Measuring Starlink Latency from RIPE Atlas

Tangerine: Maheer Aeron (maa368), Matthew Cafiero (mjc487), Joshua Church (jac726), Harris Greenstein (hag65), Skyler Krouse (smk362)

Project Goal

Our goal for this project was to analyze the latency of Starlink to assess how and why the latency of different Starlink terminals changes over time and location. To do so, we gathered a collection of RIPE Atlas probes connected to Starlink terminals and pinged them to the same site at the same time over the course of a day to compare how each terminal's latency changes.

Upon starting this project, we researched Starlink as a product. Starlink claims to offer high speed, low latency satellite based internet connectivity that outpaces previous satellite based products. Specifically, they declare a latency of around 25 ms.[1] Further, they offer such connectivity anywhere in the world.[2] In our research, we attempt to answer:

First, does Starlink deliver a low latency product regardless of where in the world a user is? Second, what is the consistency of this product over time?

We hope that the conclusions of our project are able to provide unbiased answers for anyone interested in Starlink. Such independent research of consumer products is critical in promoting corporate accountability and providing their customers with transparency.

Method

Prerequisites

For this project, we created a RIPE Atlas account and obtained the appropriate number of RIPE Atlas credits to run all of our measurements. We aimed to ping 30 probes every 15 minutes over a 24 hour period. Since each ping costs 2 credits, we determined that each probe would cost 192 credits to ping. We also planned to run one traceroute on each probe, costing 60 credits per probe. In total, we needed exactly 7,560 credits– we rounded up to 8,000 credits for headroom.

Chosen Probes

When choosing probes, we aimed to spread the probes out with variation in both geographical location as well as type of location (rural, suburban, urban). Doing this allowed us to maximize

[1] The Starlink Technology Webpage: https://www.starlink.com/technology

[2] The Starlink Webpage: https://www.starlink.com/

our ability to analyze how the Starlink probes perform in different places. Additionally, we selected probes that were close to each other in order to eliminate the impact of location and assess other patterns, such as how location type or nearby population affects latency. Please see the attached Google Sheet, Probes, for specific information on probes, and Figure 1 for a visualization of selected probes.

Probe Map

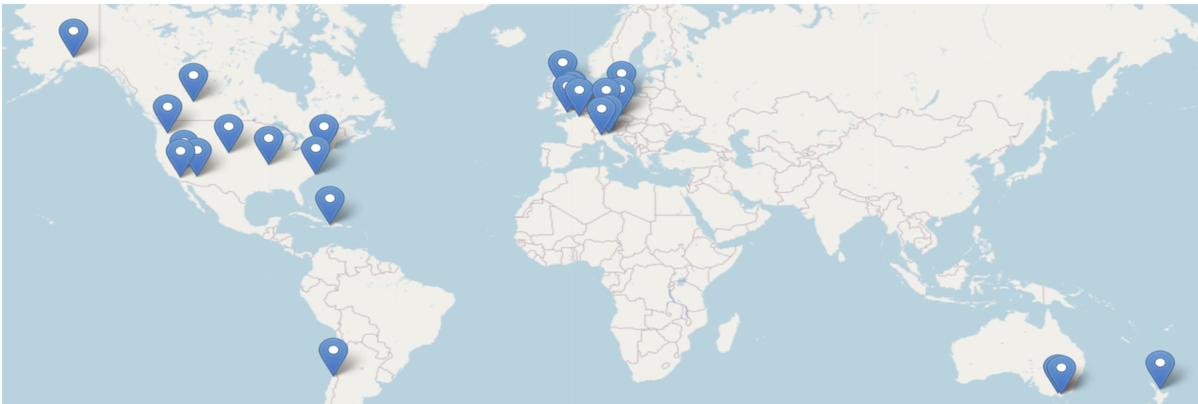


Figure 1: Location of all selected probes

Taking the Measurements

To take measurements, we queried the Ripe Atlas REST API using Python's native HTTP requests package. We first ran small tests to ensure functionality and get example results to prepare to analyze the 24 hour test later on. We ramped up from one probe and one ping request to multiple probes with multiple pings until we were confident to move on to the full 24 hour test. Over one 24 hour period (from 7:30pm Friday 4/28 to 7:30 pm Saturday 4/29), we pinged all of our selected probes every 15 minutes. Afterwards, we used the collected data to calculate the latency of each probe by tracking its Round Trip Time (RTT). We also ran one traceroute for each probe to investigate the hops that each probe would take.

Results

Latency By Geographic Location

Looking at the latencies over time for probes in nearby locations, specifically Australia, London, and the USA, there were no major or drastic differences between probes in the same place. Looking at the probes in Australia, and specifically the data shown in Figure 2, the latencies vary similarly, with the exception of one spike on probe 19983 around 4-29 5:00 UTC. Looking at the latency over time for the London probes in Figure 3, a similar pattern is noticed, with the latencies being generally similar with some spikes. Based on these findings we can tentatively conclude that there is limited variability in latency between probes in similar geographic locations.

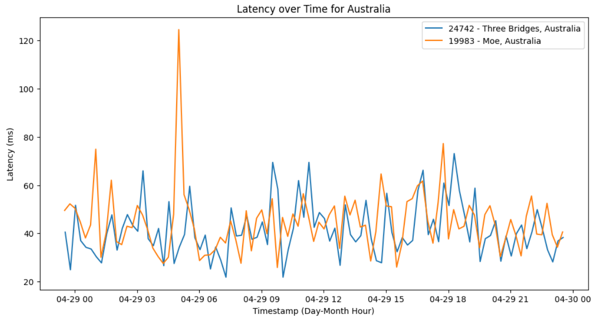


Figure 2: Latency for Australian probes

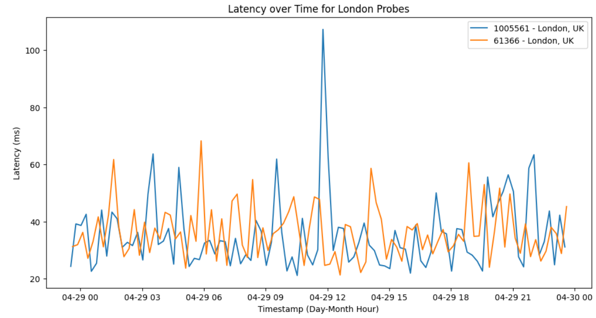


Figure 3: London probe latencies

Alaska particularly stood out as an outlier in comparison to other probes in the USA; it can be seen in red in Figure 4 in comparison to the other U.S. probes in grayscale. We sought to understand why Alaska was such an outlier given that Starlink states it is available in that region with no indication to expect higher latency. To analyze, we found a live visualization of Starlink satellites on the website starlink.sx. Watching our probe location at 30x speed, an interesting pattern emerged that explained some of the latency spikes. First, the satellites didn't allow the Butte, Alaska probe to connect to the closest ground station ~40 miles away in Anchorage but rather connected it to a ground station >2000 miles away in Nome, AK. Second, there were full periods of time where no satellite could simultaneously connect to the probe and a ground station, explaining the many dropped packets shown as dips to -1 ms in Figure 4. We maintain these results in the figure to communicate the periods of no connection that only Alaska experiences consistently.

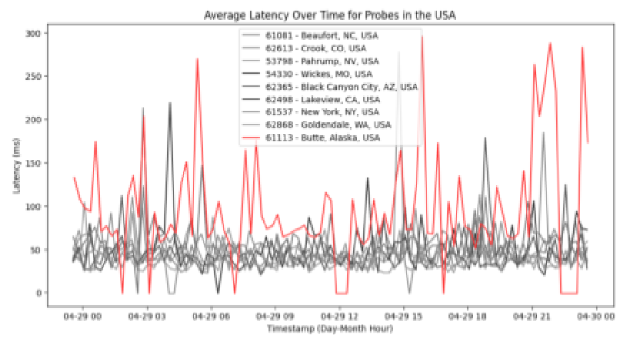


Figure 4: Alaska latency in red, rest of USA in gray

Latency in Rural, Urban, and Suburban Areas

Looking at the differences between the latency in rural, urban, and suburban areas, it seems that rural areas overall tend to have a higher latency than urban and suburban areas. The latency in suburban areas stayed relatively between urban and rural. An interesting pattern in the urban latency is that it started off noticeably lower than the other areas and then increased over time before dropping again at the end of the day.

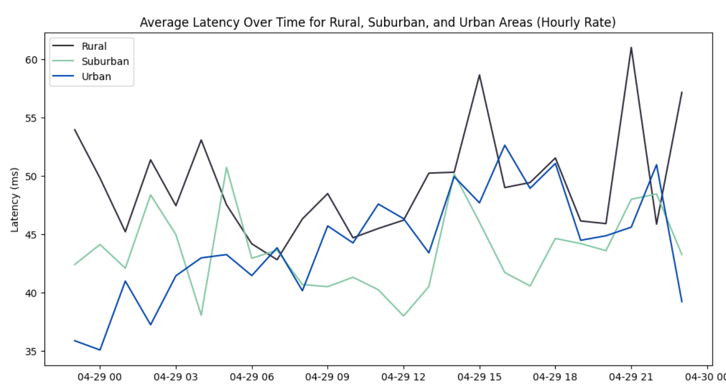


Figure 5: This graph shows the average hourly latency for probes, grouped by probes that are in rural, suburban, and urban regions.

Looking at a Traceroute

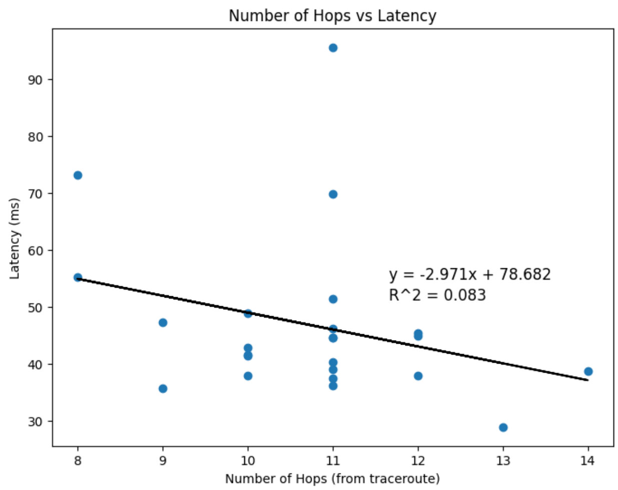


Figure 6: Low R^2 value indicates weak relationship between hops and latency.

Our team aimed to investigate whether the number of hops a packet traverses affects the latency. To achieve this, we executed a single traceroute command across all 25 probes and noted the latency and hop count for each packet. Based on Figure 6, there is minimal correlation between the number of hops and latency, indicating a negligible impact. Given that modern networking technologies and routing protocols are designed to optimize packet deliveries, we suspect the length of the packet's path to the endpoints is not a reliable indicator of latency-- longer paths could have been chosen for higher availability for instance.

Conclusions

Bringing our analysis back to Starlink, we have two major conclusions to make about this product.

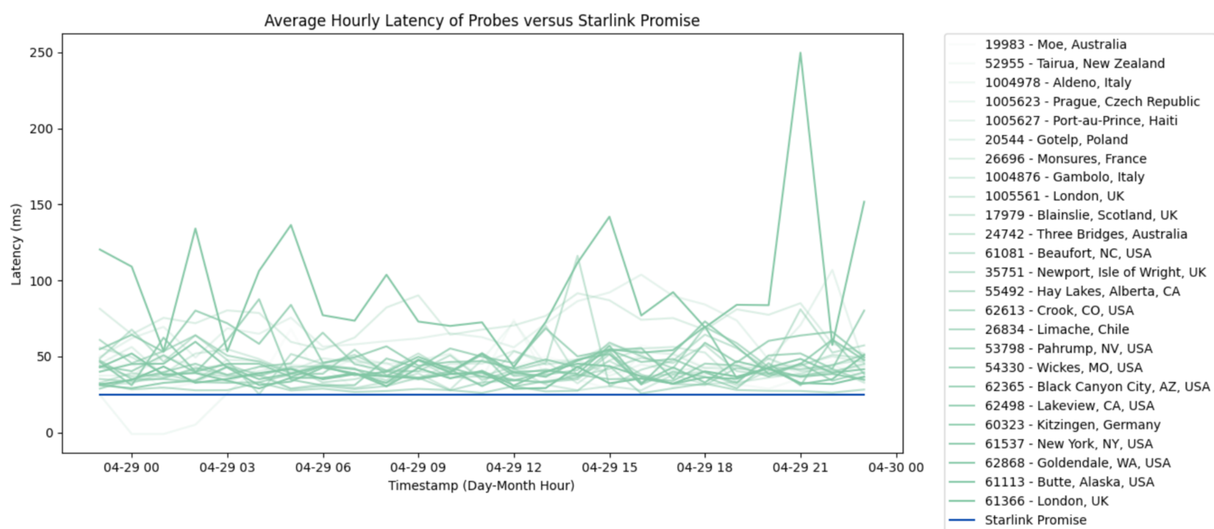


Figure 7: Starlink's promise

First, Starlink does not provide users its promised latency of 25 ms. Looking at the average hourly latency of each probe as seen in Figure 8, no probe ever achieved a sustained latency at this promise. Most probes never reached such an average latency at any point during our data collection. Further, we see that 16 probes, when we subtract their standard deviation from their mean, are still above this 25 ms promise (Please refer to difference in mean and standard deviation table for each location in the appendix for such calculations). This means, assuming latency is distributed normally, each of those probes spent at least an estimated 84% of the time we collected above this promise. Accordingly, we can conclude that this promised latency is not being delivered.

Second, we conclude that Starlink is not transparent with the true consistency of their product. Our results prove that there is variation in latency by location and time. While this would be expected with any internet product, Starlinks advertising never speaks to such variation for users, and if anything, often implies the opposite. Accordingly, we feel that Starlink needs to be more transparent with users on the latency they provide. Data such as ours should be easily accessible to consumers so they can make informed decisions, and we feel Starlink has not made that possible.

Overall, we feel we have provided an unbiased analysis of Starlink, and hope that such an analysis is useful to understanding this company and their product better.

Researching on a Budget

To begin, we want to start by defining our assumptions. We will assume that we have a means of discerning the type of satellite dish a given user is using. Accordingly, we define our metric of redundancy as probes within a given distance of one another that are using the same equipment. This distance can be defined based on the measurement budget, with distance being inversely related to the size of the budget. We choose this redundancy measure because we expect that probes close together would connect to the same satellites and ground stations, which given our assumptions would imply a marginally small difference between the latencies of said probes. Therefore, little novel data would be collected from analyzing such probes, so eliminating as many as possible for the set would save cost while largely keeping our resulting data the same.

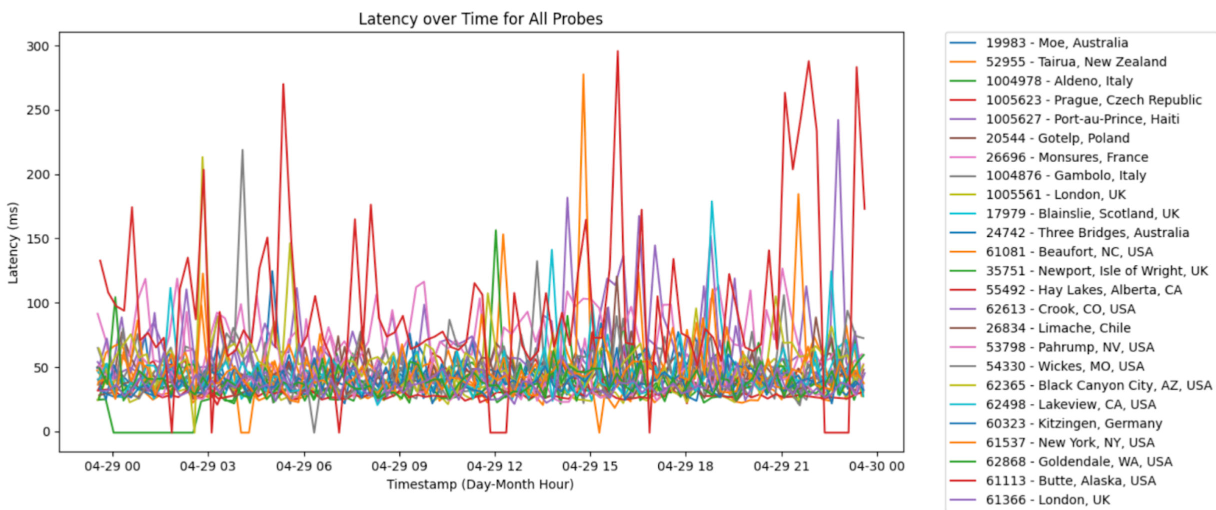
Appendix

GitHub: The repository containing the codebase run to complete the project steps can be found here.

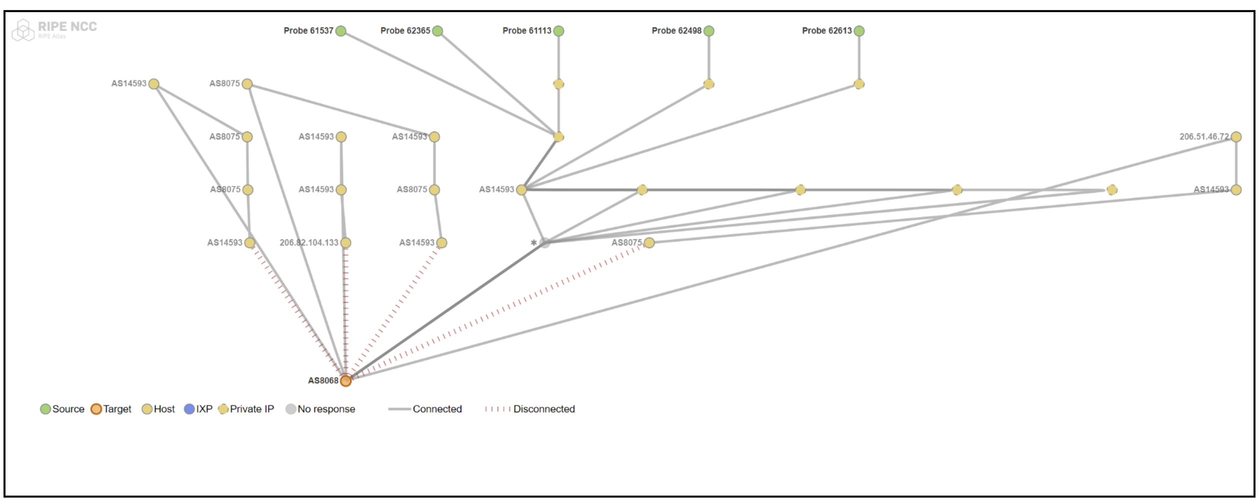
Colab Notebook: The Python notebook that parses the data can be found here.

Presentation Slides: Final Presentation slides presented on 5/3/2023.

Raw Data: Below is a copy of the raw data we retrieved, mapping the latency over time for each probe.



Traceroute Map: Graph showcasing the paths that 5 probes took to reach their destination. Probe 61113, for instance, was Alaska.



Mean and Standard Deviation per location: Table that shows the Mean - Standard deviation for all locations and tested probes.

Location	Mean - Standard Deviation
Monsures, France	51.0284
Port-au-Prince, Haiti	37.1981
Gotelp, Poland	34.5579
Prague, Czech Republic	33.8542
Moe, Australia	31.7455
Black Canyon City, AZ, USA	30.7696
Three Bridges, Australia	30.3386
Crook, CO, USA	29.8413
Gambolo, Italy	29.6352
Butte, Alaska, USA	29.3131
Kitzingen, Germany	28.4982
New York, NY, USA	27.9348
Blainslie, Scotland, UK	27.0646
London, UK	27.0211
Goldendale, WA, USA	26.6335
Pahrump, NV, USA	25.6719
Limache, Chile	24.3713
Newport, Isle of Wright, UK	24.3334
Hay Lakes, Alberta, CA	22.9829
Lakeview, CA, USA	22.9675
London, UK	22.6339
Wickes, MO, USA	22.5771
Beaufort, NC, USA	19.7469
Tairua, New Zealand	19.0222
Aldeno, Italy	15.5779

References

"REST API Reference." RIPE Atlas, RIPE Network Coordination Centre, atlas.ripe.net/docs/apis/rest-api-reference/.

"Starlink." Starlink, SpaceX, www.starlink.com/.

"Starlink." Starlink, www.starlink.sx/.