



Measuring Starlink quality of experience in rural regions



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Introduction

Starlink

Satellite-based Internet has the potential to offer lower latencies and wider global connectivity than traditional terrestrial Internet Service Providers (ISPs), with SpaceX's Starlink being the premier low Earth orbit (LEO) satellite-based ISP. There is thus a need to robustly quantify metrics of Starlink's quality of experience (QoE), with an eye towards its performance in key rural areas where Starlink may be the best or only option available.

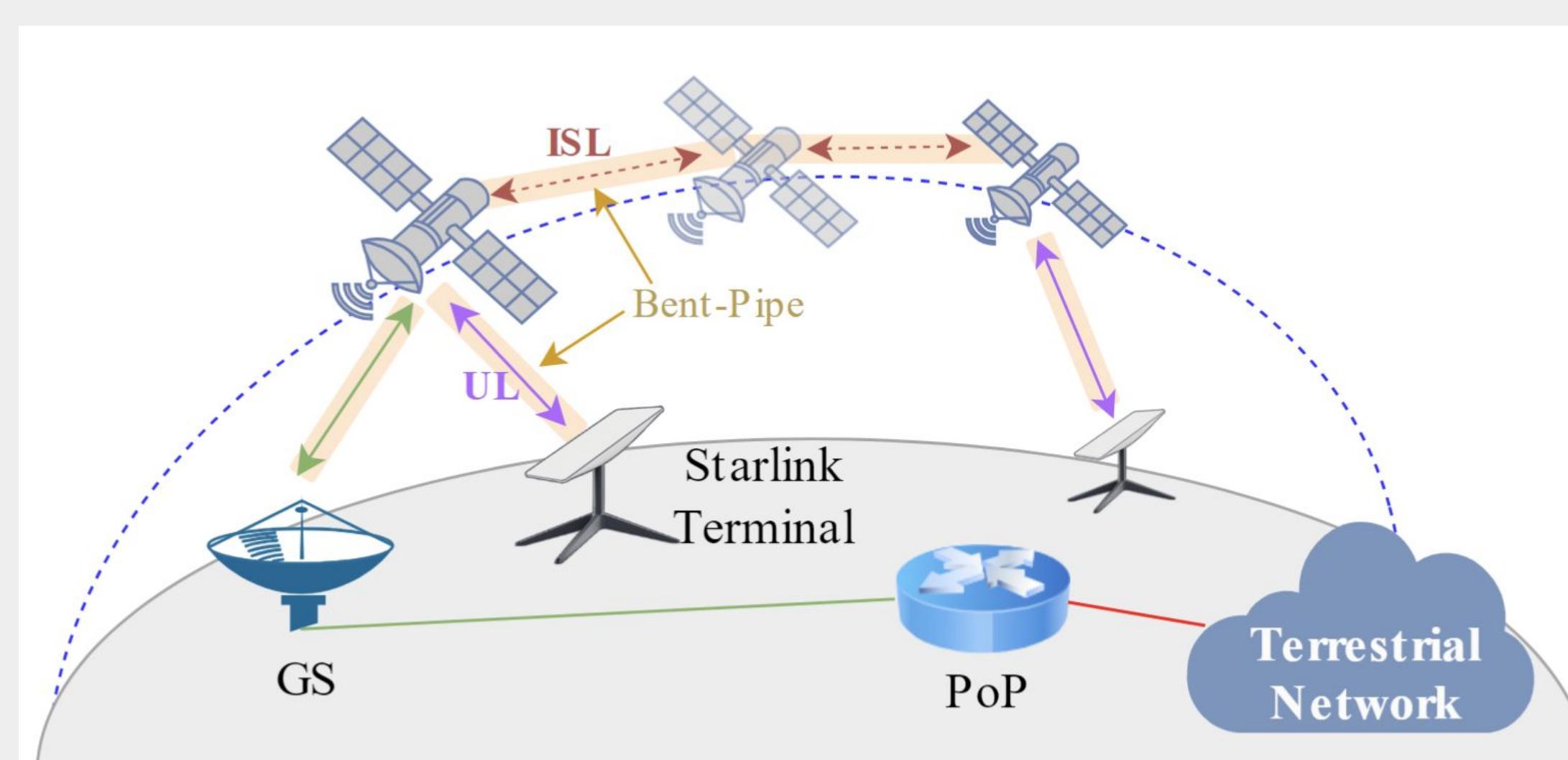


Fig 1. A depiction of Starlink's bent-pipe architecture, showing the client terminal, satellite network, and ground station.

Metrics of Internet QoE

- Latency: the round-trip time (RTT in ms) a packet takes from source (Fig 2. TP) to destination (Fig 2. A-G) to source again.
 - Packet Loss: the percentage of data packets which fail to reach their destination

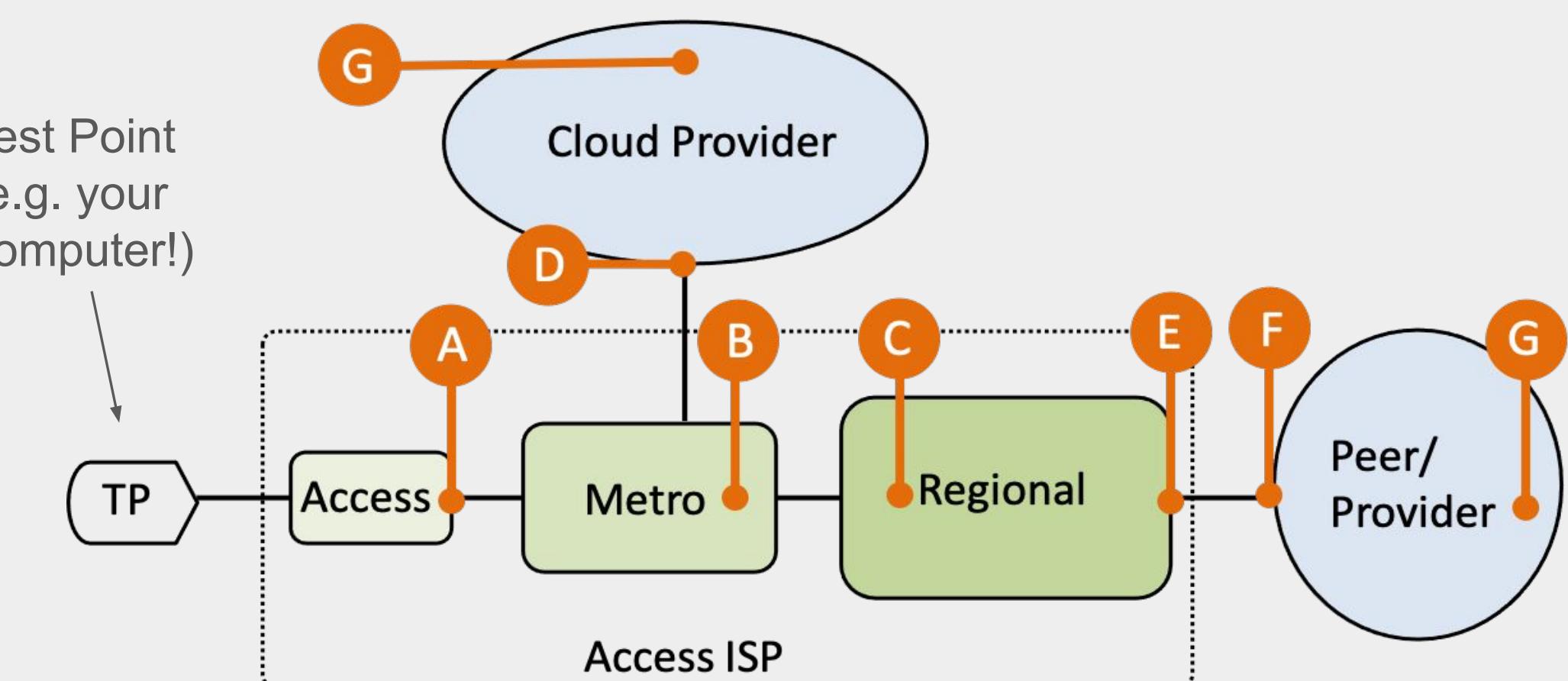


Fig 2. A diagram of the destination points to which latency can be measured in a network.

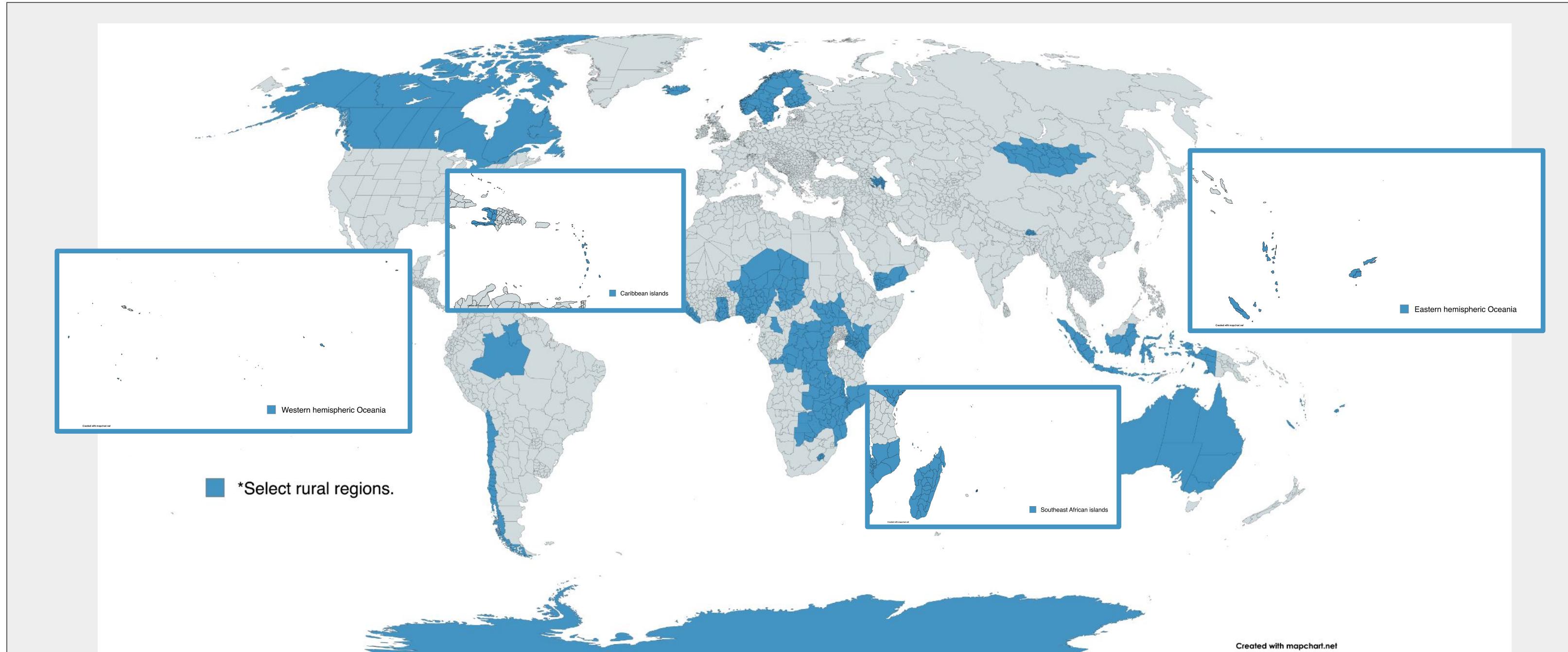


Fig 3. A world map showing the new dataset's geographic coverage in blue, to sub-national granularity.

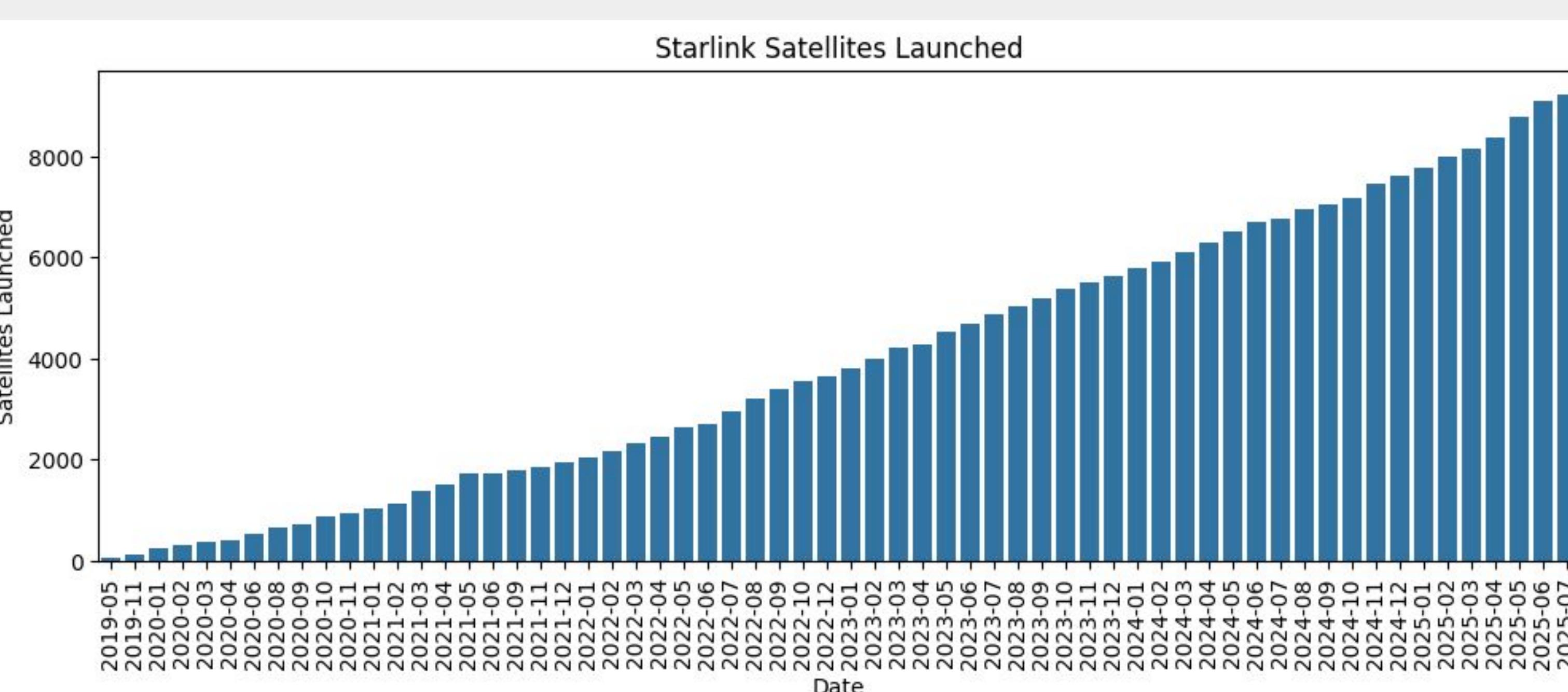


Fig 4. Cumulative Starlink satellites launched, May 2019 - July 2025.

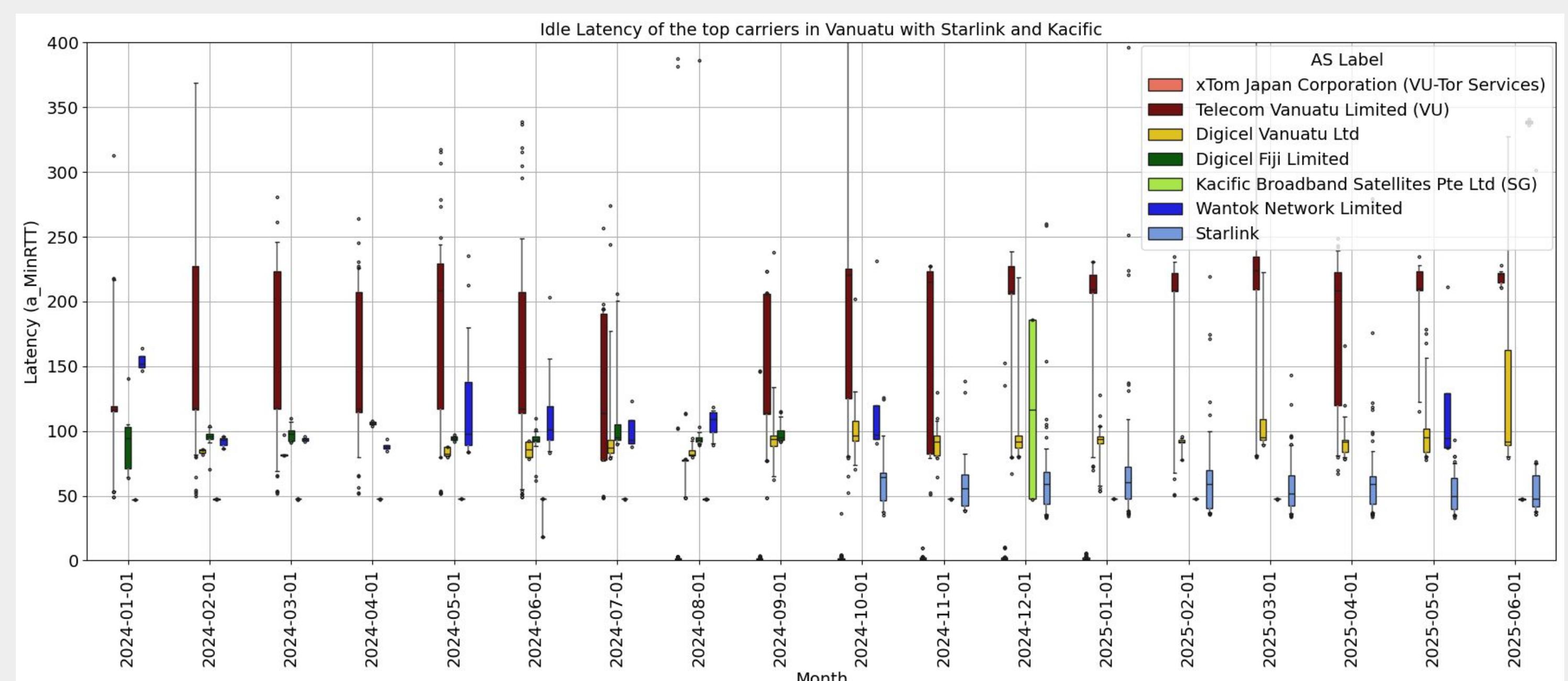


Fig 5. Comparison of latency measurements in Vanuatu by popular carriers, Jan 2024 - June 2025.

Methodology

Data Collection

For regions seen in Figure 4, data was collected from Measurement Lab (M-Lab)'s NDT and Cloudflare datasets using Google BigQuery.

```
1 SELECT measurementUUID, latencyMs, clientASN, measurementTime,  
2 serverPoP, clientIPVersion, clientCity, clientCountry,  
3 packetLoss.lossRatio, clientRegion, date  
4 FROM `measurement-lab.cloudflare.speedtest_speed1`  
5 WHERE (clientCountry = "CL" OR clientCountry = "AU"  
6 OR clientCountry = "HT") AND date > DATE("2025-01-01")  
7 AND date < DATE("2025-07-01")  
  
1 WITH filtered_data as (  
2     SELECT *  
3     FROM `measurement-lab.ndt.ndt7`  
4     WHERE date >= DATE("2025-03-01") AND  
5         date < DATE("2025-04-01") AND  
6         --client.Network.ASNumber = 14593 AND  
7         ( (a.MinRTT > 0.0 AND  
8             a.MeanThroughputMbps > 0.0 AND  
9                 a.lossrate >= 0.0  
10            ) AND ( (client.Geo.Latitude > -32) AND  
11                (client.Geo.Latitude < -18) AND  
12                    ((client.Geo.Longitude > 118) OR (client.Geo.Longitude < 146)) AND  
13                        (client.Geo.CountryCode = "AU")  
14                    )  
15                )  
16            )  
17        )  
18    )  
19 )  
20 )
```

Fig 6. Sample query of Cloudflare dataset for measurements from Chile, Australia, and Haiti.

Fig 7. Sample NDT Query for select regions of Australia, identified by latitude and longitude.

Data filters included country, city, date, latitude, and longitude.

Plots

Box plots of latency over time (see Fig 5) were made using data gleaned from M-Lab datasets (see Figs 6, 7) using Matplotlib, with measurements separated by carrier/AS. “Outliers” (represented as as fliers beyond the whiskers) were of particular interest due to the transitory nature of Internet disruptions.

Conclusions

Our findings show that Starlink performance in selected regions is comparable or superior to other network providers. Our research builds on previous work by other authors to measure Starlink's quality of experience; the resulting dataset, to our knowledge, represents the first longitudinal, global attempt to catalog Starlink performance in rural areas. This research additionally has the potential to inform technological policy in countries which have yet to grant Starlink legislative approval.

Acknowledgments

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