ANALISIS SISTEM ANTREAN PADA *BACKHAUL* SATELIT ORBIT RENDAH UNTUK JARINGAN 5G PADA WILAYAH RURAL

SKRIPSI

Diajukan untuk memenuhi sebagian syarat dalam memperoleh gelar
Sarjana Teknik pada Program Studi Sistem Telekomunikasi

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ABSTRAK

Kesenjangan akses jaringan 5G di wilayah rural menjadi tantangan utama akibat keterbatasan infrastruktur terestrial, sehingga teknologi *backhaul* satelit *Low Earth Orbit* (LEO) dipandang sebagai solusi potensial berkat cakupan luas dan latensi rendah. Namun, keterbatasan kapasitas kanal dan potensi kemacetan trafik memerlukan evaluasi kinerja yang komprehensif. Studi ini memodelkan dan membandingkan tiga sistem antrean M/M/1, M/M/1/K, dan M/M/c pada *backhaul* satelit LEO menggunakan *discrete-event simulation* berbasis pustaka SimPy, dengan variasi *arrival rate* (λ) sebesar 1–33 paket/detik dan *service rate* (μ) tetap 34 paket/detik. Hasil menunjukkan bahwa peningkatan λ meningkatkan utilitas *server* secara linear, tetapi memicu kenaikan drastis pada waktu tunggu (Wq) dan panjang antrean (Lq) di model single *server*. Model M/M/1/K menekan lonjakan Wq dan Lq pada beban tinggi melalui pembatasan kapasitas, meskipun berimplikasi pada peningkatan *packet loss*. Model M/M/c mencapai performa terbaik namun kurang efisien untuk infrastruktur rural. Berdasarkan analisis teknis dan efisiensi sumber daya, model M/M/1/K direkomendasikan sebagai konfigurasi optimal untuk pengelolaan trafik *backhaul* satelit 5G di wilayah rural.

Kata kunci: Sistem antrean, *backhaul* satelit, LEO, 5G, wilayah rural.

ABSTRACT

The disparity in 5G network access in rural areas remains a major challenge due to the limitations of terrestrial infrastructure. As a result, Low Earth Orbit (LEO) satellite backhaul technology is considered a potential solution, offering wide coverage and low latency. However, channel capacity constraints and the risk of traffic congestion necessitate comprehensive performance evaluation. This study models and compares three queuing systems—M/M/1, M/M/1/K, and M/M/c—on LEO satellite backhaul using discrete-event simulation with the SimPy library, varying the arrival rate (λ) between 1–33 packets/second while keeping the service rate (μ) fixed at 34 packets/second. The results show that increasing λ linearly raises server utilization but triggers a drastic rise in waiting time (Wq) and queue length (Lq) in the single-server model. The M/M/1/K model mitigates the surge in Wq and Lq under high load by limiting capacity, though at the cost of increased packet loss. The M/M/c model achieves the best performance but is less efficient for rural infrastructure. Based on technical analysis and resource efficiency, the M/M/1/K model is recommended as the optimal configuration for managing 5G satellite backhaul traffic in rural areas.

Keywords: Queueing system, satellite backhaul, LEO, 5G, rural areas.

DAFTAR ISI

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DAFTAR LAMPIRAN

DAFTAR PUSTAKA

Agarwal, A. (2018). *Validation of Inventory models for Single-echelon Supply Chain using Discrete-event Simulation* (arXiv:1806.07427). arXiv. https://doi.org/10.48550/arXiv.1806.07427

Bouloukakis, G., Moscholios, I., Georgantas, N., & Issarny, V. (2018). Simulation-based Queueing Models for Performance Analysis of IoT Applications. *2018 11th International Symposium on Communication Systems, Networks & Digital Signal Processing (CSNDSP)*, 1–5. https://doi.org/10.1109/CSNDSP.2018.8471798

Ding, C., Qiao, F., Wang, D., & Liu, J. (2025). A novel hybrid intelligent scheduling: Integrating human feedback into reinforcement learning for adaptive preference objectives. *International Journal of Production Research*, *63*(16), 6037–6055. https://doi.org/10.1080/00207543.2025.2467448

Gross, D., Shortle, J. F., Thompson, J. M., & Harris, C. M. (2008). *Fundamentals of Queueing Theory* (1 ed.). Wiley. https://doi.org/10.1002/9781118625651

Guidotti, A., Vanelli-Coralli, A., Conti, M., Andrenacci, S., Chatzinotas, S., Maturo, N., Evans, B., Awoseyila, A., Ugolini, A., Foggi, T., Gaudio, L., Alagha, N., & Cioni, S. (2019). Architectures and Key Technical Challenges for 5G Systems Incorporating Satellites. *IEEE Transactions on Vehicular Technology*, *68*(3), 2624–2639. https://doi.org/10.1109/TVT.2019.2895263

Hadi, A. (2018). Bridging Indonesia's Digital Divide: Rural-Urban Linkages? *Jurnal Ilmu Sosial Dan Ilmu Politik*, *22*(1), 17. https://doi.org/10.22146/jsp.31835

Heine, S., Völk, F., Schwarz, R. T., & Knopp, A. (2023). Concept and evaluation of 5G backhauling via starlink. *IET Conference Proceedings*, *2022*(29), 69–75. https://doi.org/10.1049/icp.2023.1364

Kodheli, O., Guidotti, A., & Vanelli-Coralli, A. (2017). *Integration of Satellites in 5G through LEO Constellations* (arXiv:1706.06013). arXiv. https://doi.org/10.48550/arXiv.1706.06013

Law, A. M. (2015). *Simulation Modeling and Analysis* (Fifth Edition). McGraw-Hill US Higher Ed USE Legacy.

Leyva-Mayorga, I., Soret, B., Roper, M., Wubben, D., Matthiesen, B., Dekorsy, A., & Popovski, P. (2020). LEO Small-Satellite Constellations for 5G and Beyond-5G Communications. *IEEE Access*, *8*, 184955–184964. https://doi.org/10.1109/ACCESS.2020.3029620

Marcano, N. J. H., Diez, L., Aguero, R., & Jacobsen, R. H. (2022). Finite Buffer Queuing Delay Performance in the Low Earth Orbit Land Mobile Satellite Channel. *2022 IEEE Wireless Communications and Networking Conference (WCNC)*, 132–137. https://doi.org/10.1109/WCNC51071.2022.9771859

Mubarak, R., Budiyanto, S., Wulandari, P., Rahayu, F., Adriansyah, A., & Alaydrus, M. (2021). A queue theory in the cross-polarization of

antenna in satellite communication. *Indonesian Journal of Electrical Engineering and Computer Science*, *22*(2), 884. https://doi.org/10.11591/ijeecs.v22.i2.pp884-892

Noraprilia, K., & Ahdika, A. (2018). ANALISIS ANTRIAN SINGLE CHANNEL SINGLE SERVER DENGAN LAYANAN BERKELOMPOK PADA KONEKSI INTERNET DI UNIVERSITAS ISLAM INDONESIA. *Jurnal Ilmiah Matematika dan Pendidikan Matematika*, *10*(1), 53. https://doi.org/10.20884/1.jmp.2018.10.1.2837

Otero Perez, G., Larrabeiti Lopez, D., & Hernandez, J. A. (2019). 5G New Radio Fronthaul Network Design for eCPRI-IEEE 802.1CM and Extreme Latency Percentiles. *IEEE Access*, *7*, 82218–82230. https://doi.org/10.1109/ACCESS.2019.2923020

Oughton, E. J., & Lehr, W. (2022). Surveying 5G Techno-Economic Research to Inform the Evaluation of 6G Wireless Technologies. *IEEE Access*, *10*, 25237–25257. https://doi.org/10.1109/ACCESS.2022.3153046

Rodrigues, L., Rodrigues, J. J. P. C., Serra, A. D. B., & Silva, F. A. (2022). A Queueing-Based Model Performance Evaluation for Internet of People Supported by Fog Computing. *Future Internet*, *14*(1), 23. https://doi.org/10.3390/fi14010023

Salem, H. B., Kouzayha, N., Falou, A. E., Alouini, M.-S., & Al-Naffouri, T. Y. (2023). *Exploiting Hybrid Terrestrial/LEO Satellite Systems for Rural Connectivity* (arXiv:2311.02591). arXiv. https://doi.org/10.48550/arXiv.2311.02591

Yaacoub, E., & Alouini, M.-S. (2019). *A Key 6G Challenge and Opportunity -- Connecting the Remaining 4 Billions: A Survey on Rural Connectivity* (arXiv:1906.11541). arXiv. https://doi.org/10.48550/arXiv.1906.11541

Zinoviev, D. (2024). *Discrete Event Simulation: It's Easy with SimPy!* (arXiv:2405.01562). arXiv. https://doi.org/10.48550/arXiv.2405.01562