Intro to LEO Satellite Networking

ECE 239AS

Liz Izhikevich

Low Earth Orbit (LEO) Satellite Internet is immensely useful today

SPACE

Pentagon awards SpaceX with Ukraine contract for Starlink satellite internet

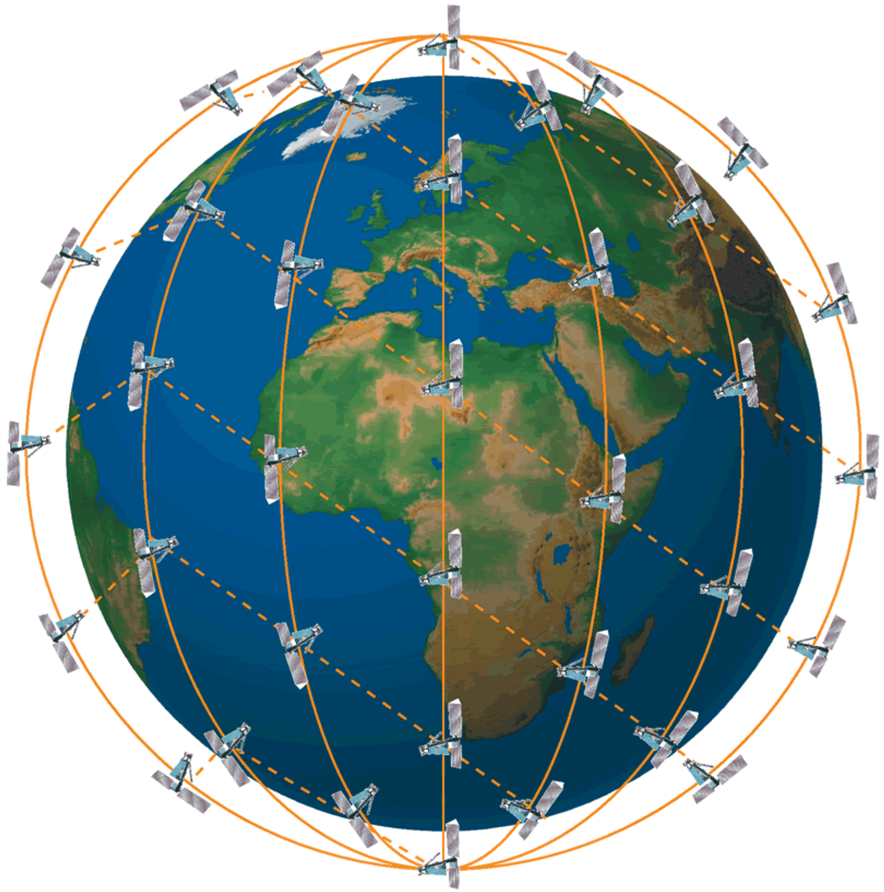
PUBLISHED THU, JUN 1 2023•12:54 PM EDT UPDATED THU, JUN 1 2023•1:53 PM EDT

Musk's Starlink connects remote Tonga villages still cut off after tsunami

By **Kirsty Needham**

February 23, 2022 12:05 AM PST · Updated a year ago

LEO Satellite Networks offer high coverage and low latency

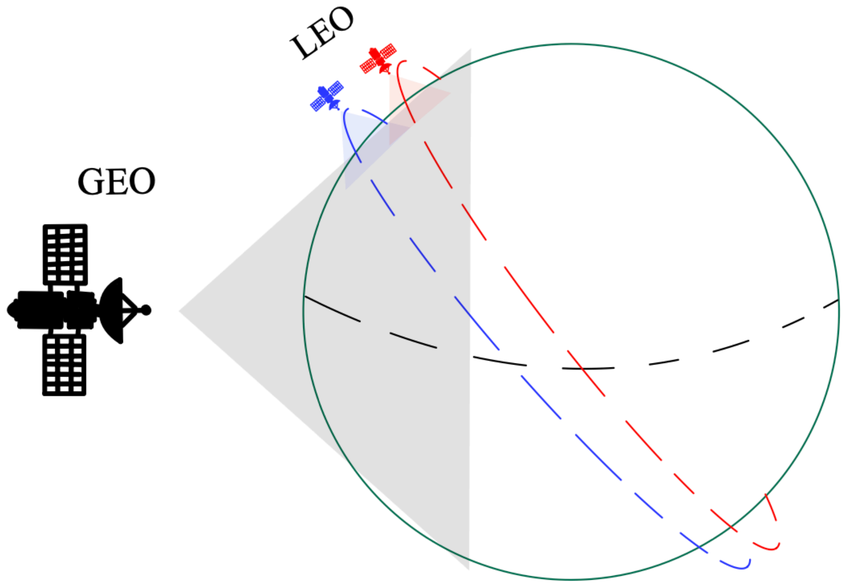


- LEO Satellites work in constellations (e.g., 100s-1000s satellites)
  - High Coverage
- LEO satellites orbit 300km -2000km from Earth
  - Low Latency: minimum RTT (~10ms), bounded by the speed of light

Internet latency standards < 100ms

Sağ, Emirhan & Kavas, Aktül. (2018). Modelling and Performance Analysis of 2.5 Gbps Inter-satellite Optical Wireless Communication (IsOWC) System in LEO Constellation. Journal of Communications. 13. 553-558. 10.12720/ jcm.13.10.553-558.

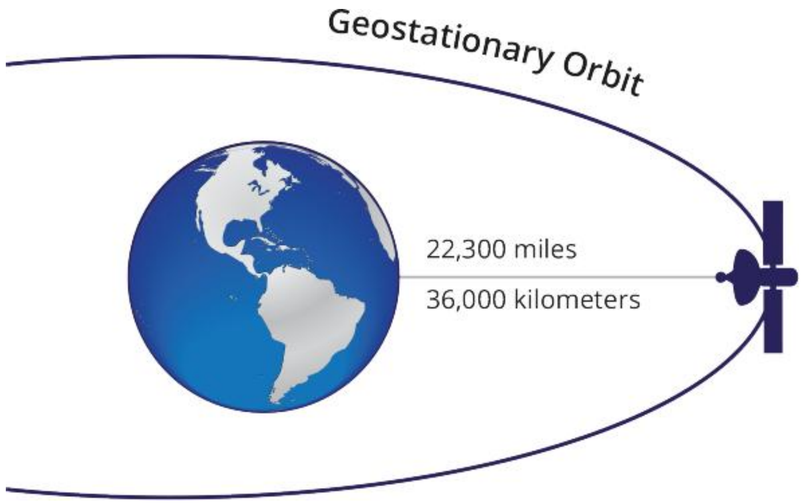
Satellite Internet is not new…for over 20 years we have used Geostationary Earth Orbits (GEO)



GEO: 3 km/s @ 36,000km altitude = 1 period of 24 hours = geostationary

LEO: 7 km/s @ 500km altitude = 1 period of 90 minutes = not geostationary

GEO network round trip times extremely long

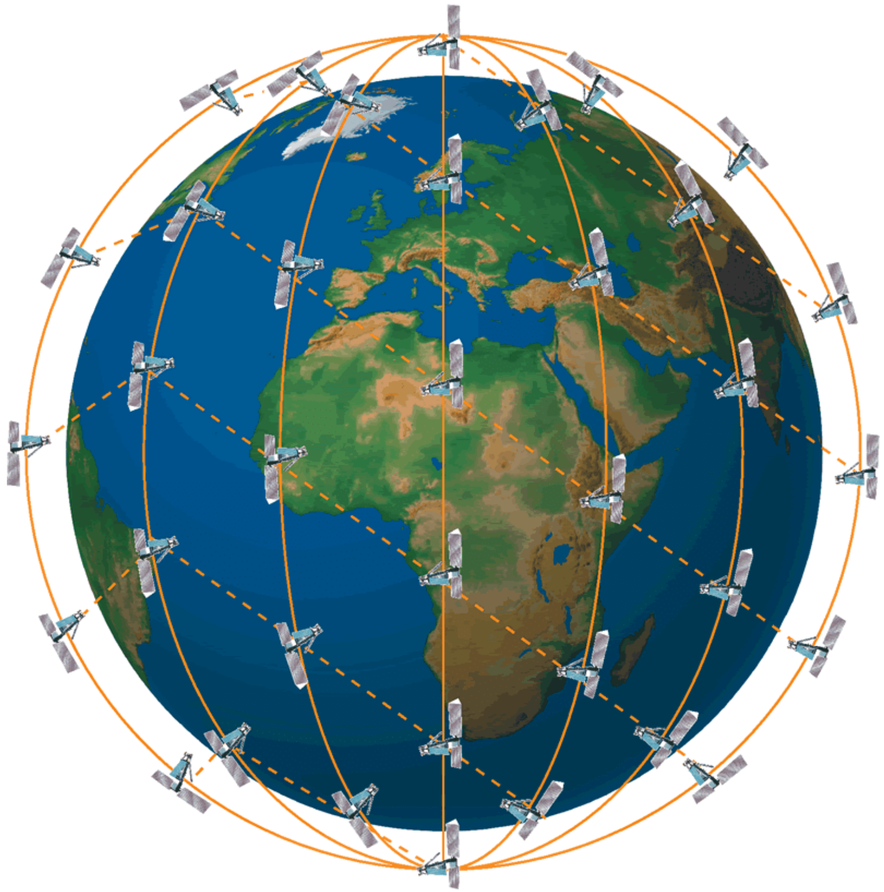


-Network speed bounded by speed of light

-minimum RTT of ~240ms

Internet latency standards < 100ms

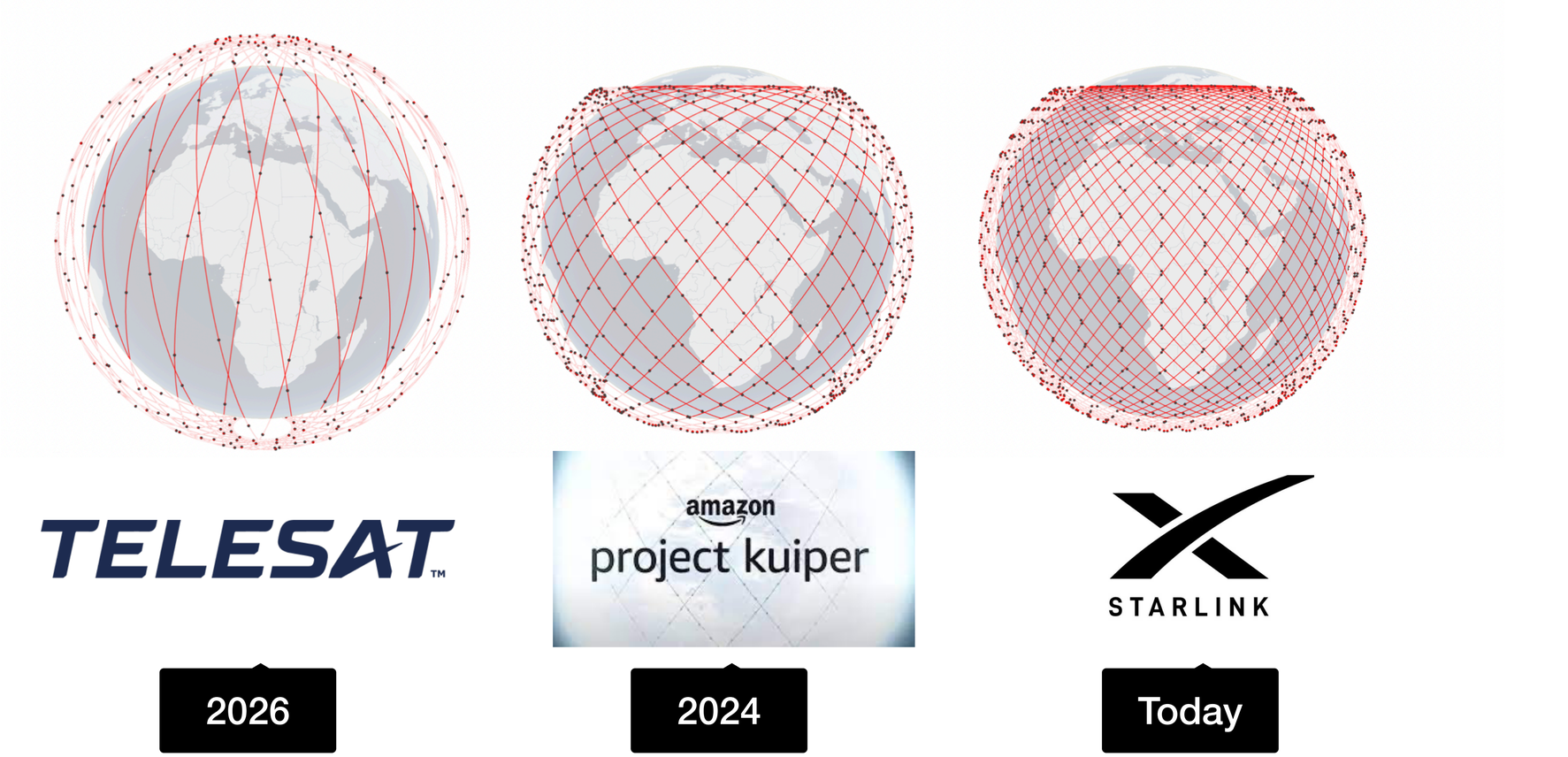
LEO solves old problems, with new challenges



- LEO closer distance -> Lower RTT , reduced coverage
- LEO speed -> core infrastructure extremely mobile

Sağ, Emirhan & Kavas, Aktül. (2018). Modelling and Performance Analysis of 2.5 Gbps Inter-satellite Optical Wireless Communication (IsOWC) System in LEO Constellation. Journal of Communications. 13. 553-558. 10.12720/ jcm.13.10.553-558.

LEO Constellations exhibit different topologies



Simon Kassing, Debopam Bhattacherjee, André Baptista Águas, Jens Eirik Saethre, and Ankit Singla. 2020. Exploring the "Internet from Space" with Hypatia. In Proceedings of the ACM Internet Measurement Conference (IMC '20). Association for Computing Machinery, New York, NY, USA, 214–229.

LEO topologies cater towards specific user locations

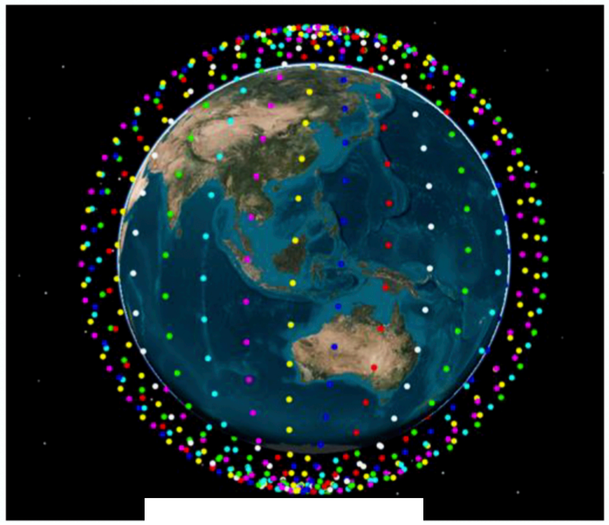
OneWeb

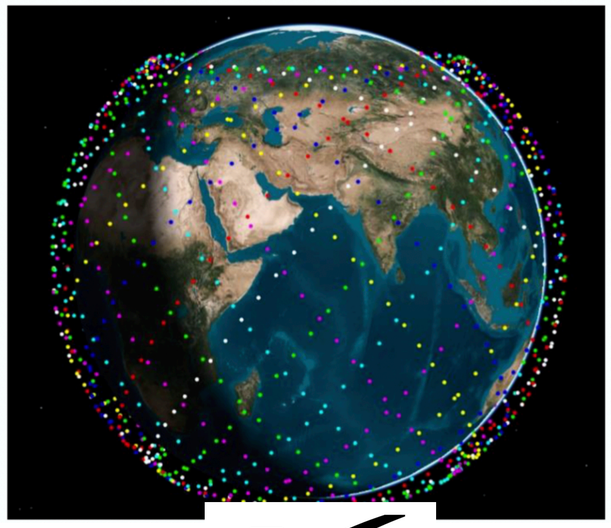
Contact us

OneWeb / Enterprise / Partnerships / Video - 18 Aug 2022

Customer Success Story - PDI in Alaska, USA

Meet the residents of Akiak Native Community in Alaska. Like many other communities in rural Alaska, Akiak has struggled with internet connectivity setbacks. Since the rollout of OneWeb commercial services in 2021, we have been connecting hard-to-reach places like Akiak, and changing lives.





OneWeb

STARLINK

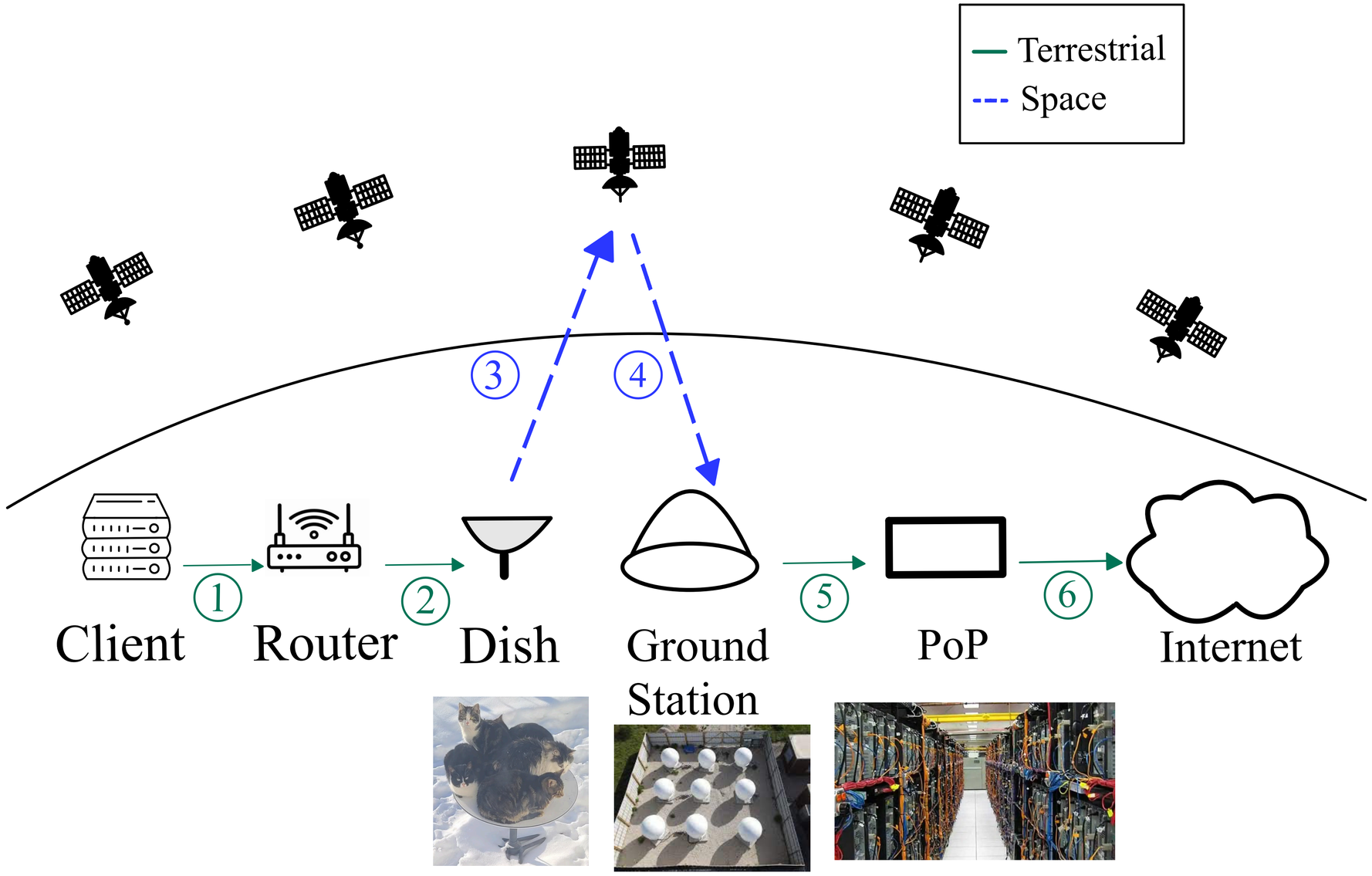
Starlink Is Now Connecting Remote Antarctic Research Camps to the Internet

After a successful test at a popular research station last September, Starlink is now connecting scientists working at remote field camps.

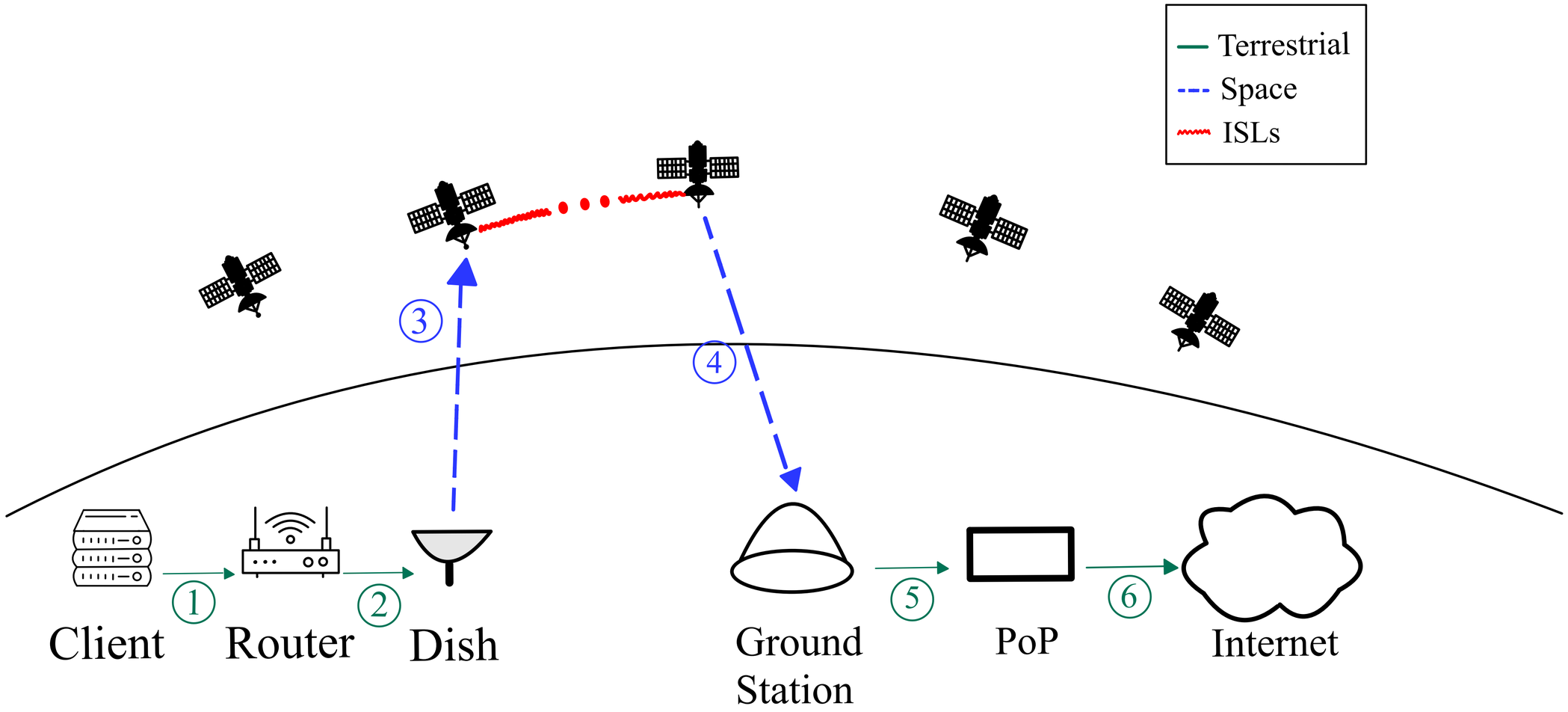
By **Kevin Hurler**

Published January 23, 2023 | Comments (6) | Alerts

“Bent-Pipe” (the most basic) LEO Routing



Inter-Satellite Link (ISL) Routing



Existing Techniques to Measure LEO Satellite Networks Are Restrictive

Option 1. Deploy Physical Hardware

Financial and Coverage Barrier

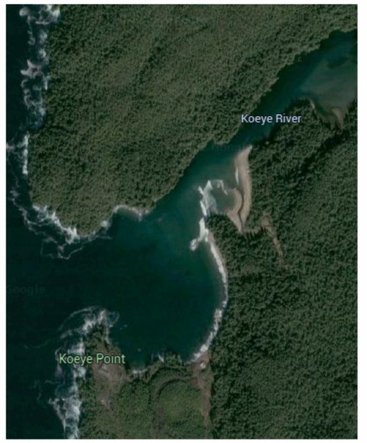
Network Characteristics of LEO Satellite Constellations:
A Starlink-Based Measurement from End Users

Sami Ma*, Yi Ching Chou*, Haoyuan Zhao*, Long Chen*, Xiaoqiang Ma†, Jiangchuan Liu*
*School of Computing Science, Simon Fraser University, Canada
†CSIS Department, Douglas College, Canada
Emails: {masamim, ycchou, hza127}@sfu.ca; {longchen.cs, mxqcs}@ieee.org; jcliu@sfu.ca

Authors purchase a $500 dish and travel with it

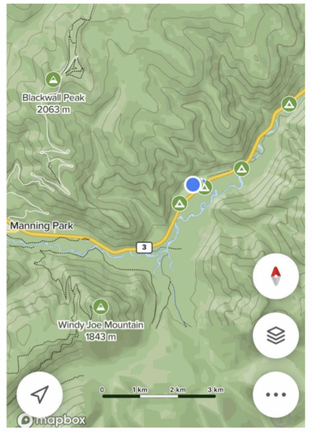
Fig. 17. A Gen-1 dish secured on the roof of a minivan.

(a) Dish F facing towards a clear sky.

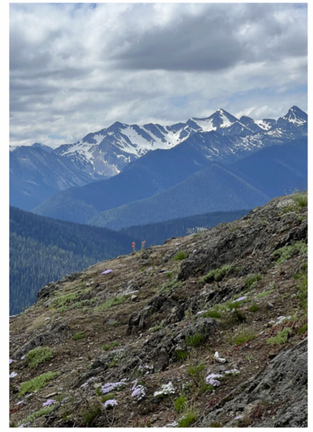


(b) Google satellite map.

Fig. 13. (a) Dish F (Gen 2) setup at (b) Koeye point (Estuary of Koeye River).



(a) The surrounding terrain map.



(b) High elevation mountains.

Fig. 14. The terrain of the valley in Manning Park. (a) Terrain map; (b) surrounding mountains.

Option 2. Recruit Existing Hardware

Labor Consuming…

A Browser-side View of Starlink Connectivity

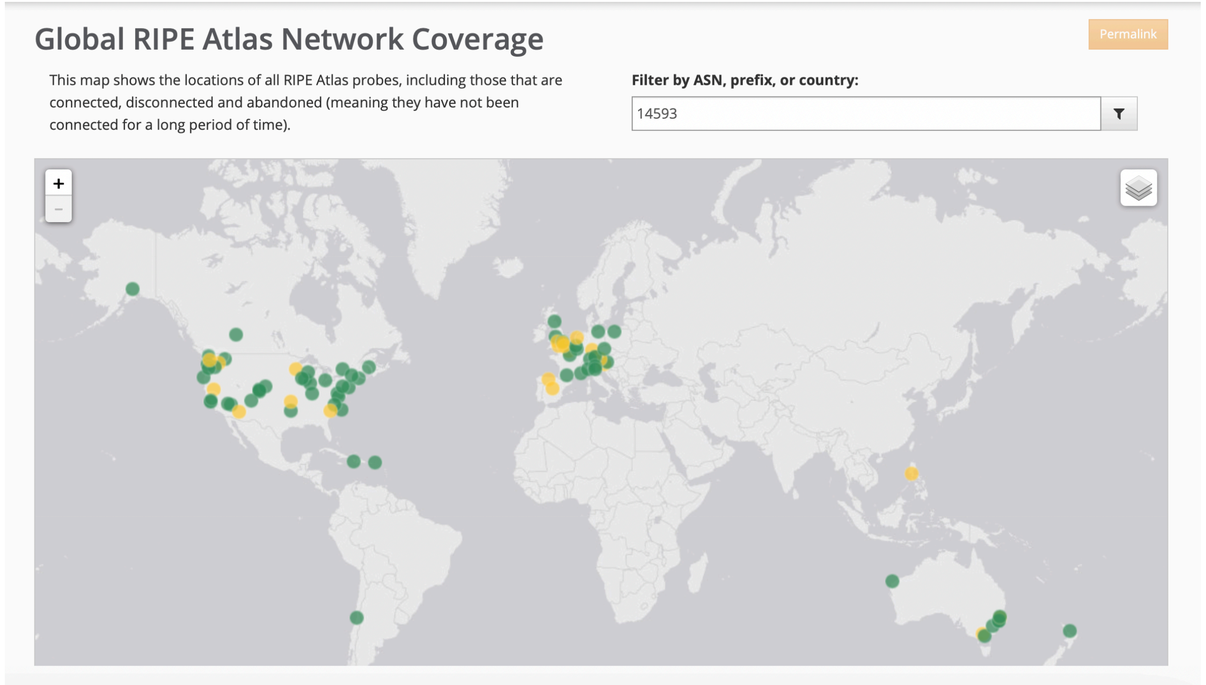
Mohamed M. Kassem
University of Surrey
UK
m.kassem@surrey.ac.uk

Aravindh Raman
Telefonica Research
Spain
aravindh.raman@telefonica.com

Diego Perino
Telefonica Research
Spain
diego.perino@telefonica.com

Nishanth Sastry
University of Surrey
UK
n.sastry@surrey.ac.uk

Authors build a chrome extension to measure 18 Starlink-user browsing performance



Ripe Atlas sends probes for ~60 Starlink users to host

Option 3. Theoretical Models based on Physics

Not validated and slow

Exploring the "Internet from space" with HYPATIA

Simon Kassing*, Debopam Bhattacherjee*, André Baptista Águas, Jens Eirik Saethre, Ankit Singla
ETH Zürich

Authors build a LEO simulator

Other work uses it to:

-Test congestion control algorithms

-Invent DDoS attacks

-Study different routing topologies

-Predict ISL performance improvements

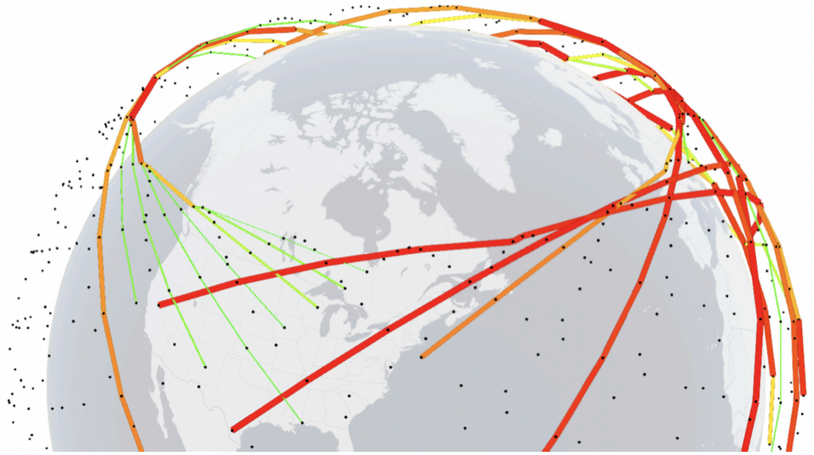


Fig. 15: *Constellation-wide utilization.* *On Kuiper, the trans-atlantic paths are highly congested for our tested traffic matrix. The red / thick ISLs are heavily utilized, while green / thin ISLs have minimal traffic. ISLs with no traffic are excluded.*

LEO-HitchHiking

- Requires no special hardware or recruitment
- Can measure satellite links wherever satellite clients are already located across the globe
  - An *order of magnitude* more coverage than prior work

Democratizing LEO Satellite Network Measurement

Liz Izhikevich
Stanford University

Manda Tran
Stanford University

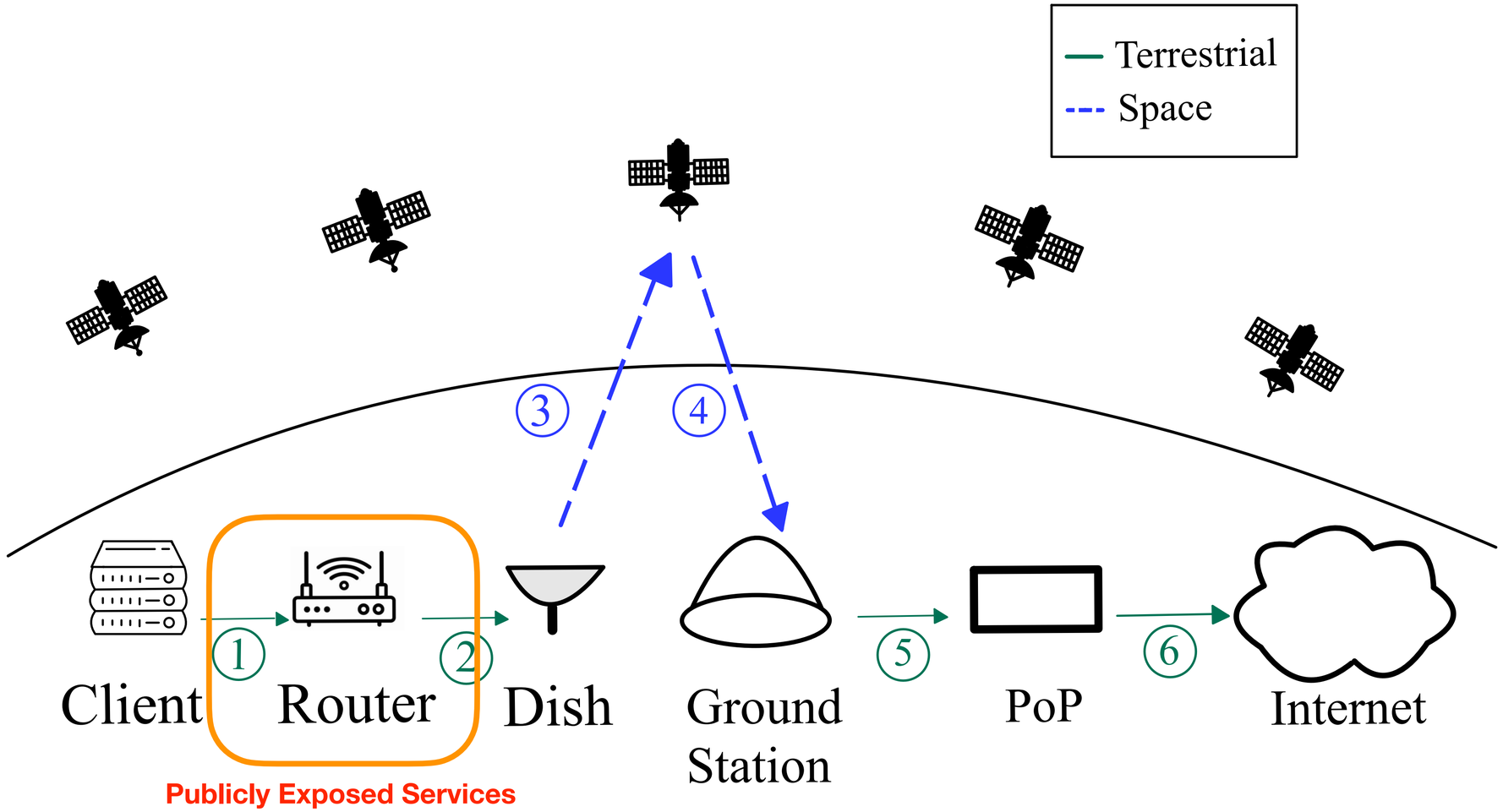
Katherine Izhikevich
UC San Diego

Gautam Akiwate
Stanford University

Zakir Durumeric
Stanford University

HitchHiking's *key observation* is publicly exposed satellite-routed devices can reveal satellite network architecture and performance

HitchHiking detects publicly exposed LEO services



HitchHiking's goal is to measure the satellite link