Deterministic QoS Guarantees in Next-Generation LEO Satellite Constellations

PARTENAIRES

CNRS

Sorbonne Université

Mine-Telecom Bretagne

Key words: LEO satellite constellations, Network Calculus, QoS, Real-Time, 6G

Department: DISC / SysCo

JOB DESCRIPTION:

Low Earth Orbit (LEO) satellite constellations — such as Starlink, OneWeb, Kuiper, and Telesat Lightspeed — are rapidly becoming a cornerstone of next-generation communication infrastructures and future 6G networks [1]. With thousands of satellites orbiting at altitudes between 500 and 2000 km, these systems offer unprecedented global coverage combined with significantly lower latency than traditional geostationary systems. The emergence of LEO constellations opens transformative opportunities for time-sensitive applications. These applications demand deterministic end-to-end delay guarantees — strict, provable upper bounds on latency — rather than best-effort performance. However, providing such guarantees in LEO constellations remains an open and largely unsolved problem. Preliminary research conducted at ISAE-SUPAERO has demonstrated that Network Calculus (NC), a mathematical framework for computing worst-case performance bounds in communication networks, can be successfully adapted to LEO satellite constellations. This PhD aims to develop a comprehensive analytical and algorithmic framework for deterministic QoS guarantees in dynamic LEO satellite constellations within a collaborative project PEPR FRONTIER funded by the ANR with many partners like CNRS, Sorbonne Université et mines-Telecom Bretagne.

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MISSIONS:

The research will pursue the following objectives:

- Develop scalable analytical models that account for the full dynamic topology of LEO constellations across successive orbital snapshots, including satellite handover events and topology reconfiguration;
- Integrate NC-based QoS analysis directly into routing algorithms to compute routes that guarantee delay requirements by construction;
- Investigate admission control mechanisms at gateways leveraging real-time NC computations to dynamically manage heterogeneous traffic (gateways, user terminals, mobile devices) while maintaining deterministic guarantees;
- Validate the full framework on realistic large-scale LEO constellation models.

REQUIRED PROFILE:

- Master's degree (or equivalent) in Computer Science, Telecommunications, Electrical Engineering, Applied Mathematics, or a closely related field.
- Strong background in networking, real-time systems, or formal performance analysis.
- Knowledge of Network Calculus is a plus.
- Good programming skills (Python, C++, or Java) and familiarity with simulation tools.
- Interest in satellite communications, 6G networks, or time-sensitive networking (TSN).
- Strong analytical and problem-solving skills, and the ability to work in an interdisciplinary research team.
- Proficiency in English (written and spoken). French is not required but would be an asset.

EXPERIENCE: 0 to 2 years

COMPENSATION: 25-35k€ brut/ AN
DURATION: 36 MOIS
RYTHM: Full time
LOCATION: TOULOUSE

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APPLICATION PROCESS:
Interested candidates should send the following documents to the supervisors:
- A detailed CV.
- A cover letter explaining your motivation and research interests.
- Master's transcripts and degree certificate (or expected graduation date).
- Two reference letters or the names of two referees.

APPLICATION DEADLINE: September 7th

REFERENCES:
[1] H. Xie, Y. Zhan, G. Zeng and X. Pan, "LEO Mega-Constellations for 6G Global Coverage: Challenges and Opportunities," in IEEE Access, vol. 9, pp. 164223-164244, 2021, doi: 10.1109/ACCESS.2021.3133301.
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[3] L. Thomas, J.-Y. Le Boudec, and A. Mifdaoui, “On Cyclic Dependencies and Regulators in Time-Sensitive Networks,” in 2019 IEEE Real-Time Systems Symposium (RTSS), 2019, pp. 299–311
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