Crowdsourced Starlink Performance Measurements from https://starlinkstatus.space

Manuel Bülo
https://starlinkstatus.space
Call sign DO5TY
support@tynet.eu

Jörg Deutschmann, Kai-Steffen Hielscher, and Reinhard German
Computer Networks and Communication Systems
Friedrich-Alexander-Universität Erlangen-Nürnberg
{joerg.deutschmann, kai-steffen.hielscher, reinhard.german}@fau.de

***Abstract*—Starlink is the largest and most powerful low Earth orbit satellite megaconstellation built to date. Since its debut in 2021, there has been an enormous interest in performance evaluations. https://starlinkstatus.space is a crowdsourced measurement platform based on the Ookla speed test.**

This paper presents its design, user statistics, and results: Almost 1.7 million measurements from 309 users and 29 countries. The median goodput rates are between 100 Mbit/s and 200 Mbit/s in the forward link (download), and between 10 Mbit/s and 20 Mbit/s in the return link (upload). Goodput rates in North America are lower than in other countries, and the time of day matters, with peak time performance down to a median of 50 Mbit/s. Median round trip times are between 40 ms and 50 ms. Latency under load seems to have improved recently. The hardware version of the standard user terminal does not seem to have an impact on the performance.

***Index Terms*—Starlink, Satellite Communication, Performance Measurement**

I. Introduction

Starlink is the largest satellite constellation built to date, with currently more than 3500 active satellites in the low Earth orbit (LEO), thus also called megaconstellation. A good visualization of the Starlink megaconstellation is available online, see https://starlink.sx or https://satellitemap.space. Other megaconstellations are also being planned and built, a comparison of different systems is given in [1], [2].

While a lot of simulation studies about megaconstellations exist [3]–[7], the performance of the actually deployed Starlink system is of major interest. Starlink offered its service to end users in 2021 starting with a Public Beta test. In May 2023, Starlink announced that they have 1.5 million active subscribers around the world.[1]

Due to the novelty of the system, only a few performance evaluations exist. Early non-peer-reviewed results were shown in [8], [9]. In [10], the performance of Starlink was compared to different geostationary satellite systems and terrestrial Internet access regarding goodput, delays, packet loss, and different applications. Michel et al. [11] compared the user-perceived performance of Starlink with a GEO satellite system regarding throughput, latencies, packet loss, and web browsing. Kassem et al. [12] built and deployed a browser extension to evaluate the performance of Starlink around the world; additionally, three measurement nodes were deployed in the USA, Spain, and UK to run more detailed Starlink experiments. Ma et al. [13] deployed four Starlink terminals to measure delays and throughput. In [14], Starlink was compared to two GEO systems considering unencrypted TCP as well as VPN software and two different congestion control algorithms. Garcia et al. [15]–[17] presented a detailed analysis and modeling of the Starlink physical layer and throughput. Pan et al. [18] mentions the use of several Starlink dishes together with data from Reddit users to determine delays and architecture of the Starlink network, and the authors extended their work in [19]. The limitation of the literature discussed so far is a limited number of users and data points. Izhikevich et al. [20] did performance measurements by evaluating IP addresses assigned to the Starlink ASN, but these measurements did not include goodput measurements. Mohan et al. [21] used M-Lab speed tests and RIPE Atlas probes to evaluate the performance of Starlink.

Ookla, the company behind https://speedtest.net, regularly releases reports about the performance of satellite Internet providers, but these are not very detailed.[2]

The first author of this paper has set up https://starlinkstatus.space, a crowdsourced measurement platform based on the Ookla speed test and remote procedure calls (RPCs) to the Starlink terminal. This provides a unique dataset, as it contains both a large number of users and detailed information. To the best of our knowledge, this is the largest measurement study comparing the worldwide performance of Starlink Internet access with a focus on latency and throughput performance. In this paper, we present how the measurements have been obtained and the results thereof.

The framework is described in Section II, statistics about the collected data is given in Section III, performance results are presented in Section IV, and Section V concludes this paper.

II. Framework Description

The framework is based on the Ookla Speedtest command-line interface (CLI),[3] RPCs to the Starlink terminal,[4] and Internet Control Message Protocol (ICMP) pings. Participants first register on https://starlinkstatus.space to obtain an

[1] https://twitter.com/Starlink/status/1654673695007457280

[2] https://www.ookla.com/articles/starlink-hughesnet-viasat-performance-q1-2023

[3] https://www.speedtest.net/apps/cli

[4] https://github.com/fullstorydev/grpcurl

Fig. 1: Screenshot from https://starlinkstatus.space showing overview of all measurements, i.e., aggregated performance results, over the last year.

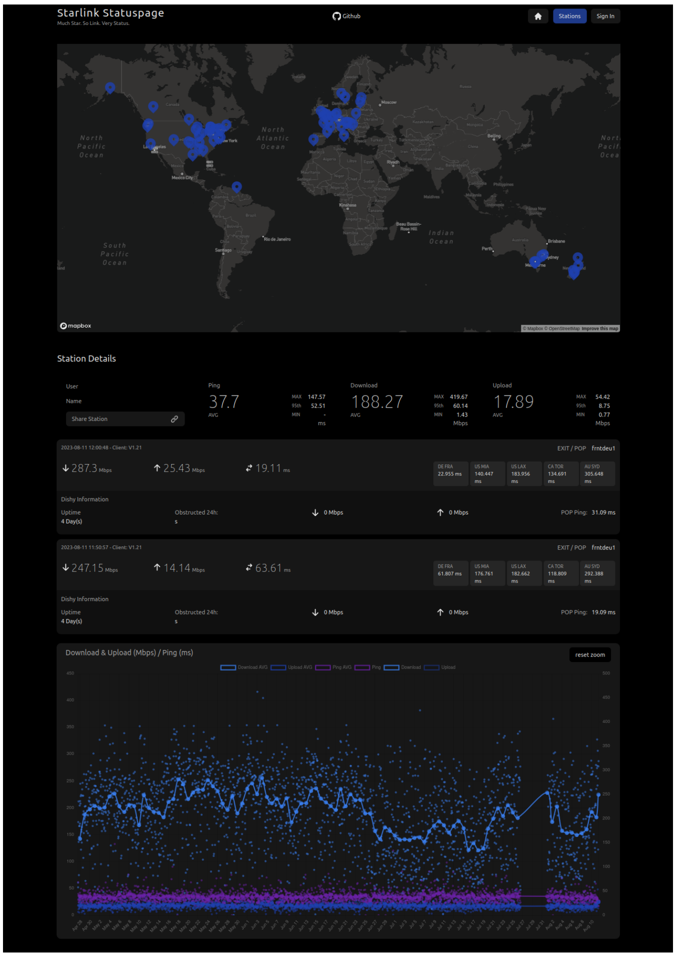


Fig. 2: Screenshot from https://starlinkstatus.space showing location of Starlink terminals and detailed station statistics.

application programming interface (API) key. Next, they install the required software and set up a script which is available online.[5] The script runs:

- ICMP pings to different servers with four packets each to measure round trip times (RTTs).
- A RPC to the Starlink Terminal, which returns information about the device, e.g., hardware version, latency to point of presence, alerts, etc.
- The Ookla Speedtest CLI, running bulk data and latency tests.
- A geolocation request using http://ip-api.com.

All data is then uploaded to the https://starlinkstatus.space API, where it is processed and made available to the World Wide Web. See Figure 1 and Figure 2 for screenshots. This includes real-time results as well as a map with the location of the Starlink terminals. The results can also be visualized via an Android app, but the app can not be used for running measurements.

[5]https://github.com/Tysonpower/starlinkstatus

A user could register multiple terminals with one API key, but in the later presented dataset, this rarely happens (six users have set up two terminals, and one user has set up three terminals). While the highest user ID is 1687, the dataset shows that less than 400 users have ever run at least one measurement. In other words, many users have registered but never contributed any measurements. This could probably be improved by a simplified setup process, e.g., providing software packages for common operating systems.

Users have the option to disable RPCs and/or the Speedtest. As described in the next section, often the RPCs and thus information about the Starlink terminal internals are missing. Users can decide on their own how often they want to run measurements. Initially, the recommendation was to run the script every 15 min. After Starlink introduced a soft data cap of 1 TB in November 2022 (which has been removed again in the meantime), a note for running the script less often has been added.

The Speedtest is not aware of cross-traffic, i.e., traffic from other applications will lead to an underestimate of the path capacity reported by the Speedtest. In order to estimate the

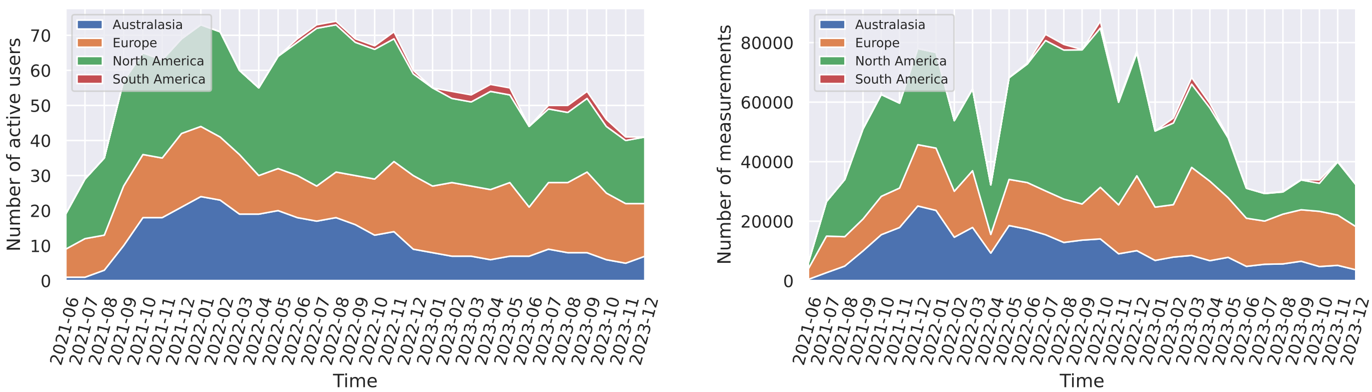


Fig. 3: Number of measurements over time (left figure) and active users over time (right figure). Japan (active February and March 2023) has been omitted due to the low number of measurements. The drop in April 2022 was due to an internal API misconfiguration, in November 2022 the number of measurements probably have been decreased due to the introduction of a soft data cap, and in June 2023 a change in the Speedtest CLI API caused fewer contributed measurements.

Country	Users	Measurements	Speedtest Download Mean	Speedtest Download Max	Speedtest Upload Mean	Speedtest Upload Max	ICMP Ping RTT Mean	ICMP Ping RTT Min
AU	30	146384	173.6	480.6	14.6	74.5	49.5	21.0
NZ	24	180622	150.0	439.3	18.6	74.5	47.6	17.0
AT	4	73331	188.1	437.0	18.3	73.0	41.0	17.0
BE	2	798	122.7	373.5	13.8	39.7	41.2	19.8
CH	2	200	200.5	357.0	19.0	66.7	40.5	19.7
CZ	1	3	217.3	262.0	22.7	32.6	40.4	32.8
DE	26	95281	161.5	419.7	19.7	76.5	39.3	17.7
EE	1	5147	182.7	409.7	17.2	65.7	46.3	23.7
ES	6	34313	195.5	425.8	21.4	68.9	50.2	17.7
FR	13	71937	208.8	443.6	18.7	76.2	45.2	18.0
GB	23	87611	164.9	429.6	13.7	65.7	41.4	13.5
HR	1	2	219.8	270.7	17.5	25.3	46.5	42.0
HU	1	44001	207.7	340.5	22.1	79.1	44.3	20.1
IT	5	10300	101.8	411.7	20.1	107.3	36.8	18.0
LT	1	5948	171.1	416.0	21.8	58.7	46.6	24.9
LV	1	2174	222.4	401.9	19.6	38.2	45.6	23.2
NL	8	14902	133.8	398.3	21.0	76.5	39.4	18.4
NO	1	33406	156.8	386.2	15.1	65.8	41.3	20.3
PL	3	16293	186.4	428.7	23.6	65.2	47.1	22.1
PT	3	5957	215.8	420.7	25.0	68.9	49.7	17.7
SE	1	1032	31.2	92.8	17.8	40.1	44.6	23.1
SK	4	248	148.1	290.6	20.1	38.2	46.8	22.0
JP	2	217	138.6	285.4	10.6	63.8	46.3	22.4
CA	28	123117	115.7	425.4	13.1	76.9	47.4	20.0
US	129	694362	109.0	431.8	10.7	74.6	50.3	17.9
BR	4	15485	196.6	417.5	23.2	73.6	45.1	20.2
CL	1	30	232.8	329.2	20.7	52.4	33.0	24.5
CO	1	3	91.1	127.4	23.7	30.5	91.3	88.0
TT	1	10	105.9	243.6	19.0	29.0	71.0	59.3
🌍	309	1663114	141.5	480.6	14.6	107.3	47.4	13.5

TABLE I: Detailed dataset statistics. Goodput in Mbit/s, RTTs in ms. Countries grouped by Australasia, Europe, Japan, North America, and South America. Global overview in last line.

severeness of this problem, we will later look at the throughput reported by the Starlink terminal before the Speedtest is run, although due to the temporal offset of both reports, this does not allow for exact calculations. We envisage to optimise the script to allow a more detailed comparison of the goodput reported by the Speedtest and the throughput reported by the terminal, but this is left to future work.

III. Dataset Statistics

Details about the dataset are shown in Table I. In the following, we explain how these numbers have been obtained.

The data is first filtered for IP addresses originating from the Starlink network (ASN 14593). In some cases, it happens that measurements are uploaded from other Internet service providers, likely due to a routing misconfiguration in the user's network or simply because Starlink is not used anymore. The unlikely case that a Speedtest is run from within the Starlink network but not actually using a Starlink satellite connection (e.g., a Starlink employee running measurements from within their network) can not be detected unless goodput or RTTs stick out of the dataset, which is not the case. Given an orbit altitude of 550 km, all reported RTTs are well above the propagation delay from terminal to satellite to ground station to satellite to terminal ($4 \cdot \frac{550\,\text{km}}{\text{speed of light}} = 7.3\,\text{ms}$) plus some other delays. After this first filtering, the dataset contains 2.6 million measurements from 378 users located in 29 countries.

Next, we address the cross-traffic problem described in the previous section. Unfortunately, a large number of measurements (700 k) do not contain Starlink terminal device-related metrics obtained via the RPC interface, therefore it is not possible to compare the Speedtest goodput with the throughput reported by the Starlink terminal. In another 300 k data points, the throughput reported by the Starlink terminal before the Speedtest is above 5 Mbit/s in the forward link or 1 Mbit/s in the return link. In other words, most of the Speedtest were done after the terminal was more or less idle. We removed measurements where no Starlink terminal RPC data exists

	STATIONARY	NOMADIC	MOBILE
BUSINESS	3673	0	0
CONSUMER	12753	1193	5082
UNKNOWN	927868	71257	21772
unspecified	39746	6652	0

TABLE II: Number of measurements regarding mobility and service classes. `UNKNOWN` is short for `UNKNOWN_USER_CLASS_OF_SERVICE`. Another 573 k measurements did neither contain mobility or service class values.

or the throughput exceeds the aforementioned thresholds, to minimize a negative impact on the evaluations.[6] After this filtering, we end up with 1 663 114 measurements from 309 users located in 29 countries.

Measurements that contain device-related Starlink terminal data via RPC reveal the following:

- Country code. In 5390 measurements, the country reported by the Starlink terminal differs from the geolocation obtained by using http://ip-api.com. In all cases, these had been neighboring countries being on the same continent. Therefore this ambiguity only impacts the results shown in Table I but no further evaluations which are grouped by continent. In case of ambiguity, we used the country code of the Starlink terminals.
- Ethernet speed and wireless LAN (WLAN). 1 148 155 measurements reported an ethernet speed of 1000 Mbit/s. 514 959 measurements had no ethernet speed set, which should correspond to WLAN users.[7] Users with an ethernet speed of 10 Mbit/s or 100 Mbit/s exist but were already removed with the aforementioned filter.
- Mobility and service class. According to the official Starlink website, four service plans are offered as of January 2024.[8] The Starlink terminal provides information about a `mobilityClass` (`STATIONARY`, `NOMADIC`, or `MOBILE`) and a `classOfService` (`BUSINESS`, `CONSUMER`, or `UNKNOWN_USER_CLASS_OF_SERVICE`). More combinations than the four beforementioned service plans are possible, see Table II for details and number of measurements. The vast majority of measurements are reported with `STATIONARY` and `UNKNOWN_USER_CLASS_OF_SERVICE`, or both mobility and service classes were unspecified. Overall we assume that most measurements were done using the cheapest service plan for private end users. The other combinations were not reported in a sufficiently large number and also did not result in noticeable better or worse performance results. We thus lump together all combinations in the following.
- Hardware version. Figure 7 shows the observed hardware versions over time.
- Alerts, e.g., isSnrAboveNoiseFloor (false: 3915), currentlyObstructed (true: 1696), motorsStuck (true: 189), mastNotNearVertical (true: 5019), isHeating (true: 61 861). Measurements with these warnings did report reasonable results, therefore we included them in our evaluation. A detailed analysis of these events is subject to future work.

25 users contributed only a single measurement, i.e., those users have run the script once. 102 users contributed less than 100 measurements each. On the other side, 52 users ran more than 10 000 measurements, and the award for most measurements goes to a user who contributed 68 730 data points. The number of users and measurements over time is shown in Figure 3.

In May 2022, Ookla announced that they enhance their Speedtest with latency under load tests.[9] This is also known as Bufferbloat.[10] We received the first measurements with the loaded latency metrics in September 2022. Because users need to update their Speedtest CLI application manually, unfortunately only a small amount of measurements (129 725) with the latency under load metric have been contributed so far.

IV. Measurement Results

Based on the large dataset, we present multiple evaluations in the following. For better readability, a detailed description and discussion of the results is added to the caption of the corresponding figures. The figures are structured as follows:

- Figure 4: Goodput in the forward link (download).
- Figure 5: Goodput in the return link (upload).
- Figure 6: Goodput in each direction depending on the time of day.
- Figure 7: Deployed hardware versions.
- Figure 8: Goodput in each direction depending on the hardware version.
- Figure 9: RTTs from different continents to different servers.
- Figure 10: RTT measurements over time.
- Figure 11: RTT measurements depending on the time of day.

V. Conclusion and Future Work

`https://starlinkstatus.space` provides crowdsourced performance measurements of the Starlink system and allows valuable insights into the overall system performance. The

[6]Evaluations without filtering this large amount of data points did not yield notable changes.

[7]We can not detect if a terminal had the Gigabit ethernet interface connected but the Speedtest was run via WLAN. We compared the ethernet and WLAN performance results but there was no notable difference.

[8]https://www.starlink.com/service-plans
One location – Standard: Fixed location, cheapest service plan intended for private end users. *One location – Priority*: Fixed location, certain amount of priority data, advertised to be best for businesses and high demand users. *On the go – Mobile*: Allows portability, advertised to be best for RVs, nomads, and campers. *On the go – Mobile Priority*: Allows in-motion use, advertised to be best for maritime, emergency response, and mobile businesses.

[9]https://www.ookla.com/articles/introducing-loaded-latency

[10]https://www.bufferbloat.net

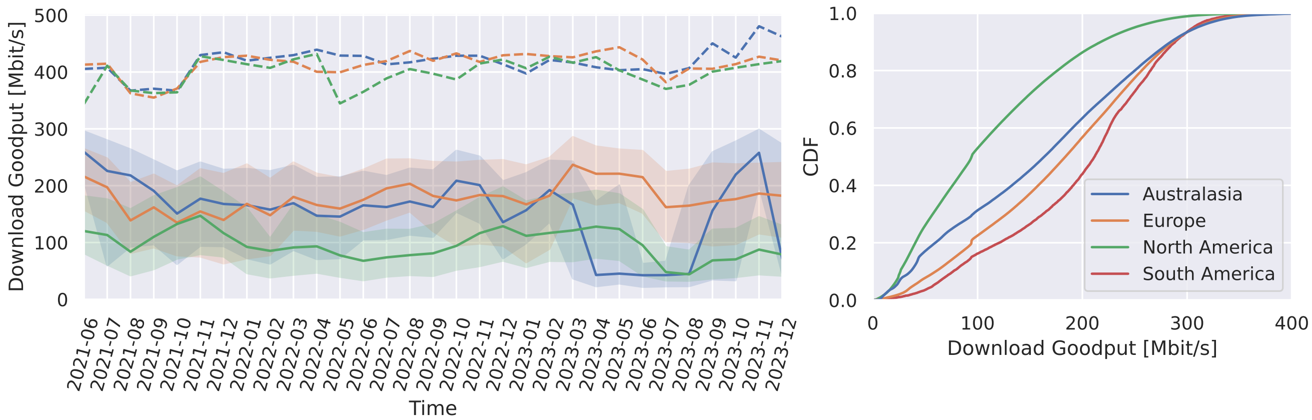


Fig. 4: Starlink goodput in the forward link (download). In the left figure, solid lines are median values; shaded areas show first and third quartiles; dashed lines are maximum values. Goodput is very variable in general. North America has lower goodputs than other countries, which is probably due to a higher subscription rate. Users from South America contributed only a few measurements (cf. Figure 3).

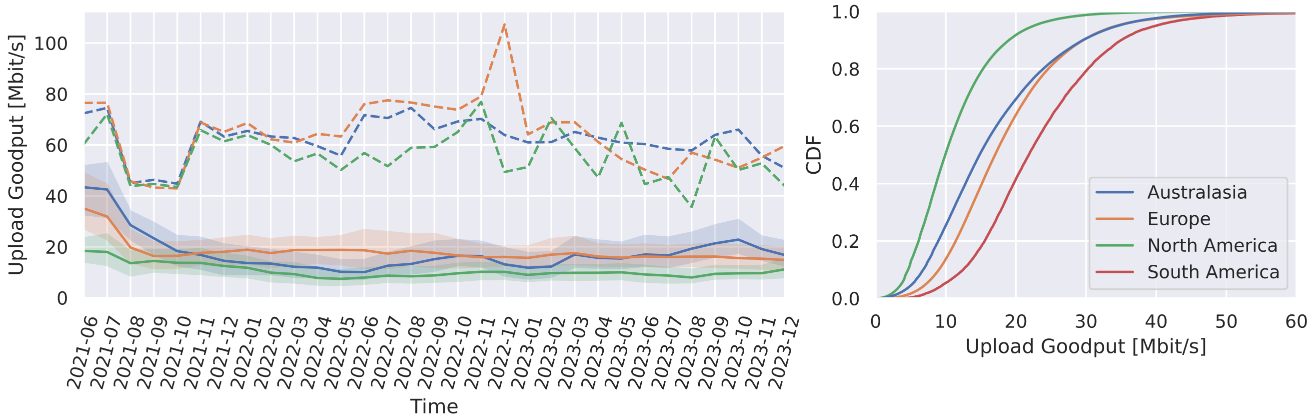


Fig. 5: Starlink goodput in the return link (upload). In the left figure, solid lines are median values; shaded areas show first and third quartiles; dashed lines are maximum values. Goodput is a bit variable and there are differences among continents. South America contributed only a few measurements (cf. Figure 3).

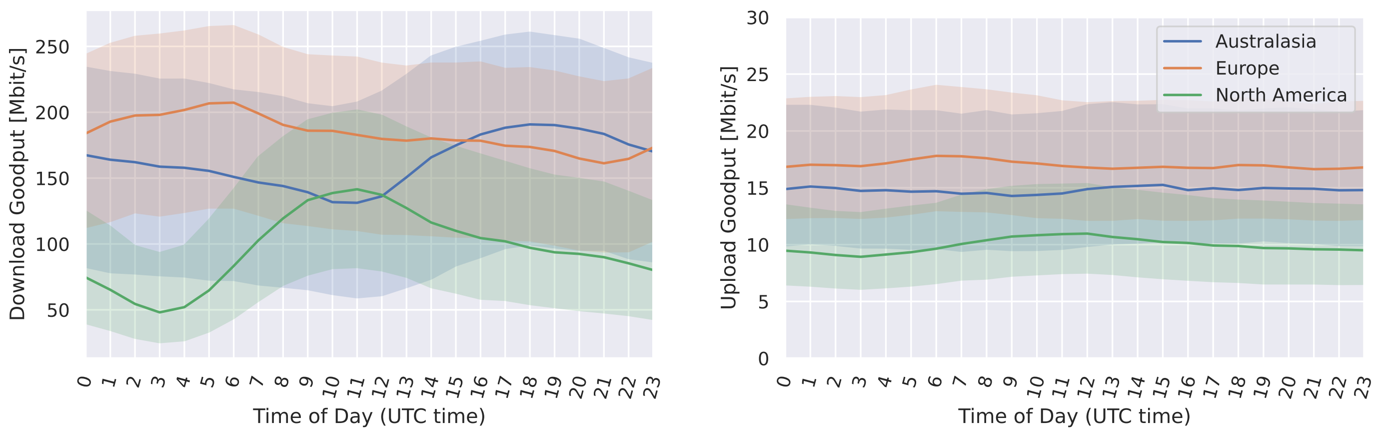
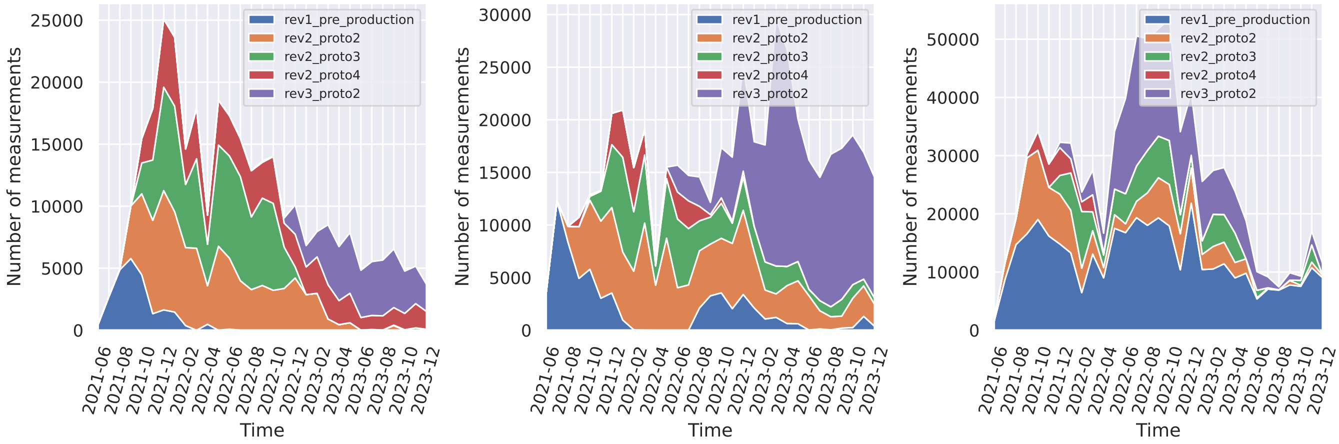


Fig. 6: Goodput in forward link (download, left figure) and return link (upload, right figure) regarding the time of day. Solid lines are median values; shaded areas show first and third quartiles. North America has the lowest download goodputs around 03:00 UTC (18:00 PST and 21:00 EST) and highest goodputs around 12:00 UTC (03:00 PST and 06:00 EST). An impact on the upload goodput is also observable but less severe. For Australasia, download goodput increases around 14:00 UTC (22:00 AWST and 02:00 NZST) and decreases roughly 12 hours before/later. No significant temporal performance impacts are visible for Australasia upload goodput and Europe goodput in either direction.



(a) Australasia (b) Europe (c) North America

Fig. 7: Hardware versions over time for different continents. In Australasia the early hardware versions were present in the beginning but did not contribute measurements in the long run. Similarly, in 2023 measurements from Europe were most often done from the latest version `rev3_proto2`. Most measurements from North America have been contributed by the first version of the Starlink dish (`rev1_pre_production`).

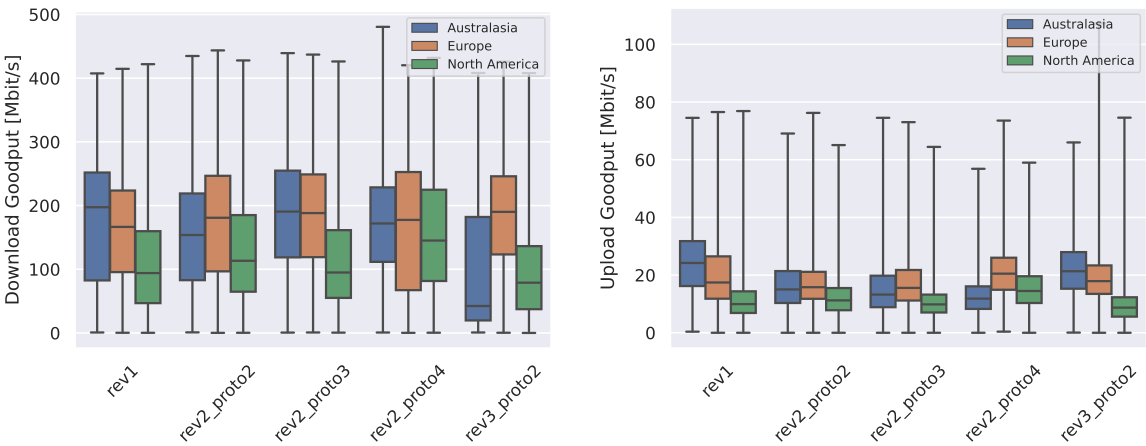


Fig. 8: Goodput vs. hardware version: Download in the left figure, upload in the right figure. Box shows quartiles, and whiskers show minimum and maximum values. In both figures, the performance mainly depends on the continent, but not on the hardware version.

software is a combination of readily available tools: Ping traces, terminal status via RPCs, and the Ookla Speedtest CLI. Thanks to a large number of contributions from many different countries, meaningful results have been obtained. Goodput and latencies are comparable with terrestrial Internet access. However, goodput in general varies in both directions, and it further depends on the continent and time of day, with North America showing signs of a higher subscription rate and lower performance.

The performance seems to be not affected by the hardware version of the terminal. At the time of writing, a new `Rev4` terminal (which is not actuated anymore) became available which did not yet show up in the measurements.

RTTs are comparable with terrestrial cellular networks and show significant variance. In the future, UDP instead of ICMP packets could be used. Regarding latency under load, only a few measurements were available, thus the results are considered preliminary. They show that latencies due to buffering were very high but also seem to have improved over the recent months. Similar to the goodput performance, increased latencies under load can be observed in North America during the evening hours. The interested reader is referred to the Starlink Bufferbloat mailing list[11] for ongoing discussions.

In the future, continued long-term measurements are planned. This is required because the number of satellites and the number of subscribers are subject to continuous change. At the same time, terminals, satellites, and the network are likely to be further optimized. Adding other satellite megaconstellation systems once they become available would allow for a comparison of different systems.

[11] https://lists.bufferbloat.net/listinfo/starlink

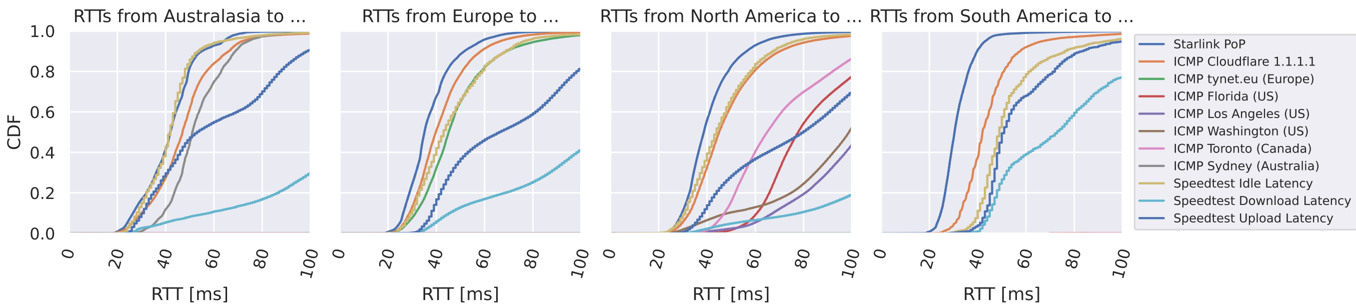
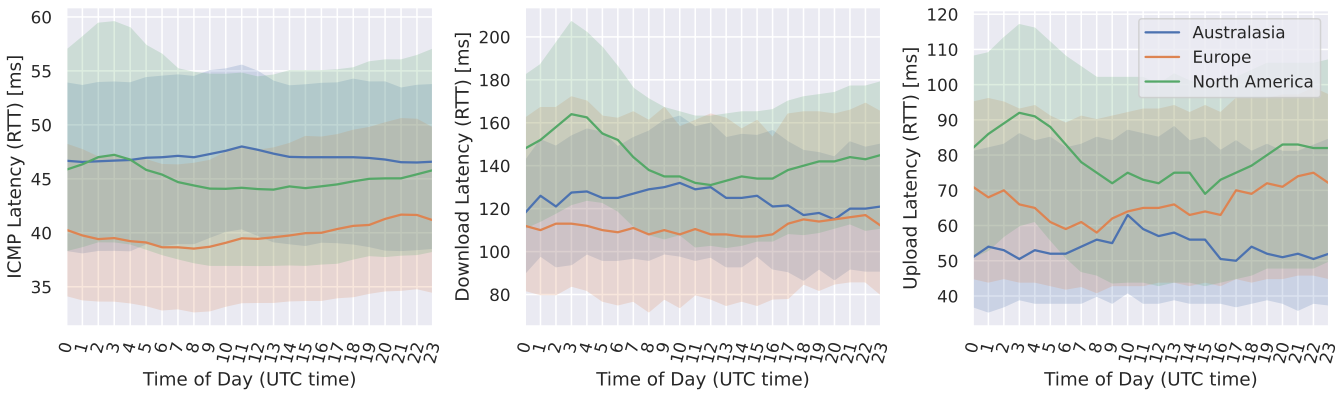


Fig. 9: RTTs from different continents to different servers. RTTs to the Starlink point of presence were obtained via RPCs to the Starlink terminal. Results from the Ookla Speedtest are rounded to full decimals, therefore the lines appear slightly ragged. ICMP packets were sent to manually selected servers across Europe, the United States, Canada, and Australia. As expected, RTTs to the point of presence are the lowest. Cloudflare's `1.1.1.1` and Speedtest servers are usually nearby, resulting in small RTTs. RTT lines not shown for a continent are not missing but have values larger than 100 ms. Latency under load increases significantly compared to unloaded paths.

(a) ICMP to Cloudflare's `1.1.1.1` (b) Speedtest Download Latency (c) Speedtest Upload Latency

Fig. 10: RTT measurements over time. Solid lines are median values; shaded areas show first and third quartiles. Please note the different scales on the vertical axis. Figure (a) shows RTTs for ICMP packets to Cloudflare's `1.1.1.1` for unloaded paths. Figures (b) and (c) show results as reported by the Ookla Speedtest for latency under load. Please note that latency under load results were only supported as of September 2022 and only a few (120 k) measurements were contributed. It seems that latency under load has decreased over time, but further measurements are needed to confirm this.



(a) ICMP to Cloudflare's `1.1.1.1` (b) Speedtest Download Latency (c) Speedtest Upload Latency

Fig. 11: RTT measurements regarding the time of day. Solid lines are median values; shaded areas show first and third quartiles. Please note the different scales on the vertical axis. Figure (a) shows RTTs for ICMP packets to Cloudflare's `1.1.1.1` for unloaded paths and do not vary a lot. Europe has lower RTTs compared to Australasia and North America. Figure (b) and (c) show results as reported by the Ookla Speedtest for latency under load, which were only supported as of September 2022 and only a few (120 k) measurements were contributed. In both figures, increased latencies can be observed during evening hours which corresponds to lower download goodput shown in Figure 6.

Acknowledgment

The contents presented are part of the outcomes of the European Space Agency (ESA) QUICOPTSAT project, see https://connectivity.esa.int/projects/quicoptsat, contract 4000139035/22/NL/AF. The authors would like to thank ESA for the project. Responsibility for the contents resides with the authors.

References

[1] I. del Portillo, B. G. Cameron, and E. F. Crawley, "A technical comparison of three low earth orbit satellite constellation systems to provide global broadband," *Acta Astronautica*, vol. 159, pp. 123–135, June 2019.

[2] N. Pachler, I. del Portillo, E. F. Crawley, and B. G. Cameron, "An Updated Comparison of Four Low Earth Orbit Satellite Constellation Systems to Provide Global Broadband," in *2021 IEEE International Conference on Communications Workshops (ICC Workshops)*, IEEE, jun 2021.

[3] D. Bhattacherjee and A. Singla, "Network topology design at 27,000 km/hour," in *Proceedings of the 15th International Conference on Emerging Networking Experiments And Technologies*, ACM, dec 2019.

[4] M. Roth, H. Brandt, and H. Bischl, "Implementation of a geographical routing scheme for low earth orbiting satellite constellations using intersatellite links," *International Journal of Satellite Communications and Networking*, vol. 39, pp. 92–107, jun 2020.

[5] A. Valentine and G. Parisis, "Developing and experimenting with LEO satellite constellations in OMNeT++," *Proceedings of the 8th OMNeT++ Community Summit Conference*, 2021.

[6] B. Kempton and A. Riedl, "Network simulator for large low earth orbit satellite networks," in *ICC 2021 - IEEE International Conference on Communications*, IEEE, jun 2021.

[7] M. Handley, "Delay is Not an Option: Low Latency Routing in Space," in *Proceedings of the 17th ACM Workshop on Hot Topics in Networks*, ACM, nov 2018.

[8] C. Uran, K. Horvath, and H. Wöllik, "Analysis of a Starlink-based Internet connection," tech. rep., Carinthia University of Applied Science, Research Group ROADMAP-5G, June 2021.

[9] C. Uran, K. Horvath, H. Wöllik, and V. Egger, "Comparison of Starlink Performance between June and September," tech. rep., Carinthia University of Applied Science, Research Group ROADMAP-5G, Nov. 2021.

[10] J. Deutschmann, K.-S. Hielscher, and R. German, "Broadband Internet Access via Satellite: Performance Measurements with different Operators and Applications," in *Broadband Coverage in Germany; 16th ITG-Symposium*, 2022.

[11] F. Michel, M. Trevisan, D. Giordano, and O. Bonaventure, "A first look at starlink performance," in *Proceedings of the 22nd ACM Internet Measurement Conference*, ACM, oct 2022.

[12] M. M. Kassem, A. Raman, D. Perino, and N. Sastry, "A browser-side view of starlink connectivity," in *Proceedings of the 22nd ACM Internet Measurement Conference*, ACM, oct 2022.

[13] S. Ma, Y. C. Chou, H. Zhao, L. Chen, X. Ma, and J. Liu, "Network Characteristics of LEO Satellite Constellations: A Starlink-Based Measurement from End Users," *IEEE INFOCOM 2023*, Dec. 2023.

[14] J. Deutschmann, S. Jahandar, K.-S. Hielscher, and R. German, "Internet via Satellite: GEO vs. LEO, OpenVPN vs. Wireguard, and CUBIC vs. BBR," in *Proceedings of the 1st ACM MobiCom Workshop on Satellite Networking and Computing*, ACM, oct 2023.

[15] J. Garcia, S. Sundberg, G. Caso, and A. Brunstrom, "Multi-Timescale Evaluation of Starlink Throughput," in *Proceedings of the 1st ACM Workshop on LEO Networking and Communication*, ACM, oct 2023.

[16] J. Garcia, S. Sundberg, and A. Brunstrom, "Inferring Starlink Physical Layer Transmission Rates Through Receiver Packet Timestamps," in *IEEE Wireless Communications and Networking Conference (WCNC)*, 04 2024.

[17] J. Garcia, S. Sundberg, and A. Brunstrom, "Fine-Grained Starlink Throughput Variation Examined With State-Transition Modeling," in *2024 19th Wireless On-Demand Network Systems and Services Conference (WONS)*, IEEE, Jan. 2024.

[18] J. Pan, J. Zhao, and L. Cai, "Measuring a low-earth-orbit satellite network," July 2023.

[19] J. Pan, J. Zhao, and L. Cai, "Measuring the Satellite Links of a LEO Network," in *IEEE International Conference on Communications*, 2024.

[20] L. Izhikevich, M. Tran, K. Izhikevich, G. Akiwate, and Z. Durumeric, "Democratizing LEO Satellite Network Measurement," June 2023.

[21] N. Mohan, A. Ferguson, H. Cech, R. Bose, P. Renatin, M. Marina, and J. Ott, "A Multifaceted Look at Starlink Performance," in *ACM The Web Conference (WWW)*, 02 2024.

All Internet links were last accessed on 2024-03-07.