for individual dishes
    - Ku for UT and Ka for GS
  - Currently >6000 active satellites
    - All launched by SpaceX
  - Currently >100x 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 ~10x ground stations
  - Very few customer PoPs now
  - High but ***relatively stable*** RTT to PoP



Application adaptation and performance enhancement over LEO networks

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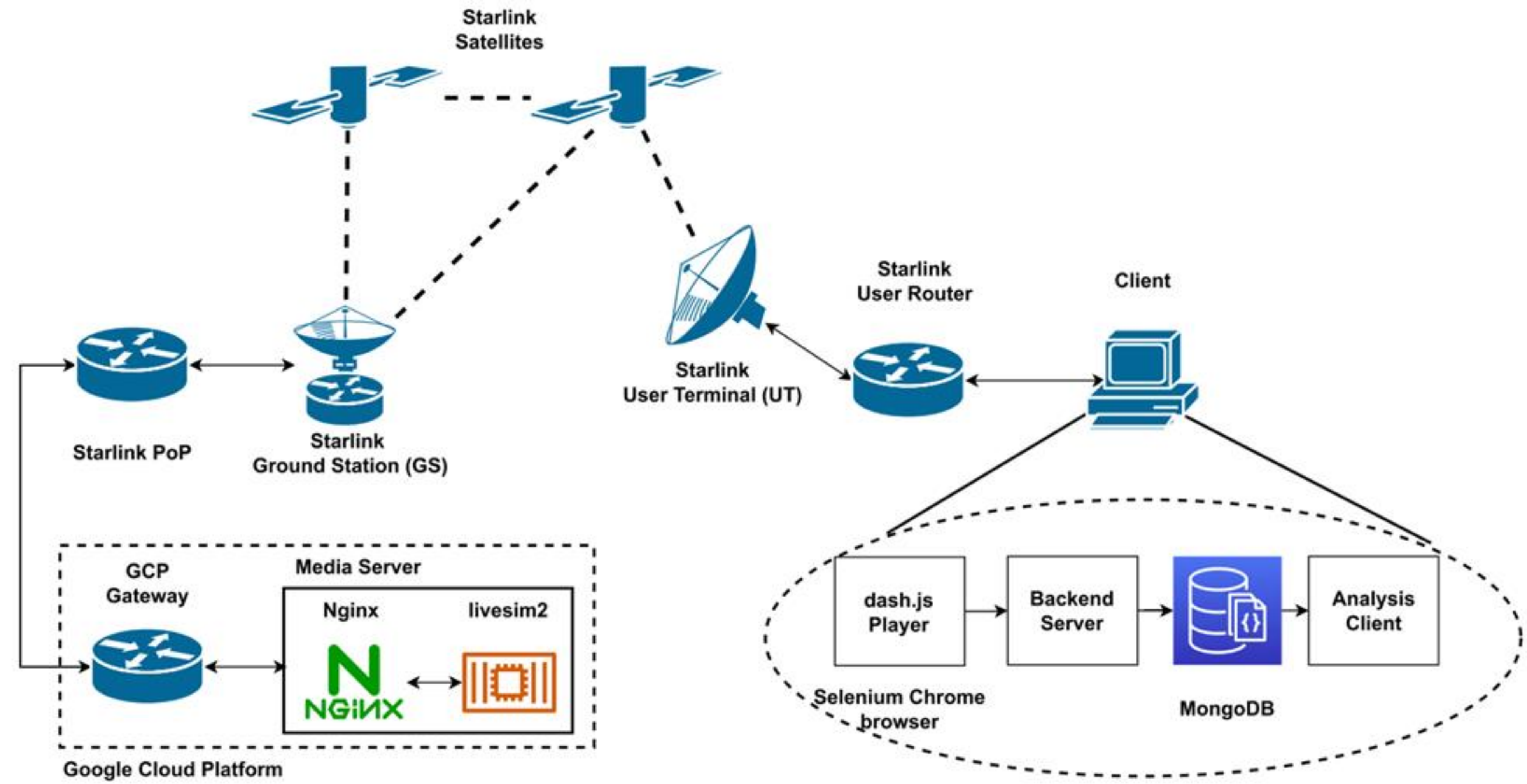
Applications - Low latency live video streaming



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[4] Low Latency Live Video Streaming over a Low-Earth-Orbit Satellite Network with DASH, Jinwei Zhao, Jianping Pan
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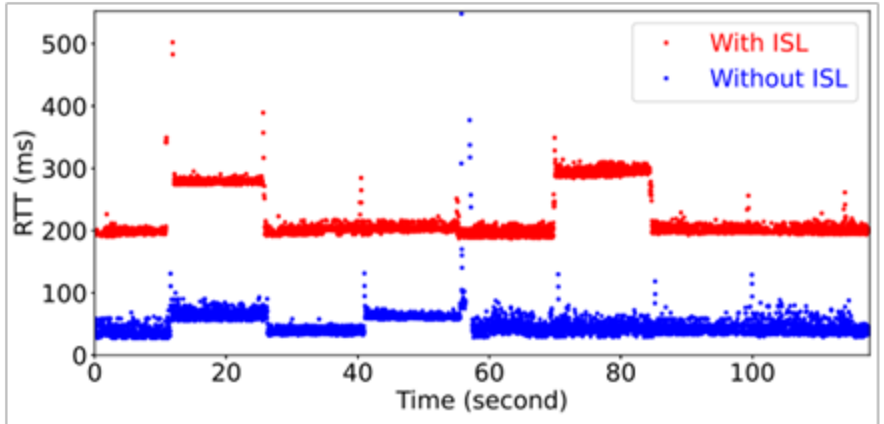
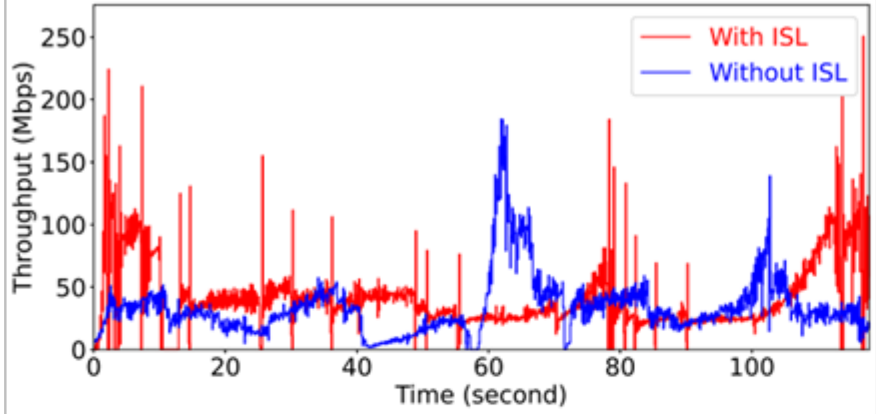
DASH-IF Excellence in DASH Award Third Place

Applications - Low latency live video streaming

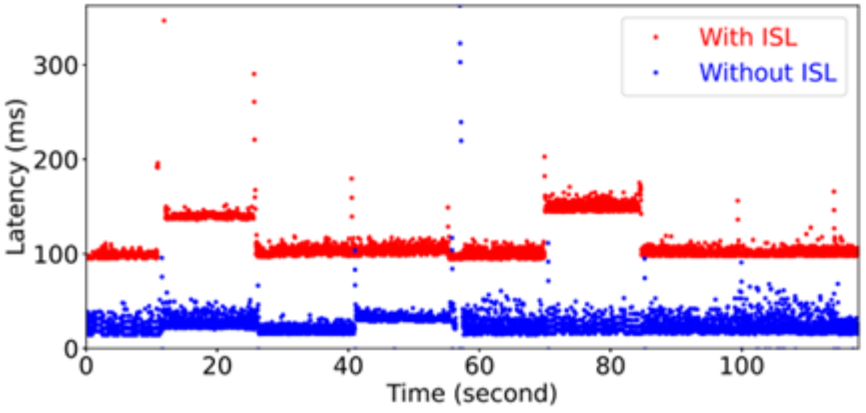


(a) E2E Latency

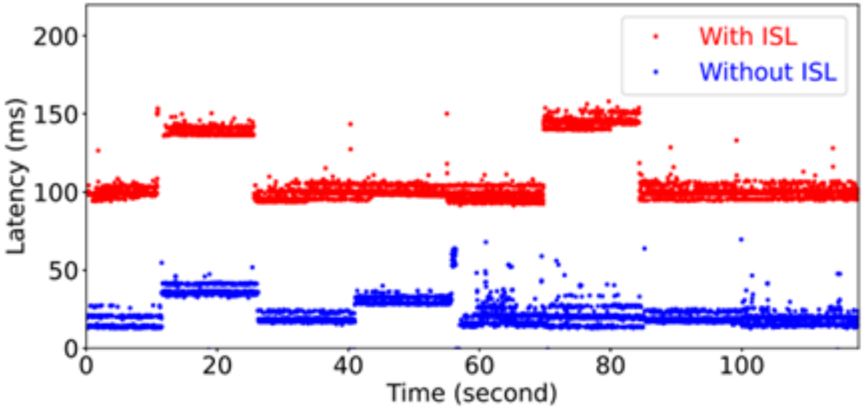


(b) Downlink Throughput

Figure 3.4: Time synchronized RTT and downlink throughput



(a) Uplink OWD



(b) Downlink OWD

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

1. Satellites handover every 15 seconds.
2. The handover timestamps are fixed at 12-27-42-57 seconds of every minute.
3. There are latency spikes and packet losses when satellite handover events happen.
4. The TCP throughput performance is affected and goes through slow-start pattern after handover events.

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Applications - Low latency live video streaming

Problem:

- Model live video streaming as an online decision-making problem with multi-armed bandit algorithms
- Dynamically choose video segments from different bitrate levels continuously.

Contextual multi-armed bandit (CMAB)

- An agent makes a sequence of decisions at time $t = \{1,2, \dots, T\}$.
- At each time t, a context vector $b(t) \in \mathbb{R}^d$ is revealed to the agent. (e.g., network latency, throughput, playback speed, buffer level, etc.)
- The agent chooses an arm/action a_t from a set of K arms (bitrate levels).
- The agent "pulls" the selected arm. Consequently, a reward r_t is observed for the selected arm from an unknown distribution.
- The rewards for other unselected arms at time t remain unknown to the agent.

- Adaptive playback speed control based on Starlink handover time slots

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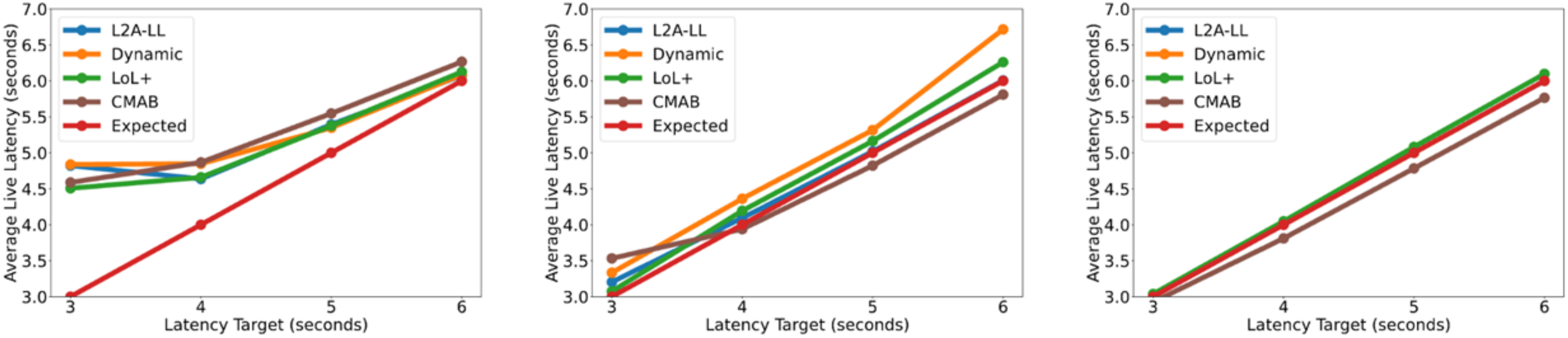
Applications - Low latency live video streaming



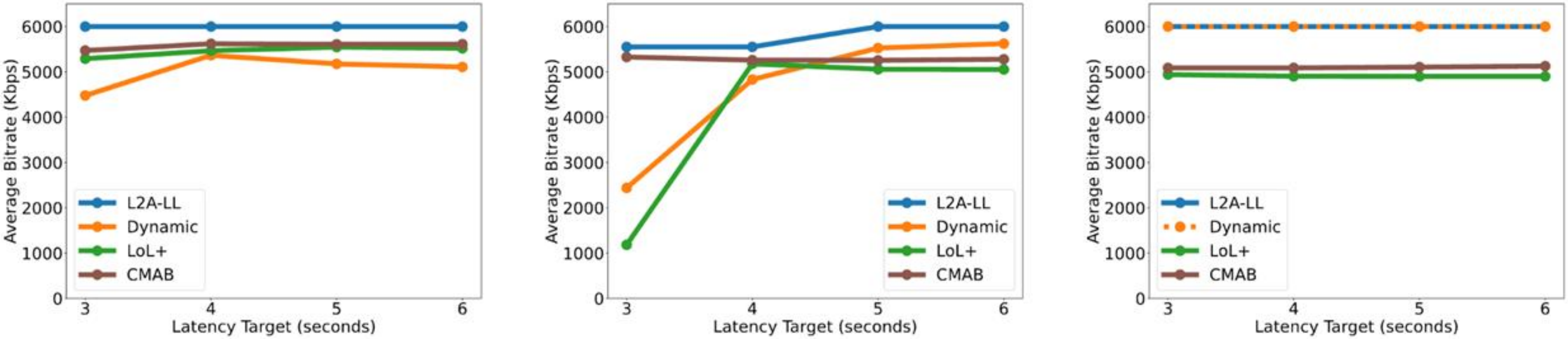
(a) Emulation

(b) Starlink

(c) Terrestrial

Figure 6: Average live latency

Applications - Low latency live video streaming



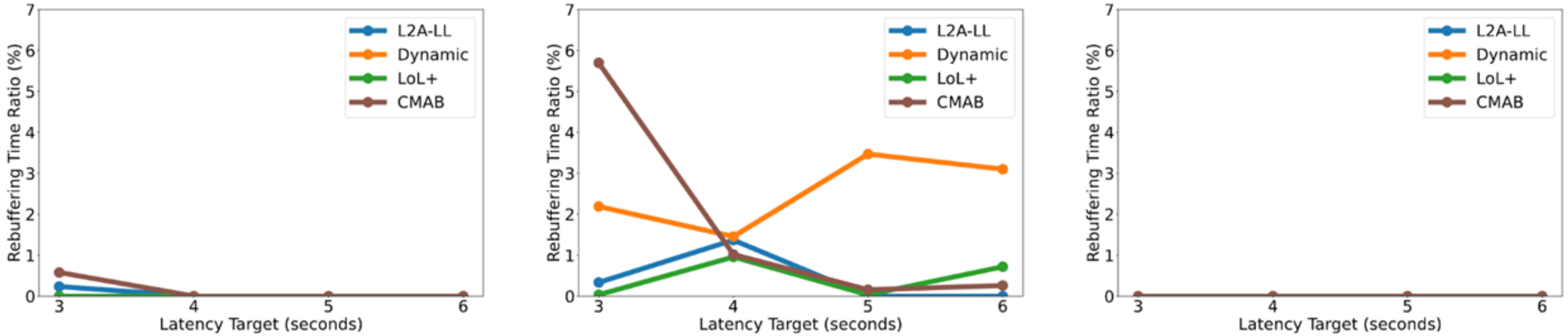
(a) Emulation

(b) Starlink

(c) Terrestrial

Figure 7: Average bitrate

Applications - Low latency live video streaming



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

Figure 8: Rebuffering time ratio (%)

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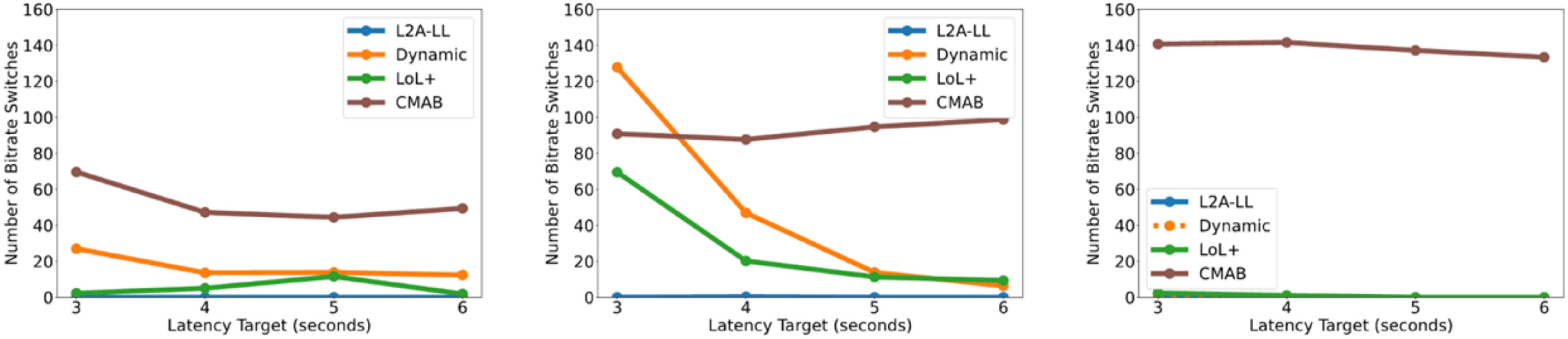
Applications - Low latency live video streaming



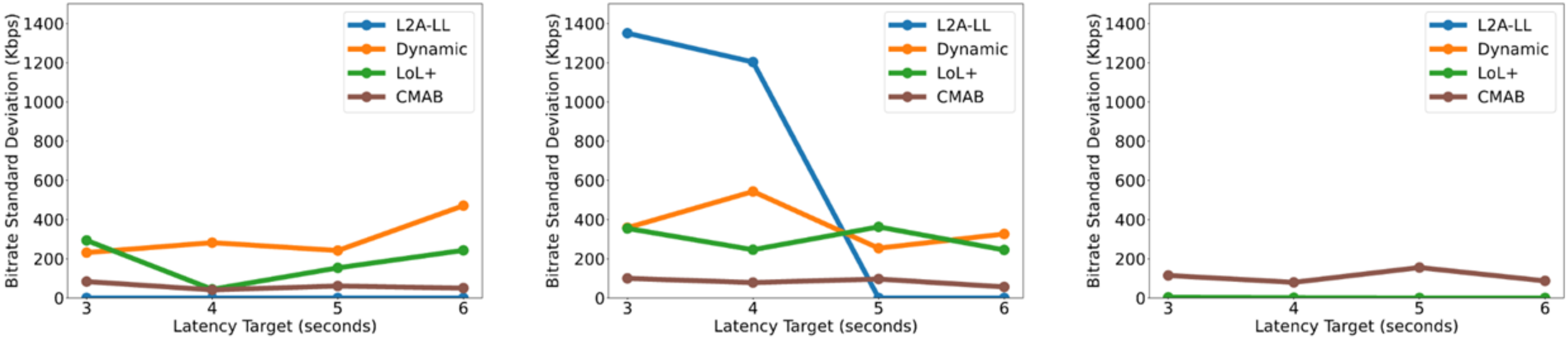
(a) Emulation

(b) Starlink

(c) Terrestrial

Figure 9: Number of bitrate switches

Applications - Low latency live video streaming



(a) Emulation

(b) Starlink

(c) Terrestrial

Figure 10: Bitrate standard deviation

Applications - Cloud gaming

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

STARLINK

NVIDIA GEFORCE NOW™

By Pouria Tolouei

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

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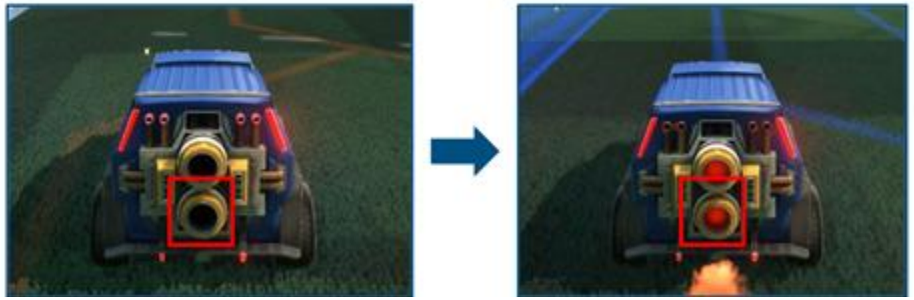
Applications - Cloud gaming

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



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

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Applications - Cloud gaming

		Ping (ms) (mean)	Input Latency (ms) (mean)	Round Packet Loss (mean)	Round Packet Loss (%) (mean)	Available Bandwidth (Mbps) (mean)	Used Bandwidth (Mbps) (mean)
Victoria Telus vs. Victoria Telus (Same)	Victoria Telus 1	31.42	72.89	62.27	0.025%	82.33	19.18
	Victoria Telus 2	31.21	74.61	62.10	0.025%	81.86	19.34
Victoria Telus vs. Victoria Telus (Different)	Victoria Telus 1	31.51	72.00	0.40	0.000%	83.75	19.27
	Victoria Telus 2	42.65	91.72	447.125	0.179%	57.95	18.03
Victoria Starlink vs. Victoria Telus	Victoria Starlink	67.04	116.92	460.04	0.184%	56.87	15.89
	Victoria Telus	31.41	74.64	16.88	0.007%	82.80	19.22
Victoria Starlink vs. Victoria Starlink	Victoria Starlink 1	70.26	121.68	730.75	0.292%	46.75	15.17
	Victoria Starlink 2	70.41	121.56	862.04	0.345%	46.54	15.19
Victoria Starlink vs. Vancouver Starlink	Victoria Starlink	67.44	116.95	608.60	0.243%	57.30	16.02
	Vancouver Starlink	65.88	118.32	727.04	0.291%	61.60	16.29
Victoria Starlink vs. Ottawa Starlink	Victoria Starlink	65.29	117.24	745.54	0.298%	59.78	17.43
	Ottawa Starlink	60.57	106.84	597.60	0.239%	51.49	13.85

The latency performance over Starlink, while has been improved a lot, it still has higher latency than terrestrial fiber networks in most regions.

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Applications - Cloud gaming

		Ping (ms) (SD)	Input Latency (ms) (SD)	Round Packet Loss (SD)	Round Packet Loss (%) (SD)	Available Bandwidth (Mbps) (SD)	Used Bandwidth (Mbps) (SD)
Victoria Telus vs. Victoria Telus (Same)	Victoria Telus 1	1.53	25.50	177.72	0.071%	12.78	1.73
	Victoria Telus 2	1.52	28.61	185.86	0.074%	12.54	1.69
Victoria Telus vs. Victoria Telus (Different)	Victoria Telus 1	1.40	20.09	2.60	0.001%	12.16	1.55
	Victoria Telus 2	8.87	39.37	107.91	0.043%	12.82	3.03
Victoria Starlink vs. Victoria Telus	Victoria Starlink	**26.50**	**84.68**	**435.34**	**0.174%**	18.50	4.91
	Victoria Telus	**1.61**	**25.15**	**48.42**	**0.019%**	12.85	1.61
Victoria Starlink vs. Victoria Starlink	Victoria Starlink 1	27.93	87.10	641.52	0.257%	14.20	4.88
	Victoria Starlink 2	29.05	97.66	925.39	0.370%	14.12	4.97
Victoria Starlink vs. Vancouver Starlink	Victoria Starlink	28.09	76.52	401.52	0.161%	17.40	4.98
	Vancouver Starlink	20.68	91.47	419.68	0.168%	21.58	4.91
Victoria Starlink vs. Ottawa Starlink	Victoria Starlink	21.27	82.65	590.57	0.236%	16.09	4.11
	Ottawa Starlink	21.35	82.22	296.46	0.119%	24.37	5.06

The higher latency variation has a much larger impact on interactive cloud gaming or video conferencing application.

Our collaborations, ongoing and future work

Collaborations:

- Measuring Starlink global latency performance with IPv6
- eBPF based trace driven LEO network emulator

Our ongoing work:

- Identifying communicating satellites by user dishes through obstruction maps and TLE
- Enhancing congestion control for LEO networks
- Lightweight Starlink throughput estimation through path characteristics

Our future work:

- Multipath transmission over Starlink/OneWeb
- Exploring LEO for real-time communications (RTC)

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Some of our open-source projects

Starlink Latency Measurement Dataset

- Only Starlink for now, OneWeb to be added
- Some backlogged months' dataset to be uploaded

https://github.com/clarkzjw/LENS

Starlink GeoIP Dataset

- Starlink GeoIP feed vs DNS PTR records
- GeoIP feed and DNS PTR records are not always accurate, complementary with each other
- Reflects Starlink's planning->deployment process

https://github.com/clarkzjw/starlink-geoip-data

Thanks!

Questions?

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Jianping Pan, pan@uvic.ca

- A global satellite network requires a global research collaboration network
  - We have three dishes in Victoria (with the Seattle PoP), Denver and Ottawa (New York City)
  - We now also have a newest v4 dish and a Starlink Mini dish
- Through collaboration, we have access to dishes associated with many other PoPs around the world
  - and also OneWeb dishes (in Alaska)
- Many Starlink users also run our backbone and access measurement scripts for us
  - Perth, Auckland, São Paulo, Los Angeles, Manila, etc.
  - and those including ourselves available on LEOScope, RIPE Atlas and Starlinkstatus.space

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