

The Starlink Robot: A Platform and Dataset for Mobile Satellite Communication

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Abstract

The integration of satellite communication into mobile devices represents a paradigm shift in connectivity, yet the performance characteristics under motion and environmental occlusion remain poorly understood. We present the Starlink Robot, the first mobile robotic platform equipped with Starlink satellite internet, comprehensive sensor suite including upward-facing camera, LiDAR, and IMU, designed to systematically study satellite communication performance during movement. Our multi-modal dataset captures synchronized communication metrics, motion dynamics, sky visibility, and 3D environmental context across diverse scenarios including steady-state motion, variable speeds, and different occlusion conditions. This platform and dataset enable researchers to develop motion-aware communication protocols, predict connectivity disruptions, and optimize satellite communication for emerging mobile applications from smartphones to autonomous vehicles. The project is available at <https://github.com/StarlinkRobot>.

Keywords

Satellite Communication, Mobile Systems, Robot, Starlink

1 Introduction

The landscape of global connectivity is undergoing a fundamental transformation. SpaceX's Starlink constellation has deployed over 5,000 satellites, delivering high-speed internet to previously unreachable locations. This success has catalyzed a broader revolution: major technology companies including Apple, Samsung, and Google are racing to integrate satellite communication capabilities directly into consumer smartphones. The promise is compelling – seamless connectivity anywhere on Earth, free from the constraints of terrestrial infrastructure.

Yet this promise faces a critical challenge. Current satellite internet deployments predominantly serve stationary users – homes, businesses, and fixed installations. The Starlink Mini's recent introduction has made portable satellite internet more accessible, but fundamental questions remain unanswered. How does motion affect satellite link quality? What happens when a device moves through environments with varying sky visibility? These questions become urgent as

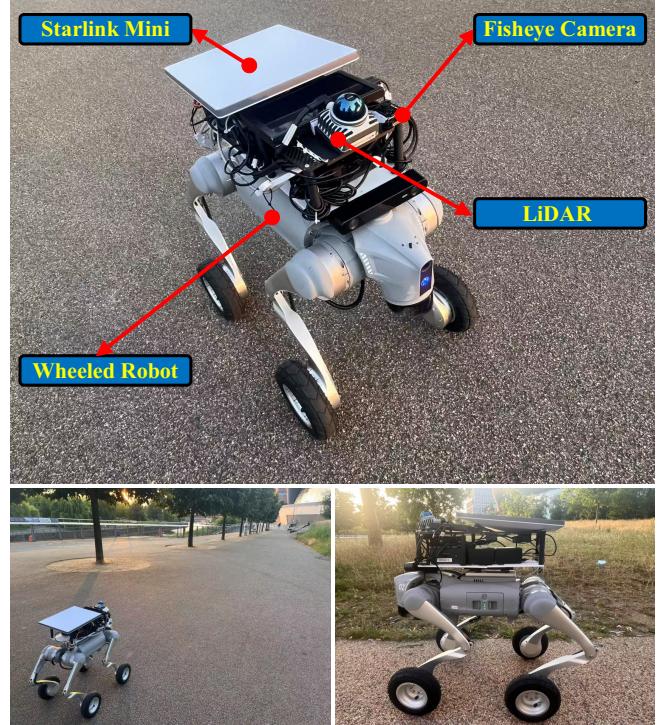


Figure 1. The Starlink Robot platform integrating a Unitree GO2 wheeled robot with Starlink Mini terminal, upward-facing fisheye camera, and Livox Mid-360 LiDAR for comprehensive mobile satellite communication research.

we envision a world where every mobile device, from smartphones to delivery robots to autonomous vehicles, maintains constant satellite connectivity.

The challenge extends beyond simple mobility. Satellite communication operates under fundamentally different constraints than terrestrial networks. A moving device must maintain connection with satellites traveling at 7.5 km/s while simultaneously dealing with local motion and environmental occlusions. Trees, buildings, and even the device's own orientation can disrupt the delicate link between Earth and space. Understanding these dynamics requires more than theoretical models – it demands real-world data collected under controlled yet realistic conditions.

To address this gap, we developed the Starlink Robot shown in Figure 1, a purpose-built platform that brings together mobile robotics and satellite communication. Our approach transforms a Unitree GO2 wheeled robot into a mobile laboratory, equipped with Starlink Mini for connectivity and a suite of sensors to capture the complete context of communication performance. The upward-facing fisheye camera observes sky visibility, the Livox Mid-360 LiDAR maps the surrounding environment, and integrated IMUs track every movement. This comprehensive sensing enables us to correlate communication metrics with physical conditions, revealing how motion and occlusion influence satellite connectivity.

Our contribution extends beyond the platform itself. We present a **multi-modal dataset** that synchronizes Starlink performance metrics – including latency, upload and download throughput, and signal quality indicators – with high-frequency motion data and environmental observations. This dataset captures diverse scenarios from steady locomotion to variable speeds, from open sky to heavily occluded urban environments. By releasing both our platform design and collected data, we provide the research community with tools to develop the next generation of mobile satellite communication systems.

2 Related Works

The rapid deployment of LEO satellite constellations has sparked significant research interest in characterizing their performance. The Starlink academic community, particularly through the University of Victoria’s PanLab, has produced comprehensive studies of Starlink’s several static performance characteristics [3–5, 7, 10–13, 15, 17–24]. Kassem et al. analyzed throughput variations across geographic locations, revealing how latitude affects connection quality due to satellite density differences [8]. Muhammad et al. investigated weather impacts, demonstrating that rain fade affects Starlink less severely than traditional geostationary satellites due to shorter signal paths [16]. These foundational studies establish baseline performance metrics but explicitly acknowledge the limitation of stationary measurements.

Recent work has begun exploring mobility scenarios, though primarily in constrained settings. Laniewski et al. conducted preliminary tests with Starlink terminals in vehicles, reporting increased latency variance during highway driving [9]. However, their study lacked synchronized motion data and environmental context, making it difficult to isolate causative factors. SpaceX Maritime [2] deployments documented by SpaceX show promising performance on ships, but the relatively stable motion and unobstructed ocean views present a best-case scenario that doesn’t translate to terrestrial mobile applications. The fundamental challenge remains: no existing work provides the fine-grained, multi-modal data necessary to understand how specific motion patterns and environmental conditions affect satellite communication.

The robotics community has long recognized the value of mobile platforms for wireless communication research. The CRAWDAD repository [1] contains numerous datasets from robot-mounted WiFi experiments, demonstrating how controlled mobility can reveal network behavior patterns invisible in static deployments. More recently, researchers have employed drones to map 5G coverage, taking advantage of three-dimensional mobility to characterize cellular networks [14]. Yet these efforts remain confined to terrestrial communication systems [6]. The unique challenges of satellite communication – including the need for precise sky visibility, the impact of antenna orientation, and the effects of Doppler shift from dual mobility – require purpose-built platforms and measurement methodologies. Our work bridges this gap by adapting mobile robotics techniques specifically for satellite communication research, creating a reproducible platform that others can build upon.

Our work addresses this gap by creating the first dedicated platform for mobile satellite communication research, providing the tools and data necessary to understand this emerging communication paradigm.

3 System Design

Creating a mobile platform for satellite communication research requires careful integration of robotics, networking, and sensing technologies. Our design philosophy prioritizes stability, reproducibility, and comprehensive data collection while maintaining the mobility necessary to explore diverse scenarios. Figure 2 illustrates the complete system architecture, from sensor integration to data analysis pipelines.

3.1 Hardware Architecture

The hardware is shown in Figure 1. The foundation of our system is the Unitree GO2 wheeled robot, chosen for its unique combination of stability and agility. Unlike legged robots that introduce gait-induced vibrations, the wheeled configuration provides smooth motion essential for maintaining satellite links. The GO2’s 15kg payload capacity accommodates our full sensor suite while maintaining dynamic performance, and its differential drive system enables precise velocity control from 0.1 to 2.0 m/s – spanning the range from slow walking to jogging speeds.

The Starlink Mini terminal mounts atop the robot via a custom aluminum frame designed to maintain the manufacturer’s recommended orientation while minimizing vibration transmission. Power delivery posed an interesting challenge: the Starlink Mini’s 12V requirement differs from the robot’s 24V battery system. We resolved this with a high-efficiency DC-DC converter that provides stable power while minimizing electromagnetic interference with the sensitive satellite receiver. The compact Intel NUC onboard computer serves as the central data collection hub, running Ubuntu 18.04 with ROS Noetic for sensor coordination and data logging.

Our sensing configuration captures the complete context needed to understand communication performance. The Livox Mid-360 LiDAR provides 360-degree environmental

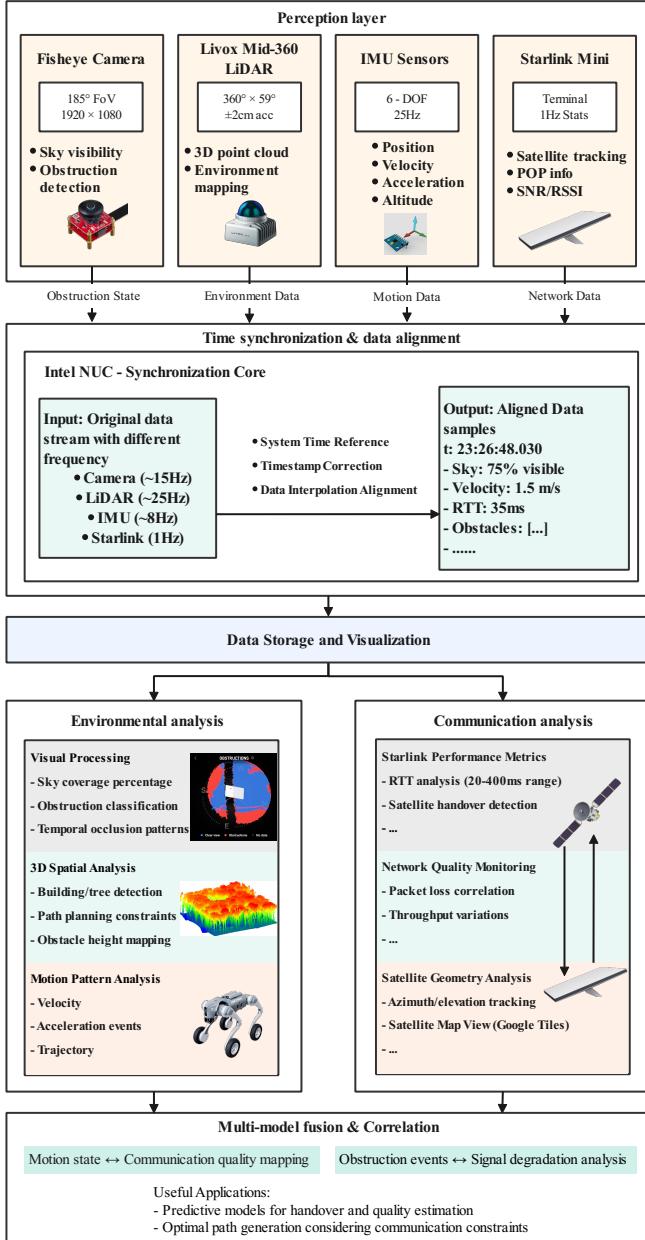


Figure 2. System architecture of the Starlink Robot platform showing multi-modal sensor integration, data synchronization pipeline, and analysis framework for correlating communication performance with environmental and motion context.

mapping with 0.05m ranging accuracy, essential for identifying potential occlusion sources before they impact connectivity. Mounted directly above the Starlink terminal, our upward-facing fisheye camera captures a 185-degree field of view of the sky. This placement allows us to correlate visible sky percentage with signal quality in real-time. The robot's integrated IMU system provides ~8Hz motion data, capturing accelerations and angular velocities that may influence antenna pointing accuracy.

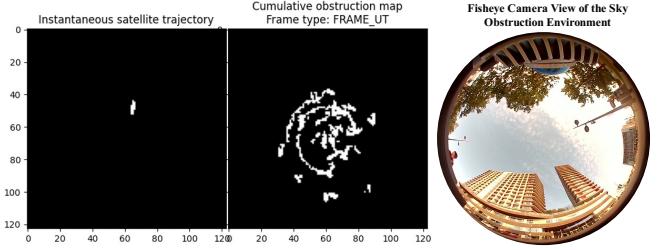


Figure 3. Starlink terminal's obstruction detection output (left) and Dual-view obstruction analysis showing fisheye camera sky visibility (right), demonstrating real-time obstruction mapping capabilities.

3.2 Software Architecture

Synchronizing diverse data streams requires careful architectural decisions. Our ROS-based framework treats time synchronization as a first-class concern. Each sensor node timestamps data using hardware triggers when available, falling back to kernel-level timestamps for software-triggered sensors. A dedicated synchronization node aligns all streams using a combination of GPS time (when available) and local clock correlation, achieving sub-millisecond alignment accuracy across all modalities.

The Starlink data collection presents unique challenges as the terminal doesn't expose a direct API. We employ a multi-layered approach: parsing the terminal's gRPC status interface provides 1Hz updates on signal quality, obstruction detection, and aggregate throughput. For finer-grained analysis, we capture packet-level data using tcpdump on the terminal's Ethernet interface, enabling microsecond-resolution latency measurements. Continuous active measurements complement passive monitoring – ICMP probes to geographically distributed servers run at 10Hz, while TCP and UDP throughput tests execute every 30 seconds to capture performance variations.

Data storage must handle high-rate sensor streams while maintaining queryability. We adopt a hybrid approach: high-frequency sensor data streams directly to ROS bag files, preserving full temporal resolution. Communication metrics and derived features are written to time-series databases for efficient analysis. A post-processing pipeline aligns all data sources, producing unified HDF5 files that researchers can analyze without wrestling with format conversions.

4 Dataset Description

Our dataset provides synchronized multi-modal sensor data from the Starlink Robot platform, capturing the complete context of mobile satellite communication. The dataset is organized as ROS bag files with extracted CSV files for communication metrics, enabling researchers to analyze the relationship between physical conditions and communication performance.

Obstruction Detection Data. As shown in Figure 3, we provide dual obstruction detection data. The fisheye camera captures 1920×1080 resolution images at ~15 Hz with

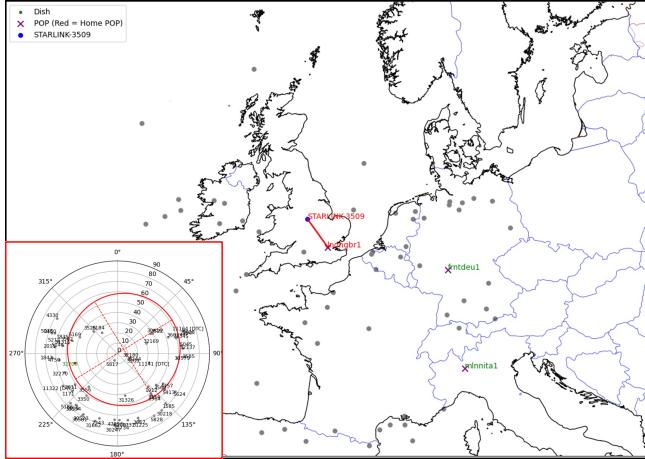


Figure 4. Real-time satellite constellation tracking visualization displaying active Starlink satellites’ positions, elevation angles, and connection status relative to the robot’s location.

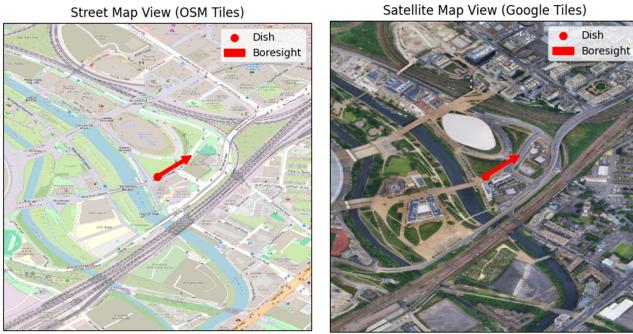


Figure 5. Google map view of the localization.

a 185-degree field of view, enabling sky visibility analysis. Additionally, we record the Starlink terminal’s internal obstruction detection output, which provides the system’s own assessment of signal blockage in a black visualization format. Both data streams are time-synchronized, allowing comparison between visual obstruction and the terminal’s detection algorithms.

Satellite Tracking Information. Figure 4 illustrates the real-time satellite tracking data collected at 1 Hz. For each visible Starlink satellite, we record azimuth, elevation, signal strength, and connection status. This data includes satellite IDs and constellation geometry, enabling analysis of handover patterns and satellite selection behavior during mobile operation.

Location and Path Data. The dataset includes GPS positioning data at 1 Hz, providing global coordinates of the robot’s trajectory. As visualized in Figure 5, our experimental paths cover diverse urban environments including open areas, tree-lined streets, and areas with varying building density. The GPS data is supplemented with wheel odometry at ~8 Hz for improved position accuracy.

3D Environmental Mapping. The Livox Mid-360 LiDAR captures 360-degree point clouds at ~25 Hz with ranging



Figure 6. LiDAR-based 3D point cloud visualization capturing environmental geometry around the robot, enabling precise obstruction detection.

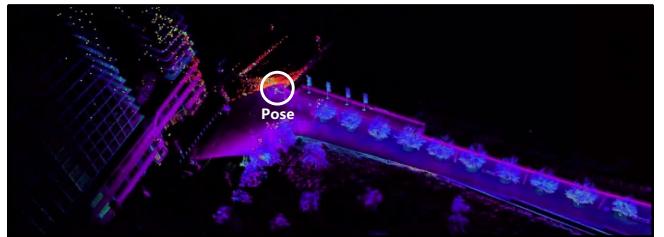


Figure 7. Robot pose and motion data indicating position, velocity, orientation, and trajectory information synchronized with communication performance metrics

accuracy of 0.05m up to 40 meters. Figure 6 shows example point cloud data revealing environmental geometry including buildings, trees, and other obstacles. The LiDAR data enables 3D reconstruction of the robot’s surroundings and correlation with communication performance.

Robot Motion and Pose Data. Figure 7 presents the comprehensive motion data captured by our platform. The onboard IMU provides ~8 Hz measurements of linear acceleration and angular velocity in three axes. Combined with wheel encoder data, we provide complete 6-DOF pose estimation including position, orientation, velocity, and acceleration. This high-frequency motion data captures vibrations, turns, and speed variations during experiments.

Communication Performance Metrics. The core of our dataset is the Starlink communication measurements shown in Figure 8. We collect: (1) Terminal-reported statistics at 1 Hz including downlink/uplink throughput, RTT, SNR, and obstruction state; (2) Active network measurements with ICMP probes at 10 Hz to multiple servers; (3) TCP/UDP throughput tests every 30 seconds. All communication data is timestamped and synchronized with sensor data.

Data Format and Organization. The dataset is structured as follows - *ROS bags*: Raw sensor data including camera images, LiDAR point clouds, IMU measurements, and GPS coordinates; *CSV files*: Extracted communication metrics, satellite tracking data, and robot pose information; *Metadata*:

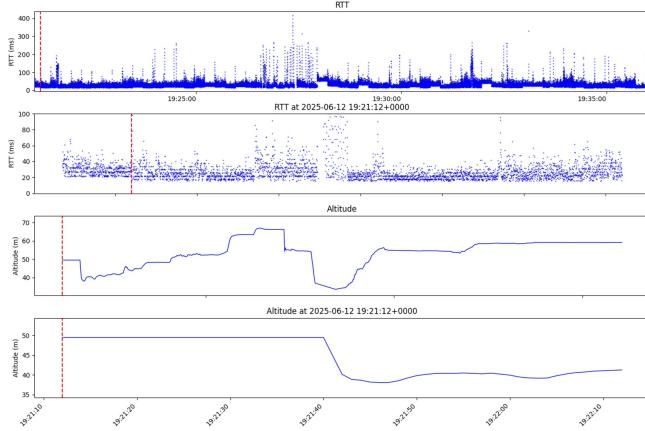


Figure 8. Multi-metric Starlink communication performance indicating RTT variations and altitude profiles during mobile operation.

Experimental conditions, calibration parameters, and time synchronization information; *Timestamps*: All data streams are synchronized using GPS time when available, with local clock correlation for continuous alignment.

Each experimental session includes data from different environmental conditions (open areas, tree-covered paths) and motion patterns (stationary, various speeds). The complete dataset with documentation and processing tools is available for download, providing researchers with the raw data necessary to develop and validate mobile satellite communication algorithms.

5 Preliminary Analysis

This preliminary analysis focuses on two critical factors: the impact of movement velocity on satellite connectivity, and variations in communication performance as mobile devices traverse diverse environments. These findings highlight unique challenges inherent to mobile satellite communication that distinguish it from traditional fixed deployments.

5.1 The Velocity Impact on Communication Performance

We analyzed communication performance at two different velocities: slow movement (approximately 0.8 m/s) and fast movement (approximately 2.0 m/s). Our findings reveal that motion speed has minimal impact on Starlink communication performance within typical pedestrian velocities.

As shown in Figures 9 and 10, RTT measurements remain remarkably stable across both speed conditions, with latency concentrated in the 35-45 ms range. Satellite handovers maintain their predictable 15-second intervals regardless of velocity, manifesting as clear step changes in RTT. While faster movement introduces slightly increased RTT variance—with occasional spikes reaching 60-70 ms—these variations remain within acceptable bounds for most applications.

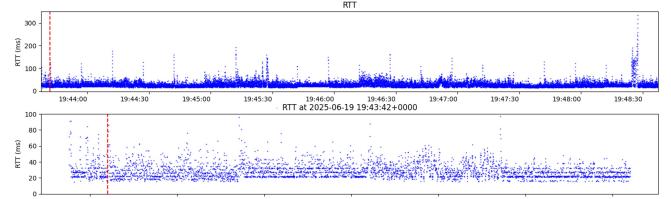


Figure 9. RTT performance during low-speed movement showing communication stability and handover patterns while maintaining slow velocity.

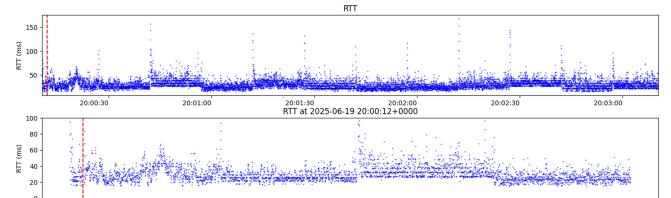


Figure 10. RTT performance during fast-speed movement (2.0 m/s) demonstrating minimal velocity impact on communication quality with slight increase in latency variance.

The minimal performance difference between velocity conditions suggests that Starlink's phased array antenna effectively compensates for motion at pedestrian speeds through electronic beam steering. This finding indicates that for applications involving pedestrian-speed mobility (delivery robots, portable terminals, walking users), velocity itself is not a primary concern for Starlink performance. Instead, as we demonstrate next, environmental factors dominate the mobile user experience.

5.2 The Environmental Impact on Mobile Satellite Communication

Mobile devices must continuously adapt to rapidly changing environmental conditions encountered in real-world scenarios. Our data captures the performance of a mobile robotic platform across two representative urban environments, demonstrating the profound influence of environmental dynamics on satellite communication.

In open environments (Figure 11) - such as the wide roads surrounding a stadium - Starlink communication reflects the core characteristics of LEO satellite systems. As illustrated in Figure 12, RTT (round-trip time) measurements exhibit periodic fluctuations, generally ranging from 20 to 40 ms, corresponding to the satellite handover process. Starlink satellites typically perform handovers approximately every 15 seconds due to their rapid orbital motion. While these handovers are temporally near-seamless, they produce distinct step changes in RTT. In open settings, this pattern is relatively consistent, though latency characteristics vary across different satellites.

In contrast, forested environments (Figure 13) introduce significantly greater variability. Tree-lined streets limit sky visibility and create a dynamic communication environment. As the robot moves along these paths, intermittent canopy



Figure 11. Environmental context and the robot running scenario in open area showing robot deployment location, surrounding infrastructure, and clear sky conditions from multiple viewpoints.

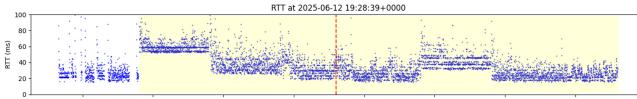


Figure 12. Extended RTT measurements in open environment demonstrating periodic satellite handover patterns and baseline performance characteristics without environmental obstructions.

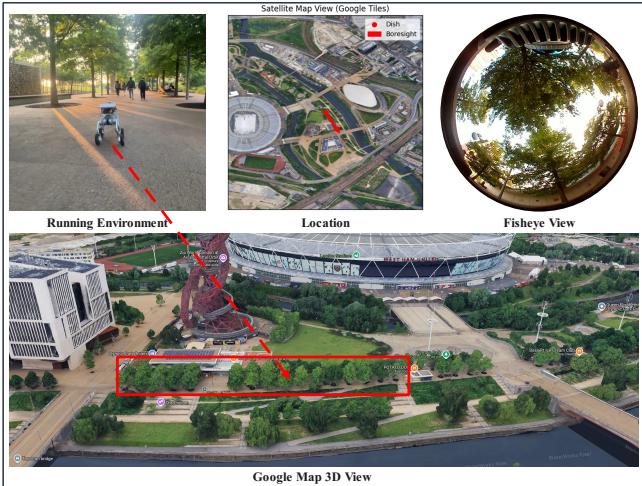


Figure 13. Environmental context and the robot running scenario in tree-covered area showing robot navigation through foliage-dense paths with limited sky visibility.

gaps continuously alter the terminal’s satellite viewing angles. As illustrated in Figure 15, RTT data reveals substantial instability, with frequent spikes reaching 40–100 ms. This degradation is not simply the result of signal attenuation; rather, it reflects the compounded effects of handover mechanisms in scenarios constrained by visibility. When fewer

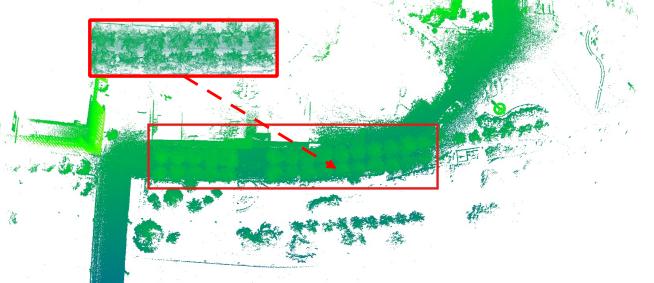


Figure 14. LiDAR point cloud visualization of tree-covered environment illustrating canopy density and potential signal obstruction patterns affecting satellite communication.

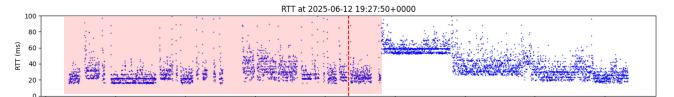


Figure 15. Communication performance in tree-covered environment demonstrating increased RTT instability and frequent spikes due to limited satellite visibility.

satellites are in view, the terminal’s handover options diminish, potentially leading to connections with suboptimal satellites or brief service interruptions.

Of particular interest are the sharp changes in communication characteristics during environmental transitions. When the device moves from forested areas into open zones or into building shadows, the system maintains connectivity and transitions to newly available satellites. However, communication performance changes markedly. Our data show significant shifts in RTT baseline, fluctuation amplitude, and overall stability before and after such transitions. These dynamic variations—absent in fixed deployments—are routine for mobile platforms.

6 Research Vision and Community Impact

The Starlink Robot platform transforms how researchers approach mobile satellite communication challenges. By providing synchronized multi-modal data, our platform enables entirely new research directions previously impossible with stationary measurements or uncontrolled mobile experiments. Researchers can now develop motion-aware protocols that anticipate and adapt to environmental changes, design predictive models that maintain quality of service during transitions, and create intelligent path planning algorithms that consider communication constraints alongside traditional navigation objectives.

Our dataset’s comprehensive nature empowers the community to tackle fundamental questions in mobile satellite networking. The correlation between sky visibility, motion patterns, and performance metrics allows researchers to move beyond empirical observations to develop theoretical models of satellite-based mobile communications. This understanding is crucial as the industry shifts from best-effort

connectivity to guaranteed service levels for critical applications like autonomous vehicles and emergency services. The platform's reproducibility ensures that innovations can be validated across diverse environments and conditions, accelerating the path from research to deployment.

Furthermore, the modular architecture invites community extensions that will shape the future of ubiquitous connectivity. As new satellite constellations launch and devices gain multi-network capabilities, researchers can leverage our framework to study heterogeneous network integration, develop seamless handover mechanisms, and optimize energy consumption across terrestrial and satellite links. By establishing this common measurement infrastructure, we enable the community to build upon each other's work systematically, fostering collaborative progress toward truly global, always-on connectivity.

7 Conclusion

This paper introduces the Starlink Robot, the first platform designed specifically for studying satellite communication under controlled mobility. Our multi-modal dataset reveals that motion and environmental dynamics significantly impact satellite performance in ways that static measurements cannot capture. By open-sourcing both the platform design and collected data, we provide the research community with essential tools for developing the next generation of mobile satellite systems.

References

- [1] 2025. CRAWDAD: Community Resource for Archiving Wireless Data at Dartmouth. <https://ieee-dataport.org/collections/crawdad>. Accessed: 2025-06-18.
- [2] 2025. Starlink Business | Maritime. <https://www.starlink.com/business/maritime>. Accessed: 2025-06-18.
- [3] Ali Ahangarpour, Jinwei Zhao, and Jianping Pan. 2024. Trajectory-based Serving Satellite Identification with User Terminal's Field-of-View. In *Proceedings of the 2nd International Workshop on LEO Networking and Communication*. 55–60.
- [4] Xia Deng, Le Chang, Shouyuan Zeng, Lin Cai, and Jianping Pan. 2022. Distance-based back-pressure routing for load-balancing LEO satellite networks. *IEEE Transactions on Vehicular Technology* 72, 1 (2022), 1240–1253.
- [5] Junhao Hu, Lin Cai, Chengcheng Zhao, and Jianping Pan. 2020. Directed percolation routing for ultra-reliable and low-latency services in low earth orbit (LEO) satellite networks. In *2020 IEEE 92nd vehicular technology conference (VTC2020-Fall)*. IEEE, 1–6.
- [6] International Telecommunication Union - Radiocommunication Sector (ITU-R). 2021. *Recommendation ITU-R M.2150: Detailed specifications of the radio interfaces of IMT-2020*. Recommendation M.2150-0. International Telecommunication Union. <https://www.itu.int/rec/R-REC-M.2150> [accessed 2025-06-18].
- [7] Victor Kamel, Jinwei Zhao, Daoping Li, and Jianping Pan. 2024. Star-QUIC: Tuning Congestion Control Algorithms for QUIC over LEO Satellite Networks. In *Proceedings of the 2nd International Workshop on LEO Networking and Communication*. 43–48.
- [8] Mohamed M Kassem, Aravindh Raman, Diego Perino, and Nishanth Sastry. 2022. A browser-side view of starlink connectivity. In *Proceedings of the 22nd ACM Internet Measurement Conference*. 151–158.
- [9] Dominic Laniewski, Eric Lanfer, and Nils Aschenbruck. 2025. Measuring Mobile Starlink Performance: A Comprehensive Look. *IEEE Open Journal of the Communications Society* (2025).
- [10] Daoping Li, Jinwei Zhao, and Jianping Pan. 2025. FTRL-WRR: Learning-Based Two-Path Scheduler for LEO Networks. In *2025 IEEE 22nd Consumer Communications & Networking Conference (CCNC)*. IEEE, 1–6.
- [11] Tengfei Liu, Tingting Wang, Ye Li, Jinwei Zhao, Ruifeng Gao, and Jianping Pan. 2025. Modeling Packet Loss of Low-Earth Orbit Satellite Networks. In *2025 IEEE Wireless Communications and Networking Conference (WCNC)*. IEEE, 1–6.
- [12] Jianping Pan, Jinwei Zhao, and Lin Cai. 2023. Measuring a low-earth-orbit satellite network. In *2023 IEEE 34th Annual International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC)*. IEEE, 1–6.
- [13] Jianping Pan, Jinwei Zhao, and Lin Cai. 2024. Measuring the satellite links of a LEO network. In *ICC 2024-IEEE International Conference on Communications*. IEEE, 4439–4444.
- [14] Valentin Platzgummer, Vaclav Raida, Gerfried Krainz, Philipp Svoboda, Martin Lerch, and Markus Rupp. 2019. UAV-based coverage measurement method for 5G. In *2019 IEEE 90th Vehicular Technology Conference (VTC2019-Fall)*. IEEE, 1–6.
- [15] Weibiao Tian, Ye Li, Jinwei Zhao, Sheng Wu, and Jianping Pan. 2024. An eBPF-Based Trace-Driven Emulation Method for Satellite Networks. *IEEE Networking Letters* (2024).
- [16] Muhammad Asad Ullah, Antti Heikkilä, Mikko Uitto, Antti Anttonen, and Konstantin Mikhaylov. 2025. Impact of Weather on Satellite Communication: Evaluating Starlink Resilience. *arXiv preprint arXiv:2505.04772* (2025).
- [17] Bingsen Wang, Xiaohui Zhang, Shuai Wang, Li Chen, Jinwei Zhao, Jianping Pan, Dan Li, and Yong Jiang. 2024. A Large-Scale IPv6-Based Measurement of the Starlink Network. *arXiv preprint arXiv:2412.18243* (2024).
- [18] Yufei Wang, Lin Cai, and Jun Liu. 2023. High-Reliability, Low-Latency, and Load-Balancing Multipath Routing for LEO Satellite Networks. In *2023 Biennial Symposium on Communications (BSC)*. IEEE, 107–111.
- [19] Wenjun Yang, Lin Cai, Shengjie Shu, and Jianping Pan. 2024. Mobility-aware congestion control for multipath QUIC in integrated terrestrial satellite networks. *IEEE Transactions on Mobile Computing* (2024).
- [20] Wenjun Yang, Shengjie Shu, Lin Cai, and Jianping Pan. 2021. MM-QUIC: Mobility-aware multipath QUIC for satellite networks. In *2021 17th International Conference on Mobility, Sensing and Networking (MSN)*. IEEE, 608–615.
- [21] Jinwei Zhao and Jianping Pan. 2024. LENS: A LEO Satellite Network Measurement Dataset. In *Proceedings of the 15th ACM Multimedia Systems Conference*. 278–284.
- [22] Jinwei Zhao and Jianping Pan. 2024. Low-Latency Live Video Streaming over a Low-Earth-Orbit Satellite Network with DASH. In *Proceedings of the 15th ACM Multimedia Systems Conference*. 109–120.
- [23] Jinkai Zheng, Tom H Luan, Guanjie Li, Yanfeng Zhang, Mingfeng Yuan, and Jianping Pan. 2025. QTER: QoS-Aware Three-Dimensional Efficient and Reliable Routing for LEO Satellite Networks. *IEEE Internet of Things Journal* (2025).
- [24] Jinkai Zheng, Tom H Luan, Jinwei Zhao, Guanjie Li, Yao Zhang, Jianping Pan, and Nan Cheng. 2024. Adaptive Multi-Link Data Allocation for LEO Satellite Networks. In *GLOBECOM 2024-2024 IEEE Global Communications Conference*. IEEE, 3021–3026.