

Low-Earth Orbit Broadband

Opportunities and Challenges

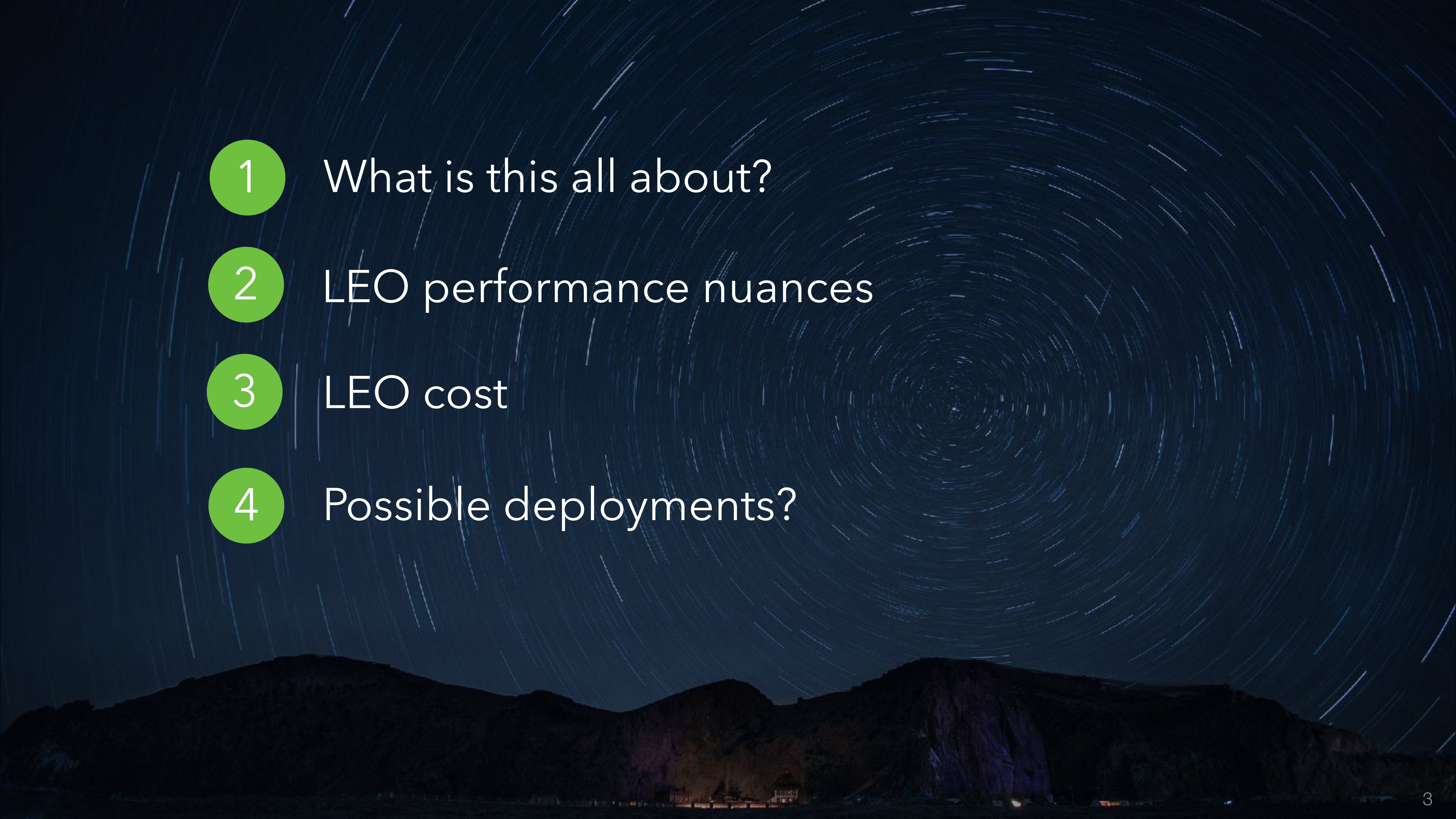
Debopam Bhattacharjee


Congratulations, Philippines!

SpaceX announces Starlink internet now available in the Philippines

FEB 22, 2023 1:24 PM PHT

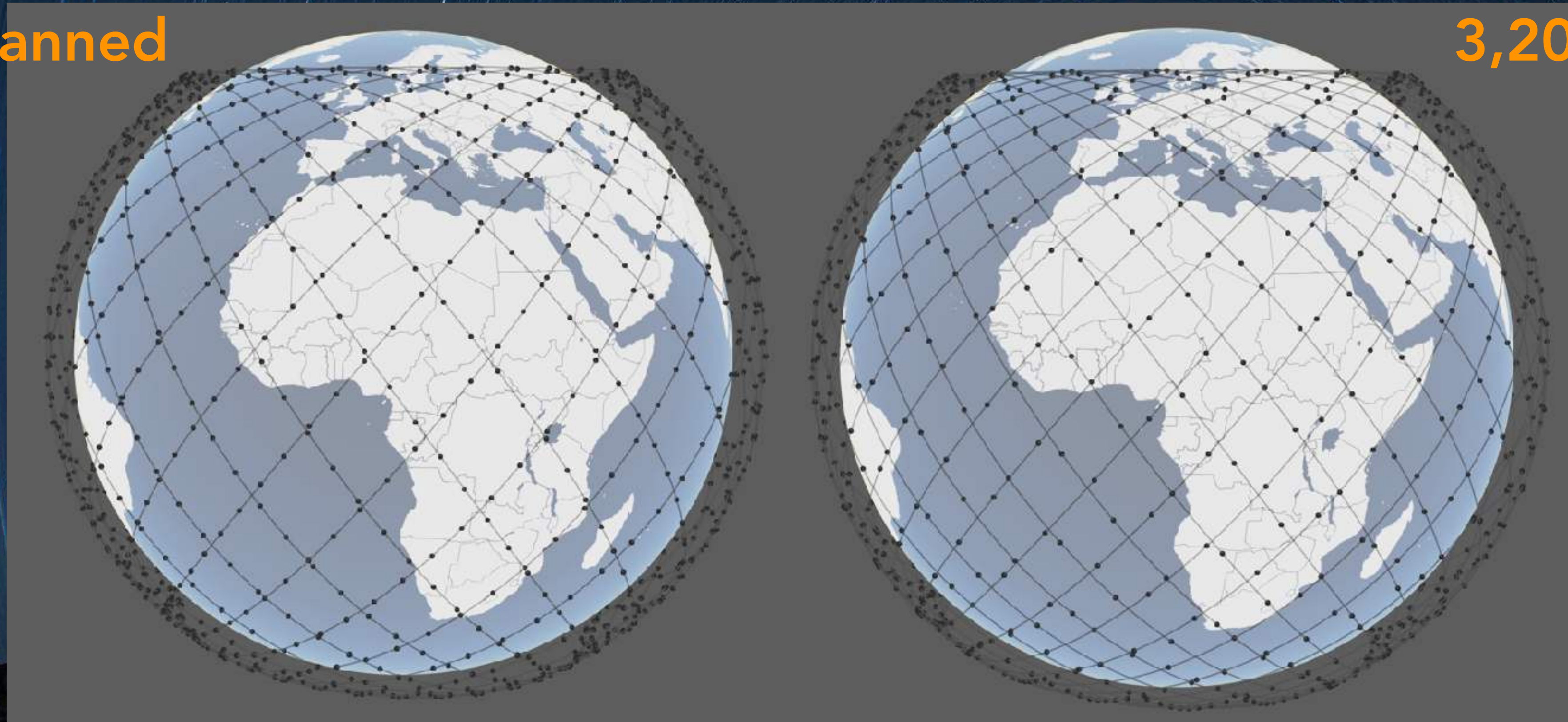
VICTOR BARREIRO JR.

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- A long-exposure photograph of a night sky showing concentric star trails. The trails are most prominent in the upper right quadrant, where they form a dense, circular pattern. The lower portion of the image shows a dark, silhouetted landscape with some distant lights, possibly a small town or village.
- 1 What is this all about?
 - 2 LEO performance nuances
 - 3 LEO cost
 - 4 Possible deployments?

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LEO broadband constellations

SpaceX Starlink
42,000 planned



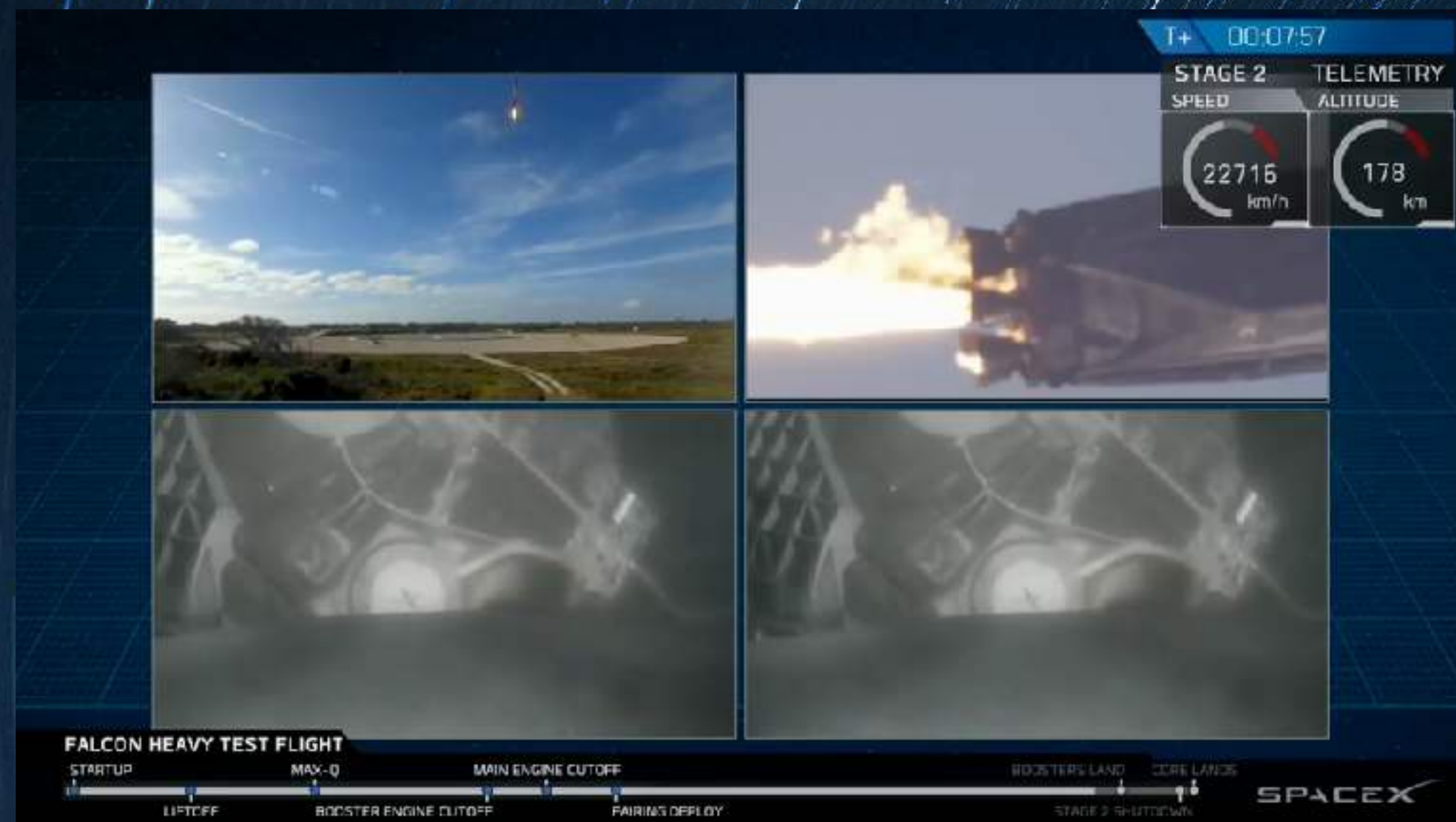
Amazon Kuiper
3,200 planned

OneWeb, Telesat, Astra, Guo Wang, E-Space, ...


What is new?

- Scale: 10s → 10,000s
- Goals: niches → global broadband
- Dynamics: GEO → LEO

Recent advances



10-20G / up to 8000 km

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GEO vs LEO



GEO

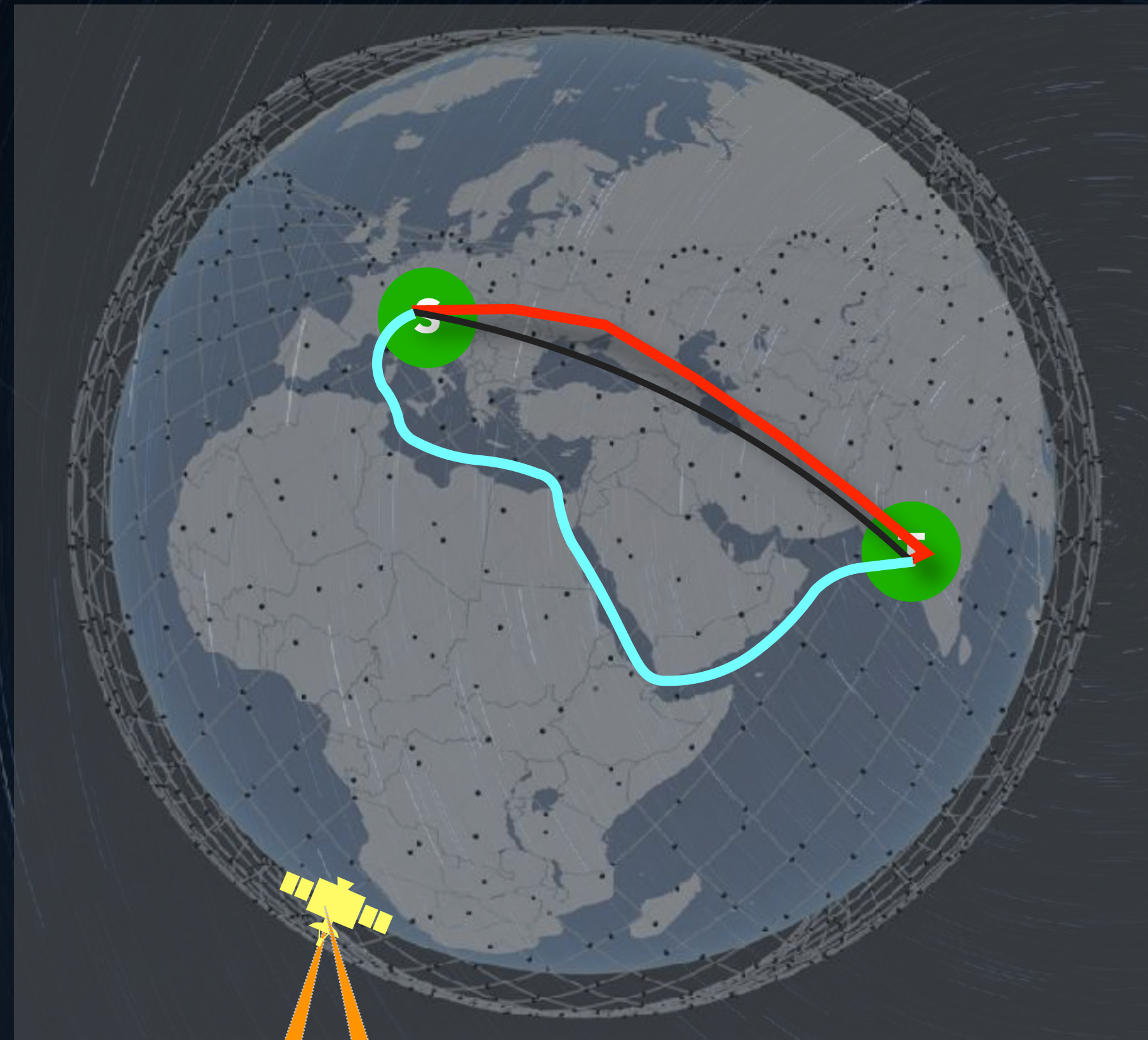
35,768 km



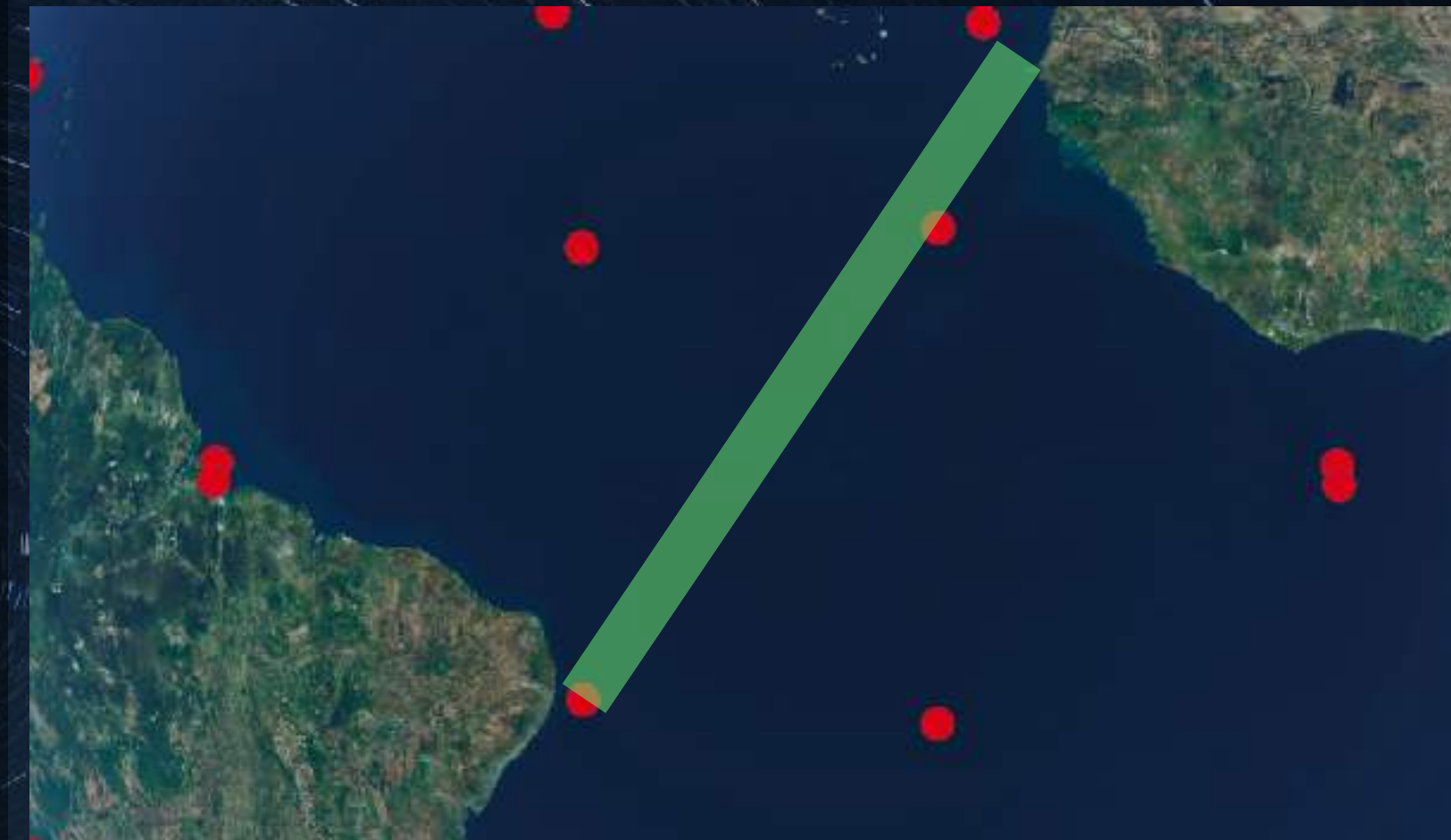
LEO

550 km

Low latency



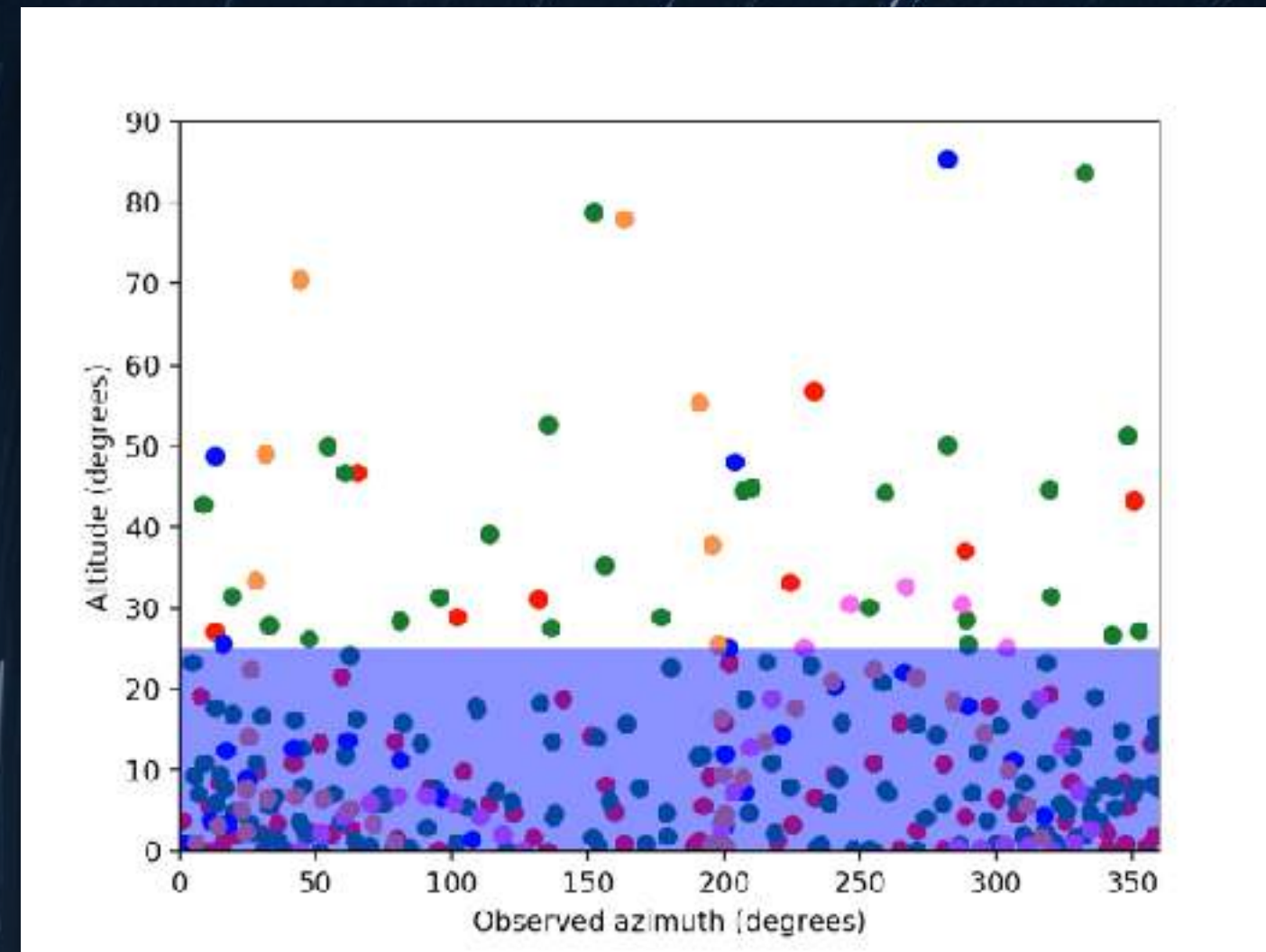
LEO dynamics



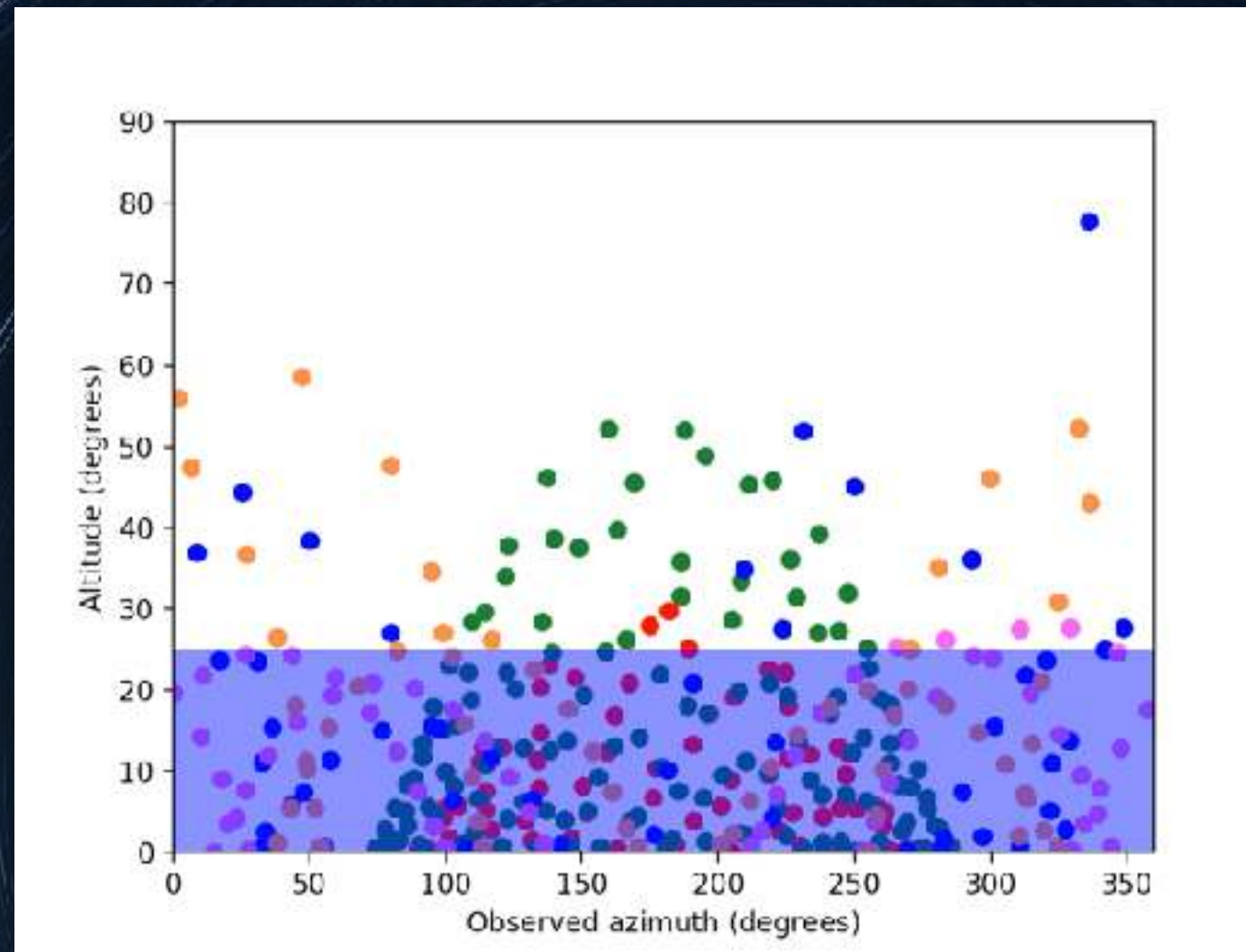
> 450 km / min

Node-local view (Starlink Phase1)

Delhi

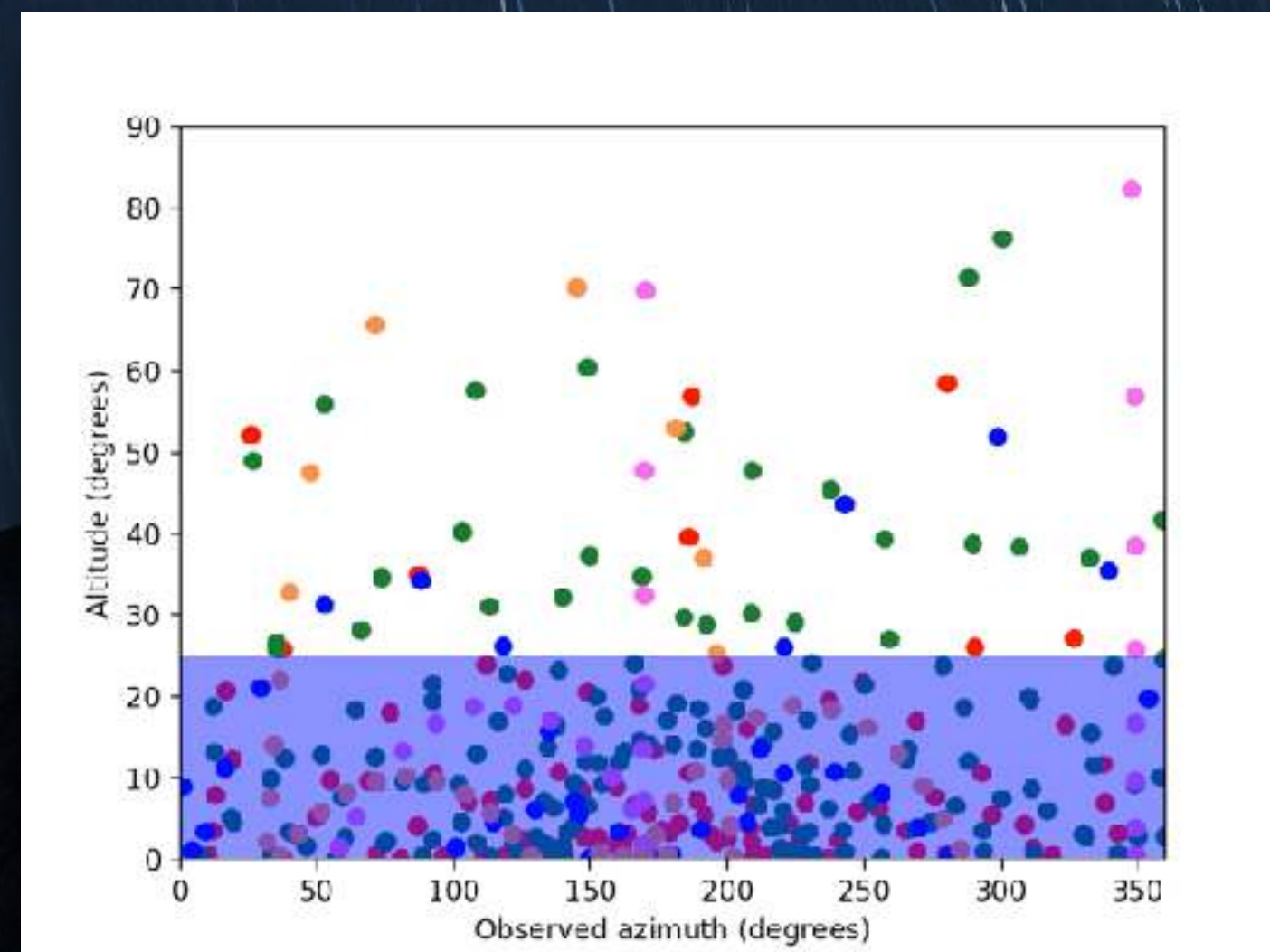


Oslo

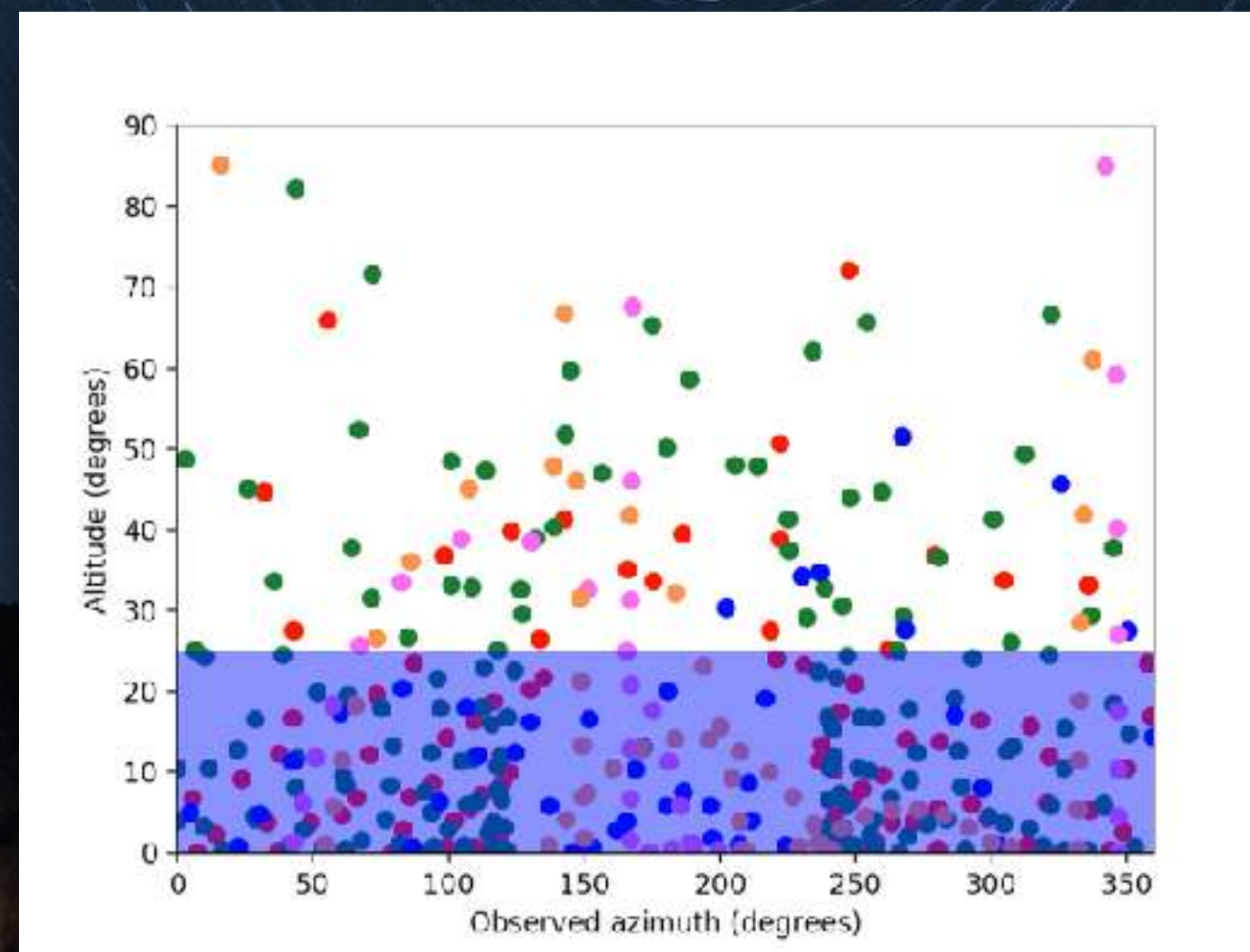


50x faster than real-time

Santiago



Christchurch



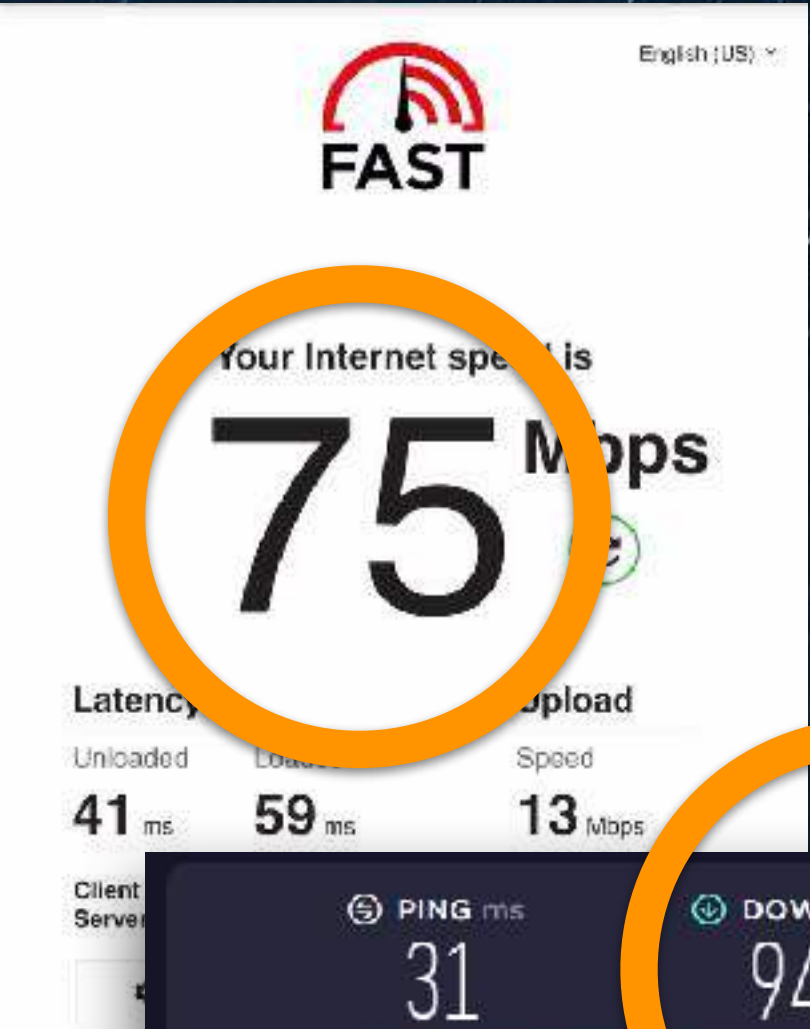
Starlink performance reports

Public Mobile 8:44 AM

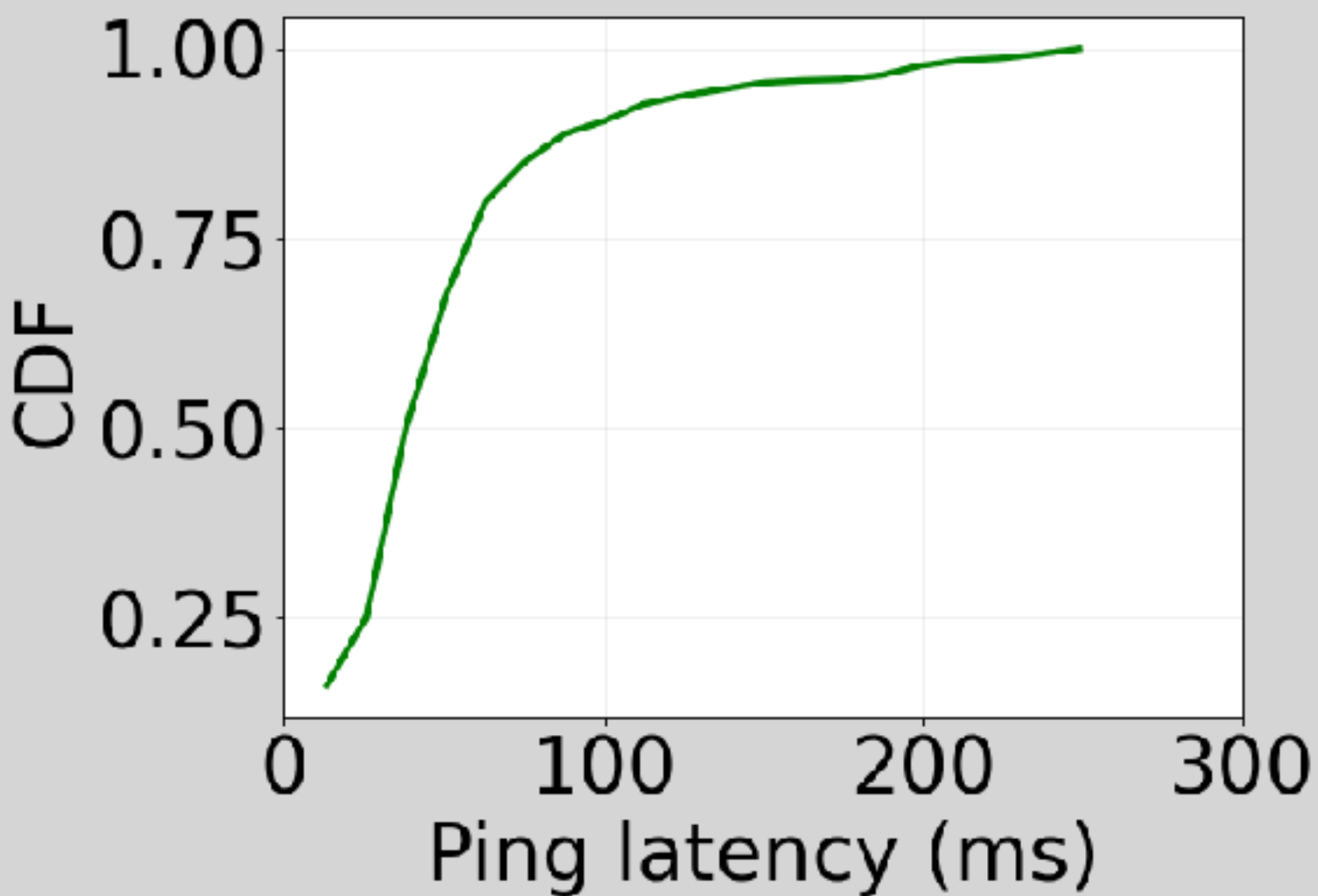
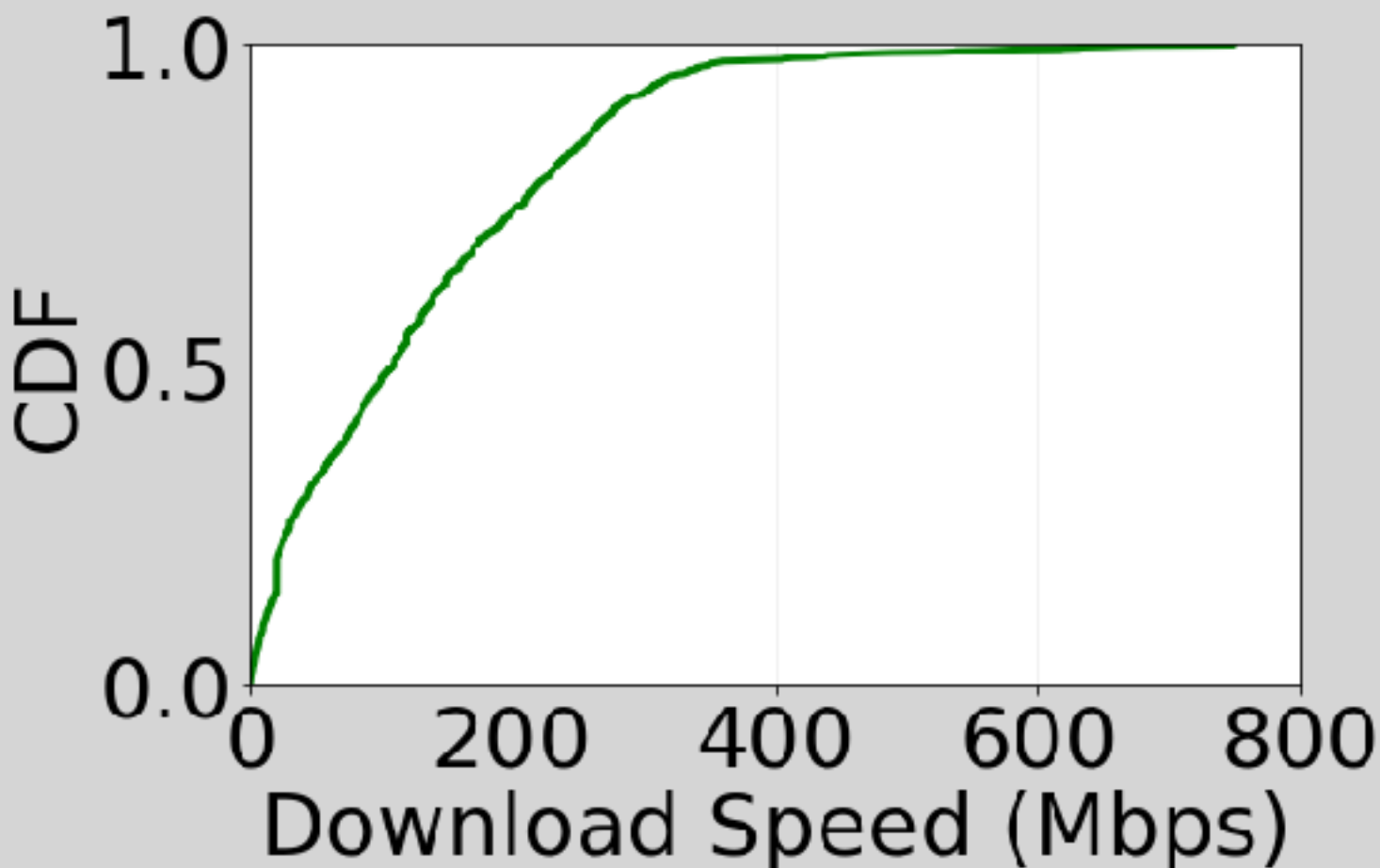
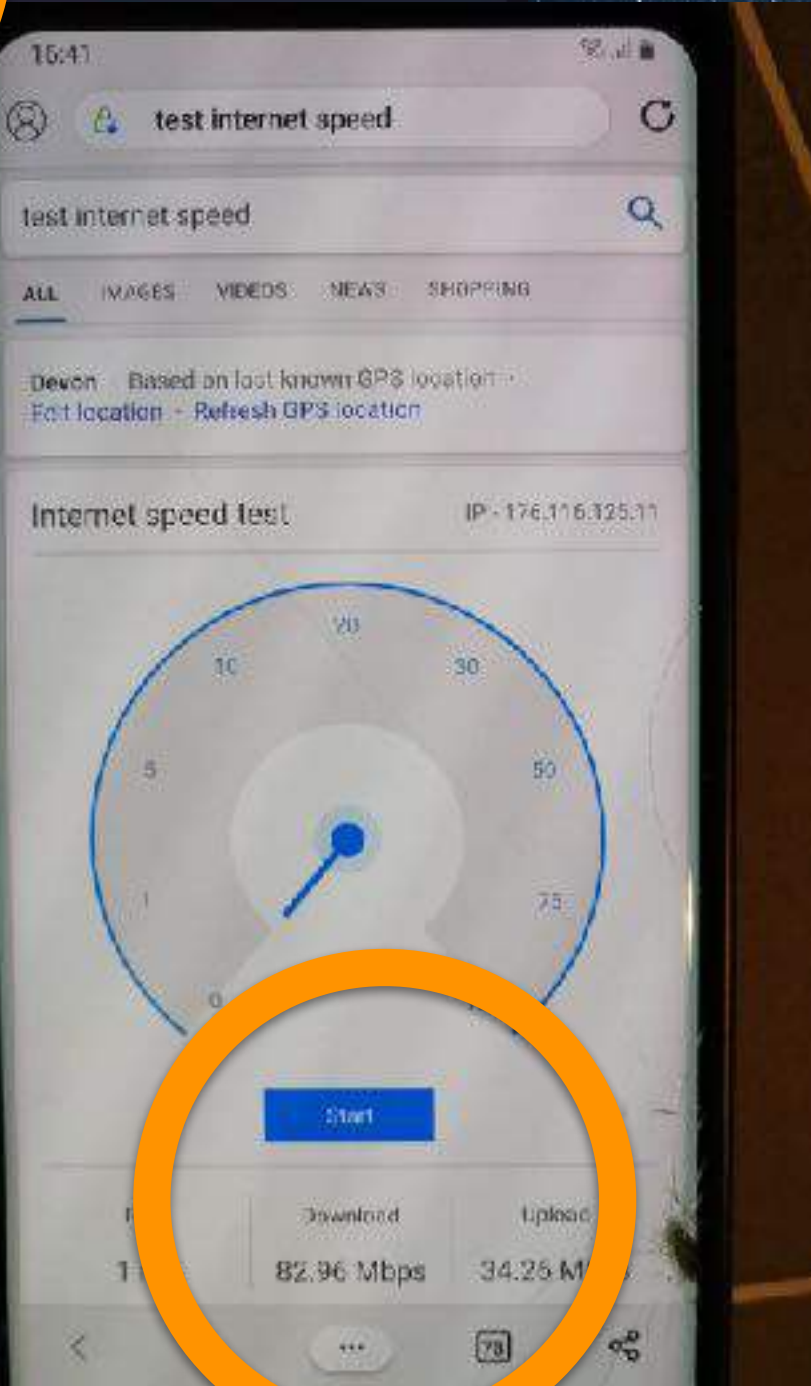
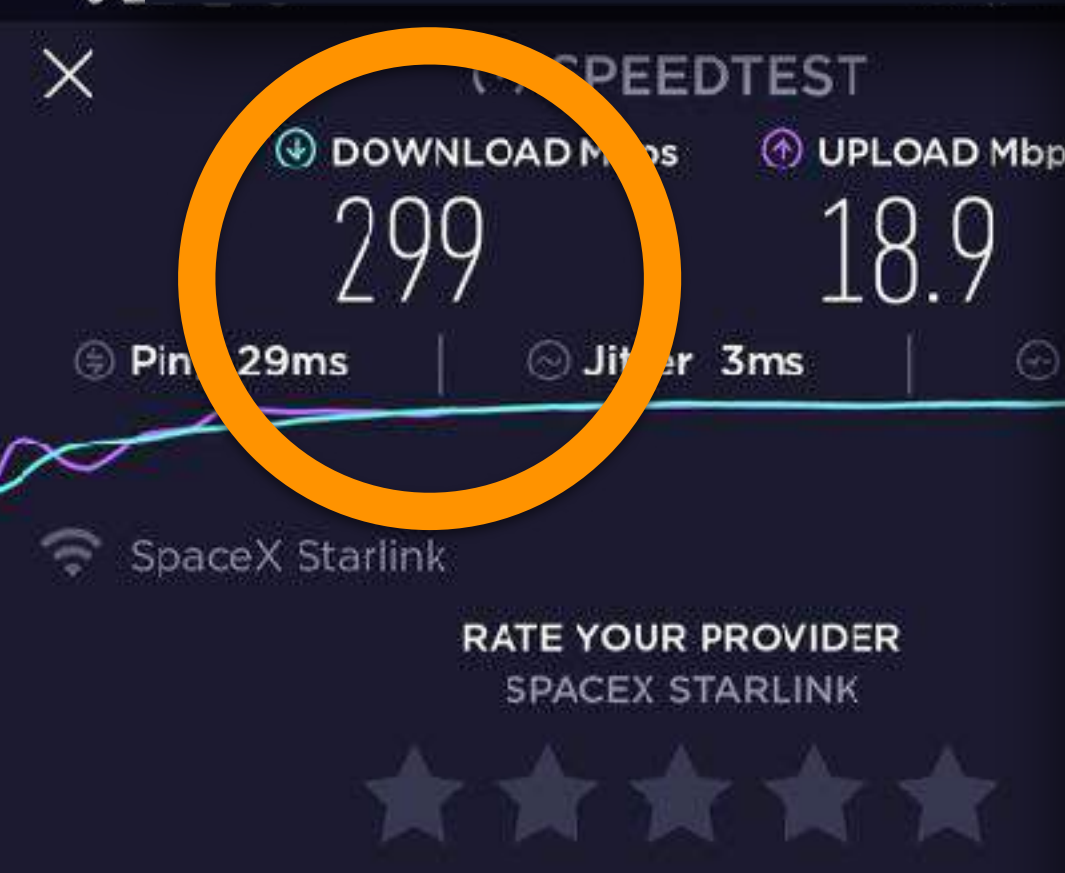
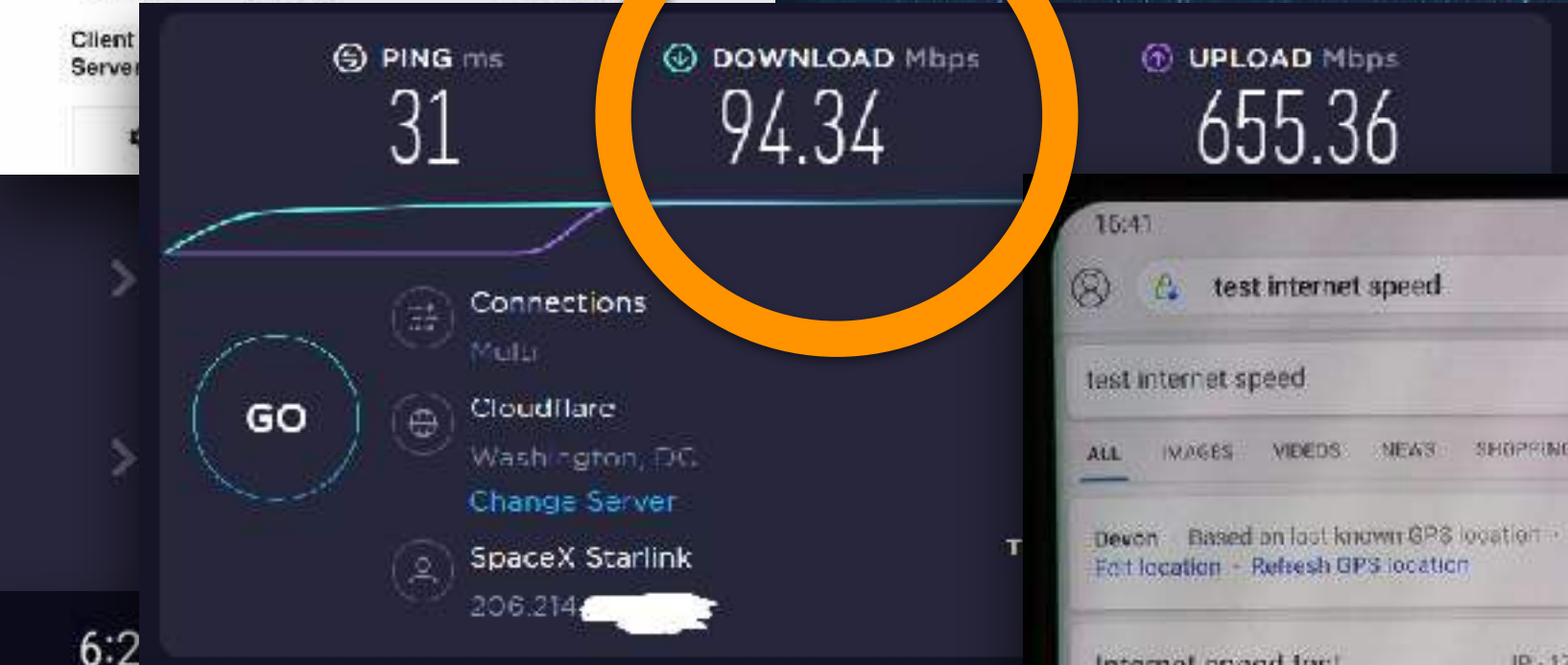
SPEEDTEST

Type	Date	Download Mbps	Upload Mbps
Wi-Fi	2021-01-03 8:43 AM	73.9	7.59
Wi-Fi	2021-01-03 8:42 AM	15.3	17.5
Wi-Fi	2021-01-03 8:23 AM	167	20.9
Wi-Fi	2021-01-03 9:00 AM	161	24.1
Wi-Fi	2021-01-03 8:20 AM	61.6	17.5
Wi-Fi	2021-01-03 8:22 AM	154	29.0
Wi-Fi	2021-01-03 7:19 AM	145	27.4
Wi-Fi	2021-01-02 2:45 PM	30.5	6.52
Wi-Fi	2021-01-03 8:47	34.1	8.47

Speed VPI Results

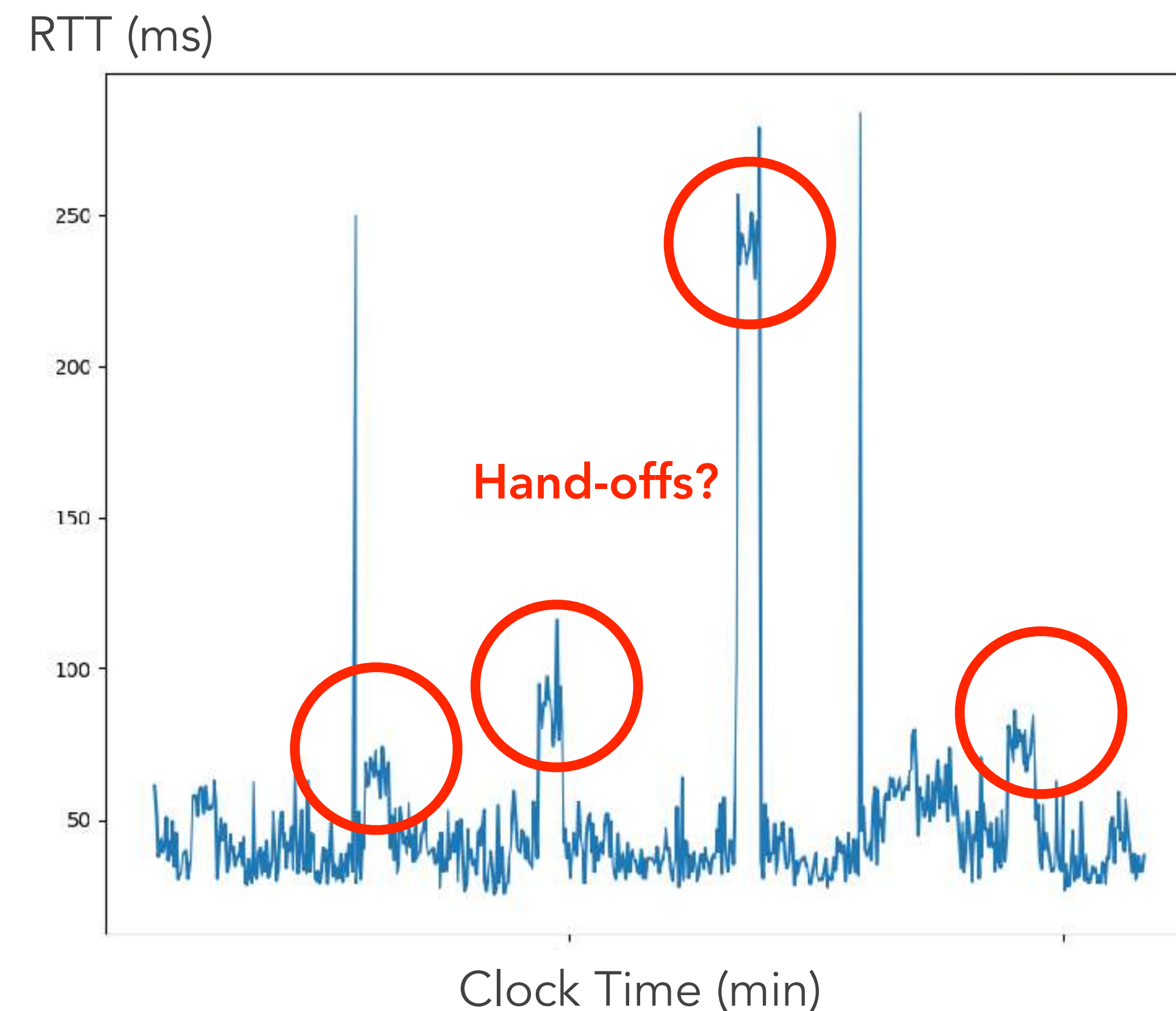
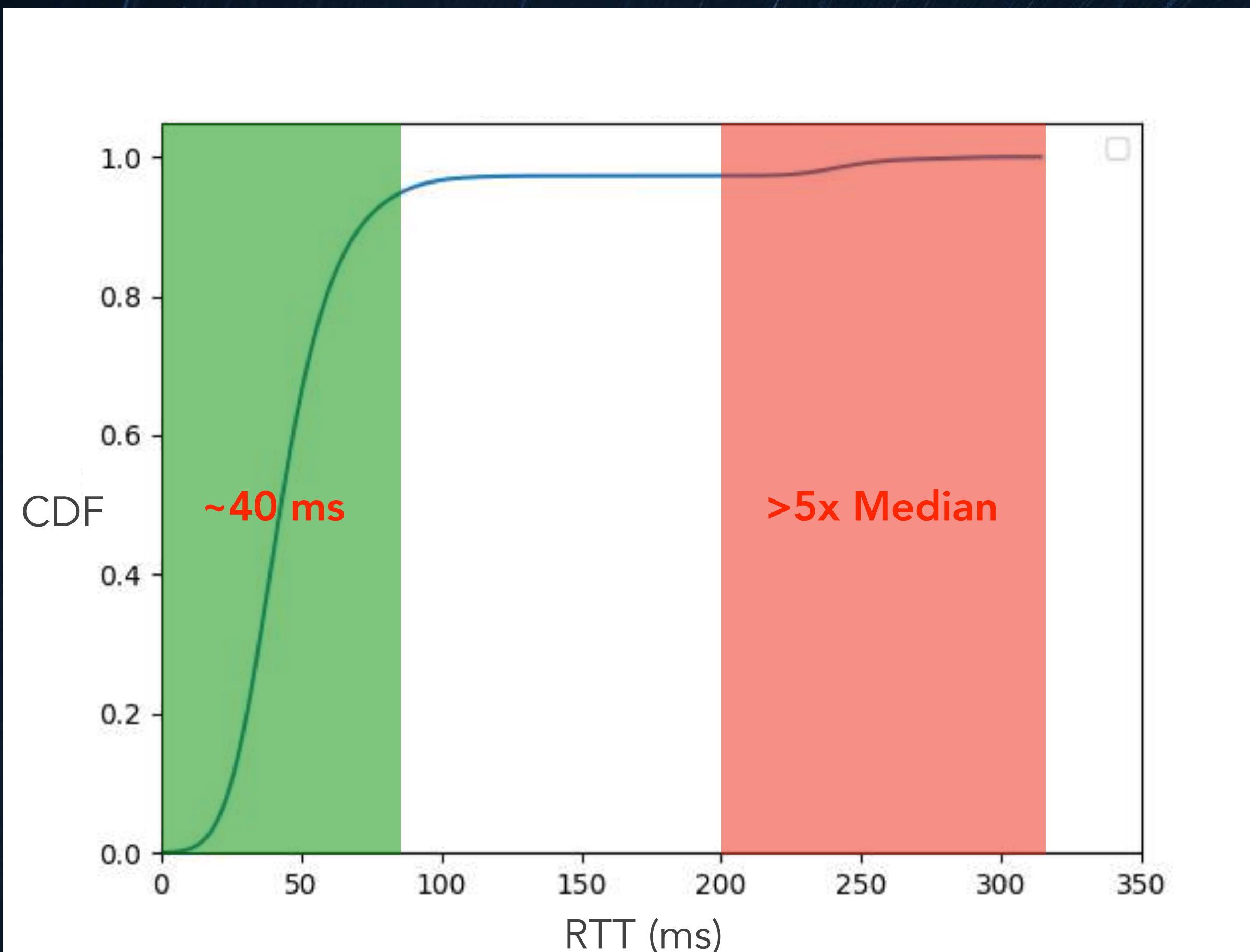


Collected from
a subReddit

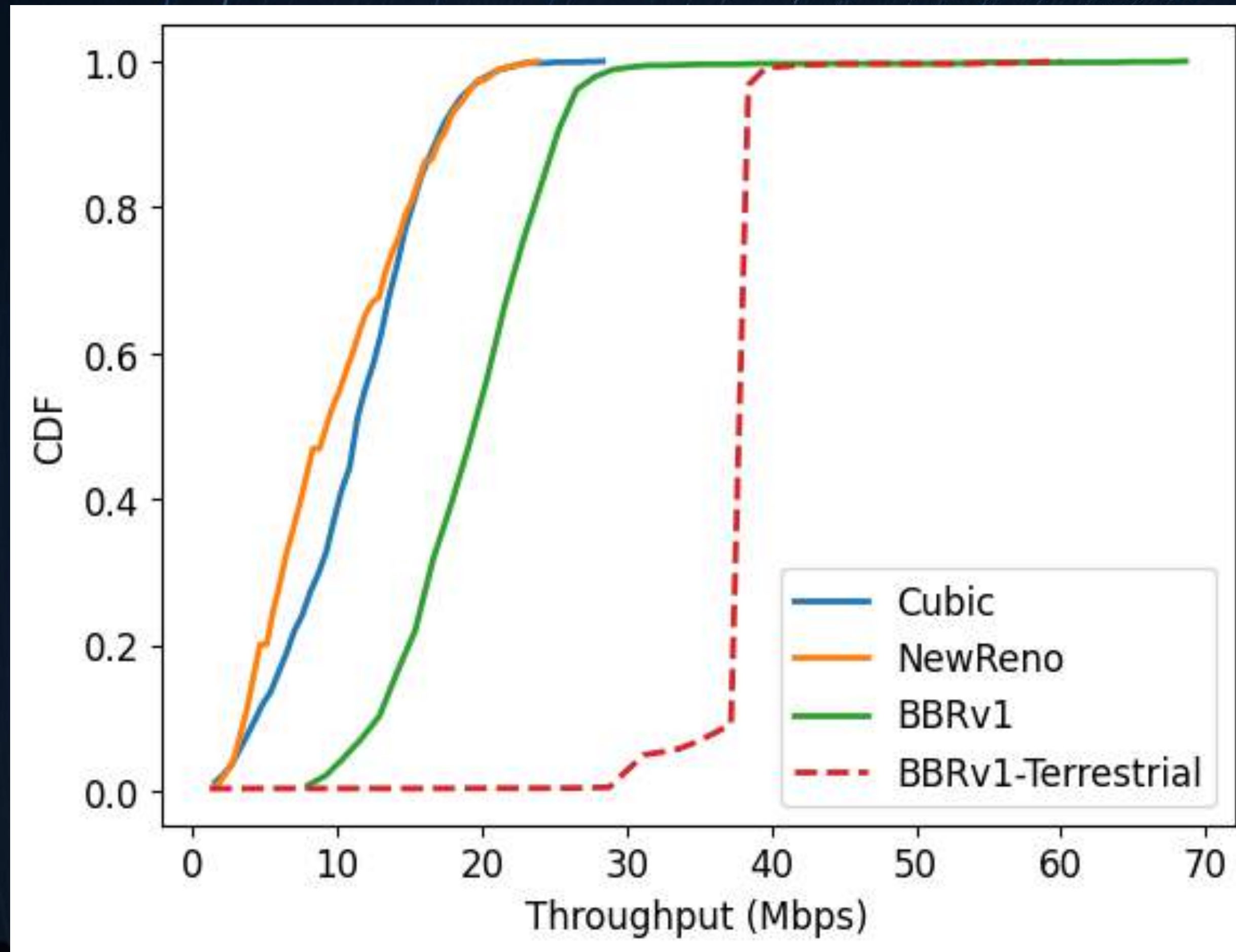


LEO latency and variations thereof


- Mostly low latency
- Long tail due to suboptimal hand-offs



Throughput observations



- Transport performance variations
- **BBR** affected due to continuous latency changes and spikes
- **TCP Cubic/NewReno** lag behind due to non-congestive loss during hand-offs and retransmissions due to path changes.
- Transport-layer bottlenecks **impact application performance** and user experience.

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- A long-exposure photograph of a night sky showing star trails as concentric white arcs. The trails are centered on a point in the sky, likely the North Star. In the foreground, the dark, silhouetted peaks of mountains are visible against the starry sky. Some small lights from buildings or settlements are visible at the base of the mountains.
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Starlink Internet cost Jan'23

Type	Kit Price ^{\$}	Subscription ^{\$}
Residential	498.59 ± 66.83 max: NZ (661) min: JP (284)	75.78 ± 20.14 max: US (110) min: CO (44.1)
Premium	2736.91 ± 287.01 max: CL (3296.8) min: CA (2365.1)	250.19 ± 108.71 max: US (500) min: UK (182.67)
RV	501.34 ± 66.23 max: NZ (661) min: JP (284)	97.57 ± 23.89 max:US (135) min: CO (54.6)
Maritime	5000	5000
Aviation	150000	12500 to 25000*

*depends on the usage
Collected from multiple sources

Starlink Internet cost Jan'23

Nigeria: Hardware cost **NGN268,584**, Monthly subscription

<https://www.commsupdate.com/articles/2023/02/02/starlink-enters-the-african-market-with-first-launch-in-nigeria>

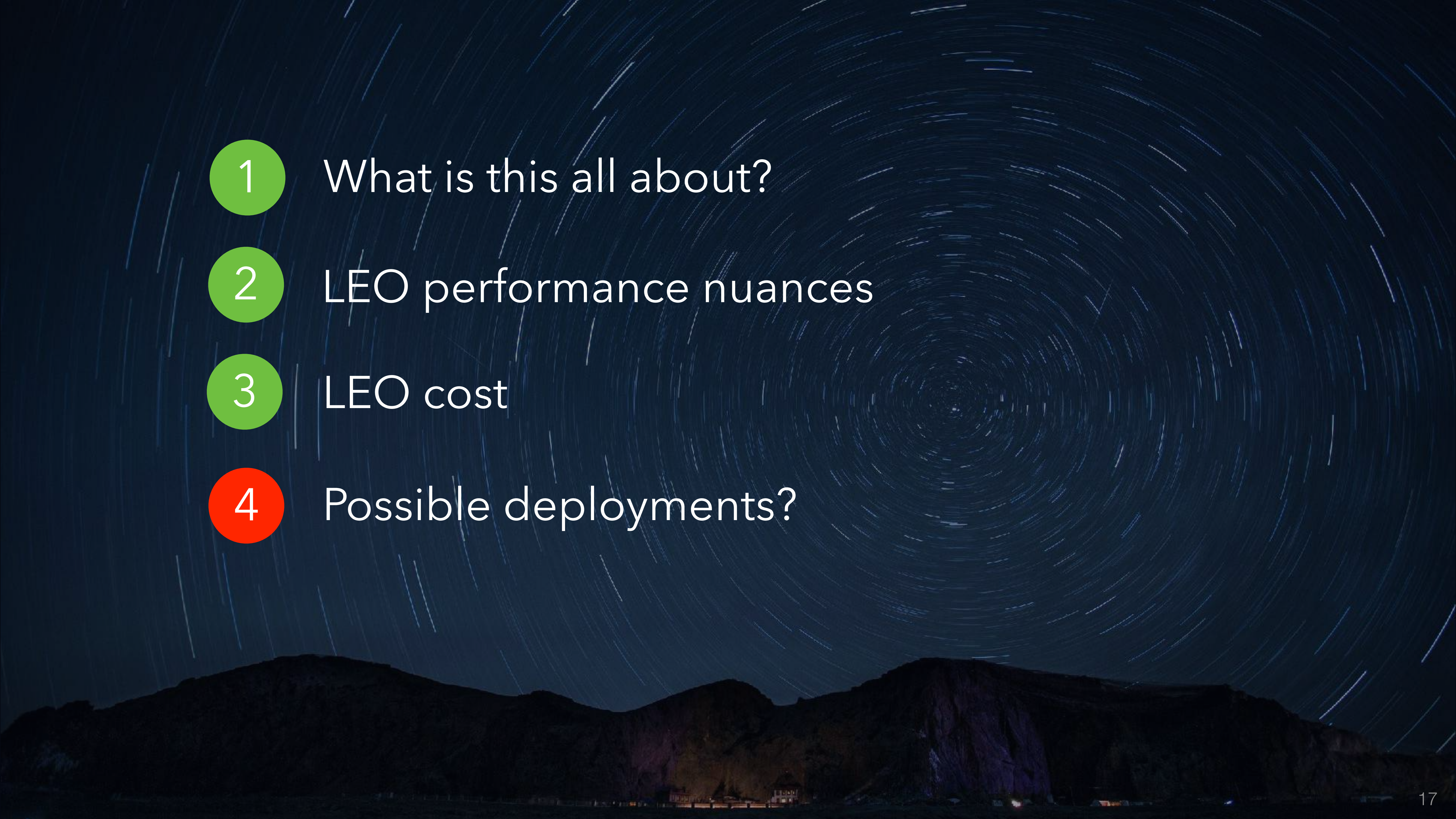
~42 USD

~43.5 USD

Rwanda: Monthly subscription

<https://africa.businessinsider.com/local/lifestyle/elon-musks-starlink-brings-high-speed-internet-to-500-schools-in-rwanda/kb4gmck>

India: 75% of rural Indians live on less than 0.5 USD a day!

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- A long-exposure photograph of a night sky showing star trails as concentric white arcs. The trails are centered on a point in the sky, likely the North Star. In the foreground, the dark, silhouetted peaks of mountains are visible against the dark sky. Some small lights from buildings or settlements are visible at the base of the mountains.
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Project BlendNet

- **Low-cost** satellite and intelligent edge based technology which delivers digital services and content to last mile underserved users.
- The intelligent edge devices receive encrypted bulk content refreshed via satellite and serve as delivery endpoints.
- Mobile application/SDK enables end-users to discover, stream and download content to their devices in an offline mode (using local Wi-Fi) without the need for internet.

AirJaldi networks

- Implements technically and economically viable Internet connectivity solutions for rural India.
- Community WiFi, public hotspots

LEO Consortium efforts

LEOCONN 2021: 2-day webinar on LEO networks

38 countries, 150+ industry attendees, 30+ CEO/VP/directors, 100+ from top 50 universities, 10 govt space agencies.

LEOCONN 2022: 1-day in-person tutorial co-located with MobiCom, Sydney

LEOCONN WS: Ongoing webinar series

2/3 speakers per session giving tech talks on LEO.

Visit: <https://leoconnws.github.io/> and **subscribe** to receive updates!

Current LEO Collaborators

- **Microsoft Research:** Shubham Tiwari, Cheng Luo, Cong Zhou, Aryan Taneja, Zhiyuan He, Lili Qiu.
- **Azure Space (Microsoft)**
- **University of Surrey, UK:** Mohamed Kassem, Nishanth Sastry
- **Telefonica Research, Spain:** Aravindh Raman

Thanks.

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