Evaluating LEO Satellite Internet in Aeronautical Mobility: a Study of Starlink from Hawaii to Japan

Luca Borgianni[1], Davide Adami[2], Stefano Giordano[1]

[1]*University of Pisa, Dept. of Information Engineering, Via G. Caruso 16, 56122 Pisa, Italy*
[2]*CNIT - University of Pisa, Dept. of Information Engineering, Via G. Caruso 16, 56122 Pisa, Italy*

Abstract—**Low Earth Orbit (LEO) satellite constellations such as Starlink are emerging as a transformative solution for providing global broadband connectivity, including environments like aeronautical and transoceanic flights for future 6G networks. This paper presents an evaluation of Starlink's performance during a commercial flight from Hawaii to Japan. By analyzing ICMP ping measurements collected throughout the journey, we assess key metrics such as latency, jitter, packet loss, and temporal stability. We further investigate statistical characteristics and frequency-domain patterns to analyze satellite handovers and oscillatory behavior in delay. Moreover, we performed a throughput evaluation using a standard speed test protocol. Our results show that while Starlink provides generally low-latency connectivity even in flight, its performance exhibits significant fluctuations and occasional disruptions, likely due to the challenges of maintaining stable satellite links in a fast-moving, high-altitude context. Moreover, we released an open-source repository for collecting datasets about in-flight Starlink measurements. This study contributes empirical insight into the feasibility and limitations of LEO satellite Internet for aeronautical mobility applications.**

Index Terms—**Low-Earth Orbit (LEO) Internet, Starlink, Aeronautical Internet, Non-Terrestrial Network**

I. INTRODUCTION

Internet connectivity aboard commercial aircraft has seen a transformation over the past two decades. The earliest attempts emerged in the early 2000s, when providers like Connexion by Boeing launched satellite-based in-flight Internet services using Geostationary Earth Orbit (GEO) satellites and Ku-band frequencies. Despite pioneering efforts, these systems faced technical and economic challenges: limited throughput (less than 1 Mbps per user), long latency (600–800 ms), and costly infrastructure led to the shutdown of Connexion by 2006.

In the following years, several commercial aviation connectivity providers, such as Gogo, Inmarsat, ViaSat, Panasonic Avionics, and Thales, developed more efficient systems. Gogo, for instance, initially offered Air-to-Ground (ATG) solutions based on terrestrial cellular towers in North America, with limited coverage over oceans or remote regions. Satellite-based solutions soon regained prominence, leveraging GEO satellites with Ka-band technology to provide higher throughput (up to 70 Mbps per aircraft in some configurations), albeit still with high latency unsuitable for real-time applications.

Over time, in-flight connectivity evolved into a hybrid model, combining GEO satellites for wide-area coverage with Ka-band or Ku-band antennas installed on aircraft fuselages, capable of tracking satellite beams dynamically during flight. Today, airlines like Emirates, Lufthansa, and Qatar Airways offer in-flight Wi-Fi via providers such as Inmarsat's GX Aviation, Panasonic's eXConnect, and ViaSat's Ka-band network, with typical download speeds of 15–50 Mbps shared among passengers.

The advent of Low Earth Orbit (LEO) satellite constellations, such as Starlink, OneWeb, and Amazon's Project Kuiper, marks a disruptive shift in this domain. Operating at altitudes between 500–1,200 km, LEO satellites offer significantly lower latency (typically 30–80 ms under ideal conditions) and better throughput per user, thanks to a denser constellation and spatial reuse [1]. In 2022, SpaceX began testing Starlink for aviation, and by 2023, several commercial airlines—including JSX, Hawaiian Airlines, and Qantas—announced partnerships to deploy Starlink onboard, promising free, high-speed Internet with video streaming capability.

However, providing reliable Internet service at 900 km/h and 10,000 meters of altitude introduces unique challenges. These include maintaining line-of-sight links while the aircraft crosses satellite coverage areas (necessitating frequent beam and satellite handovers), coping with variable link budgets due to antenna orientation and atmospheric conditions, and ensuring robust backhaul to ground stations, particularly over vast oceanic regions.

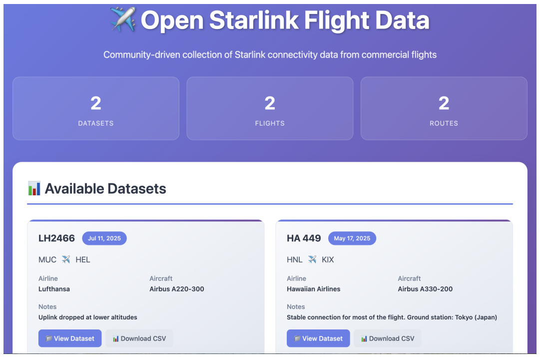
This historical and technical evolution sets the stage for our study: evaluating the performance of LEO-based in-flight connectivity, in particular Starlink, during a long-haul commercial flight over the Pacific Ocean from Hawaii (Honolulu) to Japan (Osaka). To the best of our knowledge, this is the first paper that investigates the use of Starlink in a commercial flight route over the Pacific Ocean.

We are aware that this work is limited to a single flight, and in the rest of the paper, we will give a detailed description and technical consideration of them. Furthermore, the second contribution of this paper is the creation of an open-source repository with our data and a user-friendly interface that allows users to upload data from the community about different flights (see Fig. 1). [1].

The rest of the paper is organized as follows. Section II presents the background and some of the most relevant works

---

[1] https://borgianni.github.io/starlink-flight-data/



Open Starlink Flight Data

Community-driven collection of Starlink connectivity data from commercial flights

2 DATASETS

2 FLIGHTS

2 ROUTES

Available Datasets

LH2466 Jul 11, 2025

MUC ✈ HEL

Airline: Lufthansa

Aircraft: Airbus A220-300

Notes: Uplink dropped at lower altitudes

HA 449 May 17, 2025

HNL ✈ KIX

Airline: Hawaiian Airlines

Aircraft: Airbus A330-200

Notes: Stable connection for most of the flight. Ground station: Tokyo (Japan)

Fig. 1: An open source repository for Starlink in-flight data collection

of the LEO satellite network for aeronautical purposes. Section III presents the experimental setup, and Section III-A presents the results. Finally, Section IV concludes the work.

II. BACKGROUND AND RELATED WORK

In this section, we provide an overview of recent research papers regarding in-flight Internet and Starlink. Moreover, we provide an overview of LEO satellite internet.

A. Related Work and Motivation

In recent studies focused on LEO satellite networks, the work in [2] investigates Starlink's throughput dynamics, highlighting fluctuations and identifying a recurring pattern of throughput drops approximately every 15 seconds, which is likely associated with satellite handovers. Similarly, the study in [3] offers a comprehensive examination of Starlink's global performance by combining over 19 million crowdsourced data points from 34 countries with controlled measurement campaigns. Their analysis spans aspects such as global reach, application-level performance, and internal network behavior. Although these emerging LEO satellite systems have drawn significant international attention and hold the potential to reshape Internet infrastructure, the body of research on systematic performance evaluation of networks like Starlink remains relatively sparse. In [4], the authors present the use of Starlink for position and navigation. To conclude our investigation, the authors in [5] present a system architecture and testbed implementation for delivering advanced connectivity and services aboard aircraft. The work demonstrates how 5G networks, Multi-access Edge Computing (MEC), and LEO satellite backhaul (specifically Starlink) can be integrated in an aeronautical context. In particular, the study demonstrates how a Starlink LEO constellation can provide a low-latency backhaul link to the 5G core network on the ground, enabling seamless broadband connectivity for passengers and systems aboard the aircraft.

In the literature, we can find many works that analyze the performance of Starlink, but an evaluation of it during an intercontinental flight has never been done before. In the context of 6G with an integrated Terrestrial and Non-Terrestrial Network, this evaluation paves the future research direction in the use of LEO satellite internet for aeronautical mobility.

B. A primer on LEO Satellite Internet

Although significant advancements have been made in recent years, satellite-based Internet access is not a novel concept [6]. As far back as the early 2000s, GEO satellite systems were already being used to support Internet communication. However, these earlier solutions were hampered by substantial limitations. Cost-effective options typically offered only one-way satellite links, with data transmitted downstream via satellite, while upstream communication relied on terrestrial infrastructure such as dial-up phone lines. Furthermore, performance metrics—particularly latency—fell far short of what terrestrial networks could provide.

Unlike GEO systems, LEO satellite constellations operate at altitudes ranging from 300 to 2,000 kilometers and consist of thousands of satellites working in concert to deliver widespread low-latency coverage. Projections suggest that by 2030, tens of thousands of LEO satellites will be in orbit, enabling seamless broadband access for a diverse range of users through integrated satellite-terrestrial networks.

The increasing global appetite for ubiquitous connectivity, coupled with rapid advancements in satellite and network technologies, has driven the deployment of ambitious satellite constellations. Projects such as Starlink, OneWeb, and Telesat are at the forefront of this effort. Among them, Starlink currently represents the most mature and extensive deployment.

On May 24, 2019, SpaceX initiated its Starlink project by launching the first batch of 60 prototype satellites into orbit [7]. Each satellite weighs around 260 kilograms and features a flat-panel design approximately 3 meters in width, housing both communication antennas and propulsion systems. Attached to this panel is a 9-meter-long solar array that extends perpendicularly from the main body. Once positioned in orbit at an altitude of 550 kilometers layer these satellites can appear to span an angular width of between 1 and 4 arcseconds at zenith, depending on their orientation.

III. EXPERIMENTAL SETUP AND EVALUATION

In this section, we report the setup of the test before presenting the results and the considerations.

The test was conducted during a flight from Honolulu (HNL) to Kansai International Airport (KIX), using a Boeing 787-9 Dreamliner equipped with LEO satellite-based in-flight connectivity (Starlink) (see Fig. 2) on the 17th of May 2025. The flight covered a distance of approximately 6,620 km over the Pacific Ocean, with a total airborne duration of about 8 hours and 40 minutes.

A network experiment was carried out throughout the cruise phase of the flight, while during the takeoff and the descent, the service was not available. Specifically, Internet Control Message Protocol (ICMP) echo requests (ping) were transmitted at 1-second intervals toward a ground station located in Tokyo, Japan. This ground station was automatically chosen by the Starlink service.

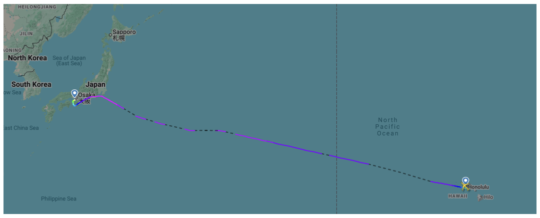


Fig. 2: Flight Route from Hawaii (Honolulu) to Japan (Osaka)

Timestamped ICMP round-trip time (RTT) measurements were logged continuously during flight to evaluate the end-to-end delay performance over the satellite link. The measured data set includes over 25,000 ICMP samples, providing a statistically meaningful time series for analysis of satellite link characteristics such as average RTT, jitter (RTT variance), correlation, and distribution.

A. *Results and Analysis*

1) Latency : In Fig. 3 and 4, we reported the RTT with the setup previously described for the entire flight from Hawaii to Japan. The first thing that we can notice is the instability with frequent spikes all along the flight.

The x-axis represents the ICMP sequence number, which correlates with time, while the y-axis shows the ping time in milliseconds. The plot reveals a clear latency gradient: at the beginning of the flight, when the aircraft is farthest from the Tokyo ground station, the latency frequently exceeds 150 ms, with occasional peaks above 250 ms and rare spikes approaching 300 ms. These peaks are likely caused by satellite handovers or temporary routing inefficiencies over longer inter-satellite links (ISLs).

As the aircraft approaches Japan, a gradual decrease in latency is observed. The average latency drops significantly, stabilizing below 70 ms in the final segment of the flight. This trend is consistent with the expected behavior of Starlink's LEO-based architecture since latency depends not only on the number of hops but also on the geometric path to the ground station, and proximity to the ground station results in lower end-to-end delay.

In Table I, we reported the number of packets with RTT greater than 150 ms, 250 ms, and 500 ms. Moreover, the average delay of the entire flight is 63.15 ms.

Parameter	**Value**
Pings $\geq$ 150 ms	273
Pings $\geq$ 250 ms	45
Pings $\geq$ 500 ms	8
Mean RTT	63.15 ms

TABLE I: Statistics and Mean RTT

2) Latency Distribution: The RTT distribution (see Fig. 5) exhibits a dominant cluster centered around 55–65 ms, a secondary concentration between 85–110 ms, and a long tail extending beyond 150 ms.

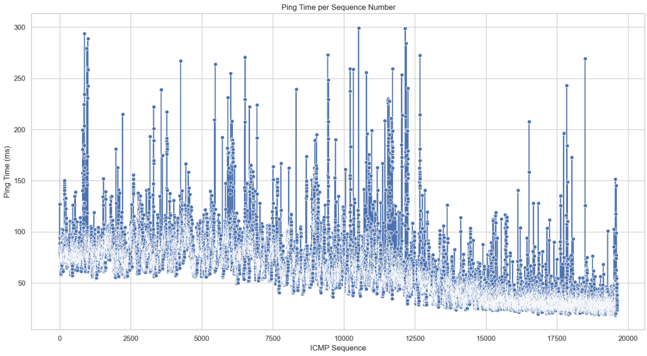


Fig. 3: RTT during the entire flight

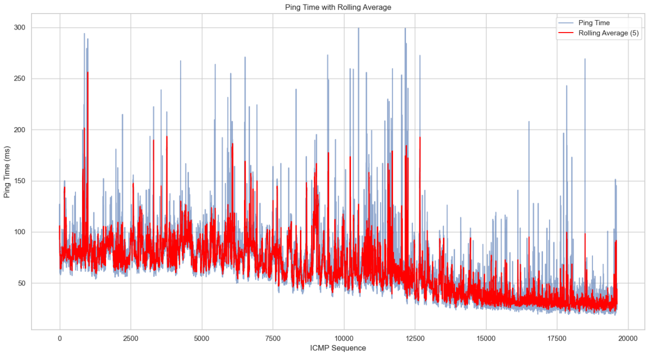


Fig. 4: RTT during the entire flight with moving average

The boxplot in Figure 6 reinforces these observations. The median RTT is approximately 60 ms, with an interquartile range (IQR) spanning from 42 ms to 87 ms. Notably, numerous outliers are present, including RTT values up to 300 ms. These outliers are indicative of temporary performance degradations, possibly due to link congestion, satellite handovers, or jitter introduced by the onboard network equipment or the satellite gateway. While the core RTT values remain within a tolerable range for web browsing and buffered streaming, the variability and presence of high-delay events

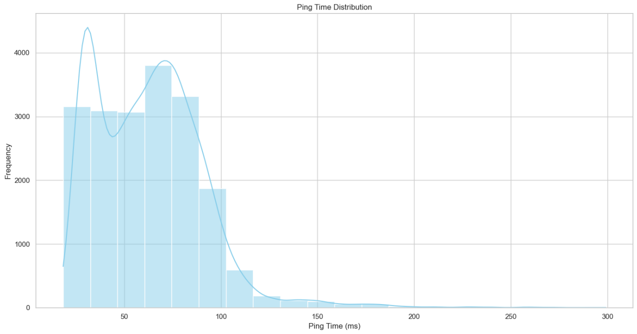


Fig. 5: Latency distribution

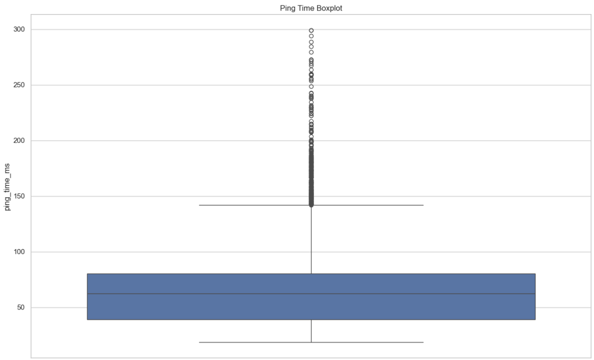


Fig. 6: Ping Time Boxplot

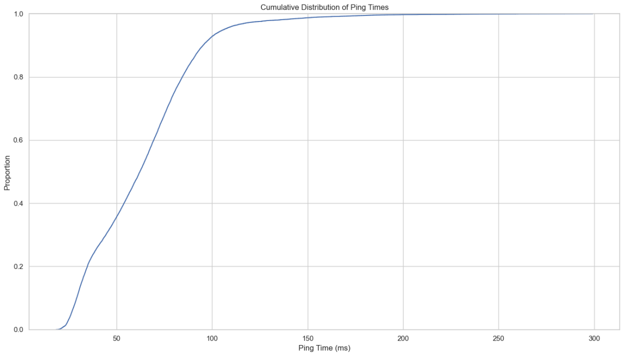


Fig. 7: Cumulative Distribution Function (CDF)

could severely impact latency-sensitive applications.

3) Cumulative Distribution Function (CDF): Fig. 7 displays the cumulative distribution function (CDF) of the ping times measured during the flight. The CDF illustrates the proportion of samples that fall below a given latency value, providing a global view of the latency distribution and helping to assess the consistency and reliability of the connection.

From the figure, we observe that:

- Approximately 25% of the ping times are below 55 ms, indicating occasional access to low-latency paths, likely when the aircraft was close to the ground station or during favorable satellite alignment.
- 50% of the latency values fall below approximately 80 ms, suggesting a median latency in that range, which is reasonable for LEO-based satellite systems.
- The curve begins to flatten beyond 100 ms, and by around 150 ms, over 95% of the pings have been accounted for.
- Only a very small fraction of pings exceed 200 ms, confirming that high-latency events are rare, likely due to brief rerouting or handover phases.

This CDF demonstrates that while Starlink latency during flight can vary significantly, the vast majority of responses remain within a range acceptable for many interactive applications. The steep slope in the central portion of the curve indicates relatively tight jitter around the median, which is beneficial for applications requiring consistent latency.

4) Autocorrelation: The Fig. 8 shows the normalized autocorrelation of the collected ping times. Autocorrelation measures the correlation of a signal with a delayed copy of itself as a function of the lag, thus providing insight into the temporal dependencies of the data. The lag n corresponds to the number of ping samples, which can also be expressed in seconds, given the sampling interval. The autocorrelation is normalized such that $R(0) = 1$, allowing direct comparison of correlation strength across lags.

At small lags, the autocorrelation is relatively high (around 0.5), indicating a strong temporal persistence of consecutive ping values. This reflects a smooth short-term trend in response times, likely due to stable link quality.

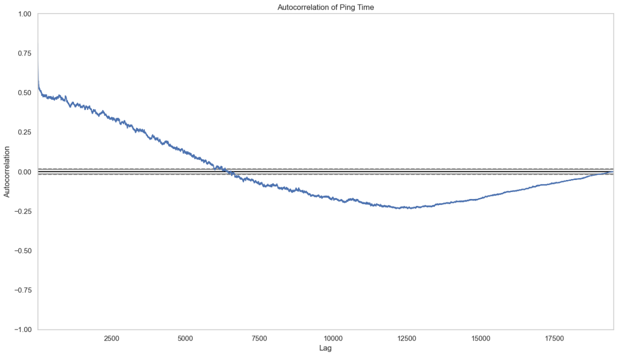


Fig. 8: Autocorrelation of Starlink ping

As the lag increases, the autocorrelation gradually decreases, becoming negative around lags of 6,000–7,000. A minimum occurs near lag 12,000, where the autocorrelation reaches about –0.3. This negative correlation indicates the presence of quasi-periodic patterns, corresponding to approximately half a cycle of the underlying oscillatory dynamics. After this point, the autocorrelation starts to increase again, trending back toward zero. The shaded region in the figure represents confidence bounds, showing that the observed correlations beyond these intervals are statistically significant and not the result of random fluctuations.

Overall, the results indicate that ping times are not randomly distributed but follow structured trends and cycles. These temporal dependencies are likely influenced by satellite transitions, beam switching, atmospheric effects, and the aircraft trajectory. Understanding these dynamics is relevant for optimizing connectivity protocols, particularly for adaptive jitter buffers and congestion-control mechanisms in latency-sensitive applications such as Video Conferencing [8] and Networked Music Performance [9].

5) Jitter: Generally, a crucial problem of Starlink is the variation of the delay. To quantify short-term variability in ping latency, we computed the jitter as the absolute difference between consecutive ICMP ping responses:

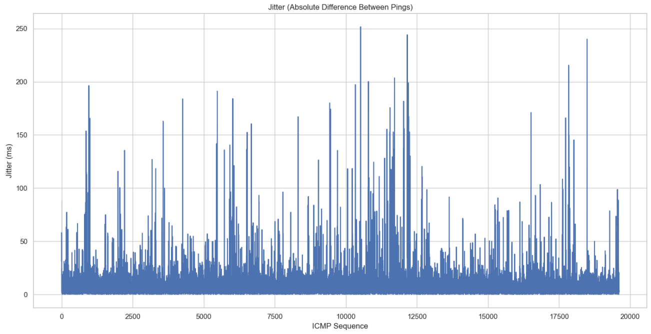


Fig. 9: Jitter measurements

$$J_n = |x_n - x_{n-1}| \tag{1}$$

where x_n represents the ping time at ICMP sequence number n, and J_n is the resulting jitter value in milliseconds.

Fig. 9 shows the jitter trend. While the majority of jitter values remain relatively low (below 50 ms), there are frequent spikes exceeding 100 ms, with a few reaching up to 250 ms, indicating irregular latency intervals. This level of jitter could negatively impact real-time applications such as VoIP, video conferencing, or Networked Music Performance [10].

6) Throughput: To conclude this evaluation, we also conducted a throughput benchmark using the commercial Speedtest.net platform. This method allows for a more comprehensive assessment of network quality, capturing both bandwidth and latency under typical user conditions. The test was conducted using a Los Angeles-based server while connected to Starlink's in-flight satellite internet service.

The following table (Table II) summarizes the key results:

TABLE II: Speedtest Results over Starlink In-Flight

Metric	**Value**
Download Speed	137.31 Mbps
Upload Speed	25.61 Mbps
Ping (Latency)	81 ms
Download Jitter	93 ms
Upload Jitter	77 ms

These results indicate that Starlink is capable of delivering high-throughput connections, with download speeds exceeding 130 Mbps and upload speeds over 25 Mbps even while onboard a transoceanic flight. However, the relatively high jitter values (77–93 ms) suggest potential instability in packet timing, confirming the previous results presented.

IV. FINAL REMARKS

This paper presents an analysis of the important role that many LEO satellites will play in shaping the connectivity in the aeronautics environment. This will be a critical element in the 6G landscape [11], in which the integration of Terrestrial and Non-Terrestrial Networks will be a key element. We presented an evaluation during an 8-hour flight from Hawaii to Japan, and we encourage the community to use and upload the data in the open-source repository starlink-flight-datahttps://borgianni.github.io/starlink-flight-data/. The collected measurements with the commercial solution Starlink confirm the interesting evolution of LEO satellite systems. The impact of Starlink and the other LEO satellite Internet commercial solutions will play a critical role in providing high-quality internet connections in aeronautical mobility.

ACKNOWLEDGMENT

This work was partially supported by the European Union - Next Generation EU under the Italian National Recovery and Resilience Plan (NRRP), Mission 4, Component 2, Investment 1.3, CUPE83C22004640001 partnership on "Telecommunications of the Future" (PE00000001 - program "RESTART") Project WATCHEDGE and by the Italian Ministry of Research (MUR) in the framework of the CrossLab and Forelab Projects (Departments of Excellence).

REFERENCES

[1] A. P. T. Adithyababu, F. Boulos, and S. Caizzone, "Avionic satellite communication terminal requirements and technology maturity analysis," *IEEE Aerospace and Electronic Systems Magazine*, vol. 39, no. 1, pp. 4–17, 2024.

[2] 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*, ser. LEO-NET '23. New York, NY, USA: Association for Computing Machinery, 2023, p. 31–36. [Online]. Available: https://doi.org/10.1145/3614204.3616108

[3] N. Mohan, A. E. Ferguson, H. Cech, R. Bose, P. R. Renatin, M. K. Marina, and J. Ott, "A multifaceted look at starlink performance," in *Proceedings of the ACM Web Conference 2024*, ser. WWW '24. New York, NY, USA: Association for Computing Machinery, 2024, p. 2723–2734. [Online]. Available: https://doi.org/10.1145/3589334.3645328

[4] E. Grayver, R. Nelson, E. McDonald, E. Sorensen, and S. Romano, "Position and navigation using starlink," in *2024 IEEE Aerospace Conference*, 2024, pp. 1–12.

[5] B. Mafakheri, C. Yan, K. Narayanaswamy, I. Trang, T. Betz, K. Pientka, and L. Goratti, "Edge intelligence in 5g and beyond aeronautical network with leo satellite backhaul," in *2023 Joint European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit)*. IEEE, 2023, pp. 579–584.

[6] O. Kodheli, E. Lagunas, N. Maturo, S. K. Sharma, B. Shankar, J. F. M. Montoya, J. C. M. Duncan, D. Spano, S. Chatzinotas, S. Kisseleff, J. Querol, L. Lei, T. X. Vu, and G. Goussetis, "Satellite communications in the new space era: A survey and future challenges," *IEEE Communications Surveys Tutorials*, vol. 23, no. 1, pp. 70–109, 2021.

[7] J. C. McDowell, "The low earth orbit satellite population and impacts of the spacex starlink constellation," *The Astrophysical Journal Letters*, vol. 892, no. 2, p. L36, apr 2020. [Online]. Available: https://dx.doi.org/10.3847/2041-8213/ab8016

[8] H. Zhao, H. Fang, F. Wang, and J. Liu, "Realtime multimedia services over starlink: A reality check," in *Proceedings of the 33rd Workshop on Network and Operating System Support for Digital Audio and Video*, 2023, pp. 43–49.

[9] L. Borgianni, D. Adami, M. Bosi, S. Giordano, and C. Chafe, "A comprehensive evaluation of networked music performance using leo satellite internet: The starlink use case," *IEEE Transactions on Network and Service Management*, pp. 1–1, 2025.

[10] L. Borgianni, S. Giordano, and C. Chafe, "Democratizing networked music performance with a rl-based sd-wan," *IEEE Communications Magazine*, vol. 62, no. 12, pp. 26–32, 2024.

[11] M. Giordani, M. Polese, M. Mezzavilla, S. Rangan, and M. Zorzi, "Toward 6g networks: Use cases and technologies," *IEEE communications magazine*, vol. 58, no. 3, pp. 55–61, 2020.