Master's Thesis Proposal

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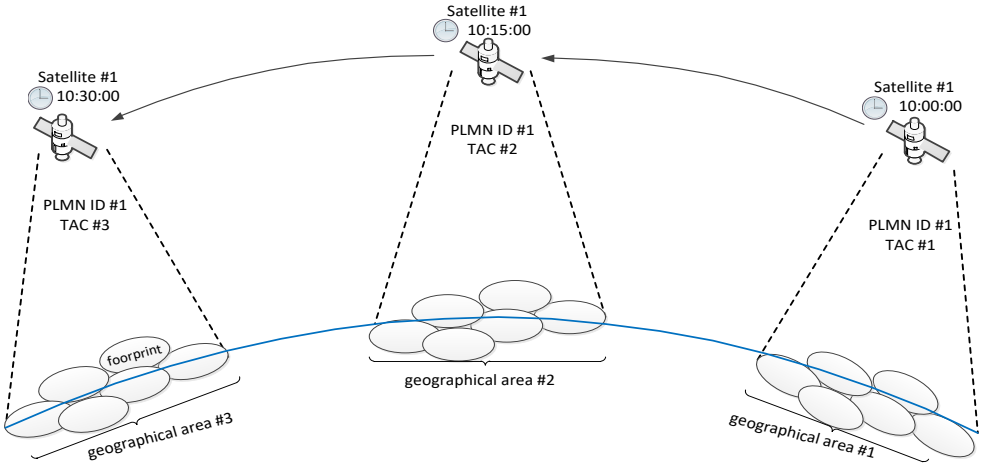
Title

Performance Evaluation of NTN, IoT Satellite Networks Based on LoRa: A Comparative Study of LR-FHSS and Classical LoRa

Problem Statement

Non-Terrestrial Networks (NTN), and particularly Low Earth Orbit (LEO) satellite constellations, are emerging as a key enabler for extending IoT connectivity beyond terrestrial infrastructures. However, the dynamic nature of LEO satellites — which are constantly in motion — introduces variable distances between the devices and the satellite, thereby impacting signal quality and the probability of successful packet transmission.

LoRa technology, and more recently LR-FHSS (Long Range – Frequency Hopping Spread Spectrum), are promising physical layer solutions for long-range, low-power IoT communication over satellite links. While both approaches are suitable for NTN IoT scenarios, there is still limited comparative analysis regarding their performance in realistic satellite conditions.



Fixed Tracking Area for NTN LEO [7]

Objectives

This thesis aims to:

1. Evaluate and compare the performance of **LR-FHSS (with different Data Rates)** and **classical LoRa (with different Spreading Factors)** in an NTN IoT satellite network.
2. Analyze the **packet success probability** as a function of:
    - the **number of IoT devices** transmitting,
    - their **relative positions** with respect to the moving LEO satellite.
3. Investigate how the **mobility of LEO satellites** affects transmission reliability.
4. Assess the benefits and limitations of existing **simulation tools** (such as **LR-FHSS Sim**) and explore the possibility of developing a **custom Python-based simulator** for specific scenarios.

Methodology

The study will be carried out in the following steps:

1. **Literature Review**
    - Study NTN architectures, LoRa modulation principles, and LR-FHSS mechanisms.
    - Review previous performance evaluations of LoRa over satellite channels.
2. **Modeling the Scenario**
    - Define a network model with a LEO satellite and IoT devices distributed over a coverage area.
    - Integrate realistic parameters such as link budget, path loss, and satellite mobility.
3. **Simulation Tools**
    - Use **LR-FHSS Sim** (dedicated simulator) to evaluate LR-FHSS performance.
    - Optionally develop a **Python-based simulator** to validate and extend the results.
    - Compare results with classical LoRa across different SFs and data rates.
4. **Performance Evaluation**

- Measure the **probability of successful packet reception** under different network loads and device-satellite distances.
- Compare LR-FHSS vs. LoRa in terms of robustness, scalability, and fairness.

5. **Analysis and Discussion**
   - Interpret the results with respect to NTN requirements.
   - Highlight trade-offs between **coverage, capacity, and reliability**.

Expected Contributions

- A **quantitative performance comparison** between LR-FHSS and classical LoRa in NTN IoT scenarios.
- Insights into the **impact of satellite mobility** on LoRa-based communications.
- An evaluation of the **usefulness and limitations of current simulation tools** for NTN IoT.
- Potential development of a **custom Python framework** for future NTN IoT performance studies.
- Submission of one or more **scientific publications**:
  - **Conference papers** in reputable venues (e.g., IEEE ICC, IEEE Globecom, IEEE VTC).
  - A **journal article** in an international peer-reviewed journal with a significant Impact Factor (e.g., *IEEE Internet of Things Journal*, *IEEE Access*, *Elsevier Computer Communications*).

Bibliographie

[1] LoRa Alliance — « LoRaWAN® Regional Parameters RP002-1.0.2 », 2020.

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», 2020.

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[6] Improving Uplink Scalability of LoRa-Based Direct-to-Satellite IoT Networks, IEEE INTERNET OF THINGS JOURNAL, VOL. 11, NO. 7, 1 APRIL 2024

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