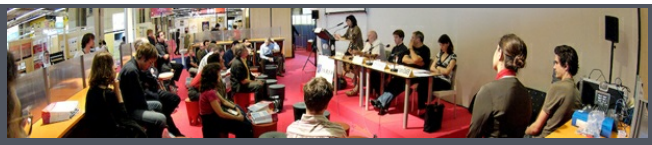
INTERNATIONAL RELATIONS



INTERNSHIP SUBJECT

## 2886 - Realistic Channel Modelling for Satellite - Internet of Things

This work will occur in the Inria Agora research team in Lyon in the framework of the DORSAL-IoT Associated Team between Inria Agora, Universidad de Chile and Pontificia Universidad Católica de Chile. The internship student will be supervised by Dr. Juan Fraire (Inria Agora) and will work closely with Dr. Cesar Azurdia (Universidad de Chile).

**Keywords:** satellite communication, Internet of Things (IoT), Low-Power Wide Area Networks (LPWAN), channel modelling, LoRa, LoRaWAN.

### Context

The Internet of Things (IoT) has emerged as a transformative convergence of telecommunications, information technology, and various industrial sectors, including automation, logistics, and energy. Low Earth Orbit (LEO) satellites offer a promising path for extensive IoT connectivity through direct-to-satellite (DtS) IoT links, providing a cost-effective solution to achieve global coverage [1], with LoRa [2], and LR-FHSS [3], paired with LoRaWAN [4], as one of the prominent technologies for long-range terrestrial communication networks. Despite its potential, DtS-IoT connectivity introduces significant challenges at the physical and medium access control (MAC) layers, mainly associated with the dynamic nature of time-varying channels, which result from the trajectory of LEO satellites as they travel in their orbit. These challenges include time-varying propagation delays in radio links, time-varying elevation angles between the satellite and the terminal, and signal deterioration due to the Doppler effect, multipath fading, and shadowing [5].

### Assignment

Accurate channel modeling is crucial for optimizing DtS-IoT communications via LEO satellites. Traditional channel models for land-mobile satellite systems often overlook the significant impact of shadowing at low elevation angles, limiting their applicability to DtS-IoT scenarios. In light of this, this internship will focus on studying and implementing realistic channel models in the FLoRaSAT framework [6]. FLoRaSat (Framework for LoRa-based Satellite Networks) is an Omnet++ (C++) based discrete-event simulator for comprehensive satellite IoT simulations developed in the Inria Agora team and maintained by Dr. Juan Fraire. While the simulator already accommodates orbital mechanics, the LoRaWAN Medium Access Control (MAC) layer, and a basic free space model of the physical layer, it lacks a real representation of the dynamic nature of time-varying channels resulting from the trajectory of LEO satellites.

More precisely, the student will have to:

- Study the latest state of the art in DtS-IoT channel modeling, starting with the model proposed by Núñez-González et al [7].
- Propose a realistic channel model for DtS-IoT scenarios.
- Familiarize with the Omnet++ framework, the FLoRaSat software architecture, and the LoRa, LR-FHSS, and LoRaWAN technologies.
- Develop and integrate new C++ classes (Omnet++ modules) for the proposed channel model.
- Perform performance evaluation campaigns within case study scenarios using the newly implemented channel model, incorporating LEO satellites and ground nodes. Analyze the collected data, draw insights from the findings, and compile a report.

### Bibliography:

[1] J. A. Fraire, O. Iova, and F. Valois, Space-Terrestrial Integrated Internet of Things: Challenges and Opportunities, in IEEE Communications Magazine, vol. 60, no. 12, pp. 64-70, 2022.
[2] Semtech, LoRa - Long Range Technology: https://www.semtech.com/lora
[3] Semtech, Long Range - Frequency Hopping Spread Spectrum (LR-FHSS): https://blog.semtech.com/lorawan-protocol-expands-network-capacity-with-new-long-range-frequency-hopping-spread-spectrum-technology
[4] LoRa Alliance, LoRaWAN 1.1 Specification, 2017.
[5] L.M. Davis, I.B. Collings, R.J. Evans, Estimation of LEO satellite channels, in International Conference on Information, Communications and Signal Processing,

### Required Skills

**Required Skills**

We encourage applications from students pursuing a Computing Engineering or Electrical Engineering degree. Practical proficiency with programming languages (C/C++ and Python) is desirable. A solid understanding of mathematics and wireless networking is preferred. Applicants must have fluency in English; proficiency in French is not a prerequisite but would be advantageous. We are seeking candidates who are empathetic, proactive, and self-motivated.

### General Information

- **Research Theme :** Networks and Telecommunications
- **Locality :** Villeurbanne
- **Level :** Master
- **Period :** 1st January 2026 -> 31st March 2026 (3 months)

> ⚠ *These are approximative dates. Please contact the training supervisor to know the precise period.*

- **Deadline to apply :** 1st July 2025 (midnight)

### Contacts

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- **Team Manager :** Herve Rivano / herve.rivano@inria.fr

### More information

- **Inria Team :** AGORA
- **Inria Center :** Centre Inria de Lyon

1997.
[6] FLoRaSat simulator: https://gitlab.inria.fr/jfraire/florasat
[7] T. B. Núñez-González, C. A. Azurdia-Meza, R. Ortigueira, S. Montejo-Sánchez, J. A. Ordenes-Pinto, M. E. Diago-Mosquera, S. Céspedes, Enhancing LEO direct-to-satellite channel modeling with the shadowing effect via K-distribution, ICT Express, 2025.