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A Framework for Blockchain-Verified Ground Infrastructure: Enabling Open Source CubeSat Communications Through Decentralized Networks

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CubeSat missions face critical ground station access bottlenecks that limit mission effectiveness. Traditional centralized ground networks are characterized by high deployment costs, significant downlink latencies exceeding 90 minutes [1], and long periods of idleness, with stations often unused for over 85% of potential satellite pass times [2]. Furthermore, geographic distribution imbalances, known as the Uneven Queuing Effect, can result in a 13–31% loss in potential throughput [3]. These combined factors create substantial barriers for academic institutions and open-source space projects seeking affordable and responsive ground station access.

We are developing a research framework to investigate the viability of Decentralized Physical Infrastructure Networks (DePIN) for ground stations through a methodology combining literature review, economic modeling, and experimental validation [4]. This framework examines the coordination of federated traditional, amateur and Ground-Station-as-a-Service (GSaaS) providers [5] using blockchain consensus mechanisms [6]. Our experimental work involves the implementation and testing of four novel cryptographic proof systems designed to verifiably report on physical infrastructure performance: Proof-of-Location (POL) [7], Proof-of-Accuracy (POA) [7], Proof-of-Backhaul (PoB) [8], and Proof-of-Flow (PoF) [9]. Current experiments focus on implementing a distributed hash-based verification system for ground station telemetry and evaluating consensus overhead in simulated satellite pass scenarios.

Literature analysis demonstrates that distributed ground networks could potentially reduce data downlink latency by up to 76% (from over 90 minutes to 21 minutes) [1] and improve throughput by 13–31% through intelligent, network-wide scheduling [3]. Our economic modeling suggests that a federated network could achieve break-even points with as few as 50 participating stations, offering potential cost reductions of 60–80% for university-scale operators [2, 5]. Preliminary digital experiments and implementations testing the cryptographic proof mechanisms show sub-second verification times, indicating their suitability for real-time ground station coordination [7, 8, 9]. Ongoing testing is focused on evaluating consensus latency and the scalability of proof validation under realistic LEO communication windows.

Our analysis indicates that blockchain-based coordination could enable trustless, dynamic collaboration between diverse ground station operators without requiring complex legal frameworks, significantly lowering barriers for educational and research-focused CubeSat missions [4]. The proposed framework supports the development of open-source ground station virtualization standards while maintaining compatibility with existing infrastructure [10]. Key research challenges remain, including the optimization of consensus mechanisms for real-time satellite pass constraints [11] and ensuring regulatory compliance across international boundaries [12]. Future experimental work will seek to validate whether these cryptographic proof systems can operate effectively within CubeSat communication windows while delivering the security and decentralization benefits required by the global educational and open-source space community.

References

[1] Vasisht, D., Shenoy, J., & Chandra, R. (2021). L2D2: Low Latency Distributed Downlink for Low Earth Orbit Satellites. Proceedings of the ACM SIGCOMM 2021 Conference.

[2] Oh, S., & Vasisht, D. (2024). A Call for Decentralized Satellite Networks. Proceedings of the 23rd ACM Workshop on Hot Topics in Networks (HotNets '24).

[3] Tao, B., Masood, M., Gupta, I., & Vasisht, D. (2023). Transmitting, Fast and Slow: Scheduling Satellite Traffic through Space and Time. Proceedings of the 29th Annual International Conference on Mobile Computing and Networking (ACM MobiCom '23).

[4] Rad, P., Pour, M. S., Jozani, M., Zanella, G., & Abhari, K. (2025). Reimagining the Sharing Economy through Blockchain: The Case of Helium's Decentralized Wireless Network. Proceedings of the 58th Hawaii International Conference on System Sciences.

[5] Zhao, H., Cen, S., & Zhu, Y. (2024). The Space Above the Sky: Uniting Global-Scale Ground Station as a Service for Efficient Orbital Data Processing. In 2024 IEEE 32nd International Conference on Network Protocols (ICNP). DOI: 10.1109/ICNP61940.2024.10858567.

[6] Nguyen, C. T., Hoang, D. T., Nguyen, D. N., Niyato, D., Nguyen, H. T., & Dutkiewicz, E. (2019). Proof-of-Stake Consensus Mechanisms for Future Blockchain Networks: Fundamentals, Applications and Opportunities. IEEE Access, 7, 85727-85745.

[7] Horton, M., Chen, D., Yi, Y., Wen, X., & Doebbler, J. (2023). GEODNET: Global Earth Observation Decentralized Network. NAVIGATION, Journal of the Institute of Navigation, 70(4).

[8] Sheng, P., Yadav, N., Sevani, V., Babu, A., Anand, S. V. R., Tyagi, H., & Viswanath, P. (2024). Proof of Backhaul: Trustfree Measurement of Broadband Bandwidth. Proceedings of the Network and Distributed System Security (NDSS) Symposium. DOI: 10.14722/ndss.2024.24764.

[9] Yan, X., & Gao, B. (2024). A Communication Satellite Services Based Decentralized Network Protocol. arXiv preprint arXiv:2406.18032. DOI: 10.48550/arXiv.2406.18032.

[10] Cutler, J. (2003). Ground Station Virtualization. Proceedings of the Fifth International Symposium on Reducing the Cost of Spacecraft Ground Systems and Operations (RCSGSO).

[11] So, J., Hsieh, K., Arzani, B., Noghabi, S., Avestimehr, S., & Chandra, R. (2022). FedSpace: An Efficient Federated Learning Framework at Satellites and Ground Stations. arXiv preprint arXiv:2202.01267.

[12] Liu, L., & Omote, K. (2025). A traceable authentication system based on blockchain for decentralized physical infrastructure networks. Sci Rep 15, 16708.

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