LABO – LIMOS Axe SIC

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Title of PhD subject
Learning-Based Adaptive Approaches for Improving LoRaWAN Performance in Mobile Environments

Summary :

Low Power Wide Area Networks (LPWANs), and in particular LoRaWAN, have emerged as a key technology for the deployment of the Internet of Things (IoT) due to their extended range, low deployment cost, and energy efficiency. While LoRaWAN performs well in static scenarios, its original design does not account for node mobility, which limits its reliability and efficiency in dynamic environments. Applications such as connected vehicles, drones, and other mobile IoT devices introduce challenges including packet loss, variable link quality, and difficulties in adapting protocol parameters in real time. Addressing these limitations is crucial to ensure continuous, reliable, and energy-efficient communication in mobile IoT networks.

This thesis aims to design, implement, and validate adaptive mechanisms for LoRaWAN based on machine learning techniques, targeting improved reliability and energy efficiency in mobile scenarios. To achieve this, it is necessary to go beyond classical learning approaches and consider paradigms suited for large-scale deployments, such as distributed learning, online learning, and edge computing. These paradigms allow balancing the trade-off between learning effectiveness and computational or communication costs, which is particularly important in LoRa networks with constrained resources and intermittent connectivity.

The proposed contributions of this thesis focus on several key areas:

- Detection and modeling of node mobility: Supervised learning models will be developed to identify mobility patterns based on radio indicators such as RSSI, SNR, and estimated Doppler shifts. Software-defined radios (USRP) will be used to collect raw data and train models capable of accurately distinguishing between different mobility regimes.
- Dynamic adaptation of radio link parameters: The existing Adaptive Data Rate (ADR) mechanism will be enhanced using reinforcement learning techniques to dynamically adjust communication parameters such as spreading factor, transmission power, and channel selection. This adaptation aims to maintain link reliability and optimize energy consumption in the presence of mobility.
- Predictive handover between gateways: Sequential learning models will be employed to anticipate coverage changes and manage gateway handovers proactively. This predictive approach is intended to minimize packet loss, reduce latency, and ensure continuity of service for mobile nodes.
- Learning architectures for mobile LoRaWAN: Scalable and efficient learning architectures will be designed to support large-scale deployments of mobile LoRa nodes. This involves optimizing model distribution and computation to reduce overhead while maintaining high learning performance.
- Experimental validation: A testbed using software-defined radios (USRP) will be implemented to evaluate both the standard LoRaWAN performance and the proposed adaptive mechanisms. Real mobility scenarios will be reproduced to validate the effectiveness of the models and algorithms in practical conditions.

Expected outcomes of this thesis include precise models for mobility detection and radio parameter adaptation, experimentally validated intelligent ADR and handover mechanisms, efficient learning architectures for large-scale mobile LoRaWAN networks, and demonstrable improvements in packet delivery rate and energy efficiency. The results of this research are expected to contribute to the deployment of more robust, adaptive, and energy-efficient LoRaWAN-based IoT systems in dynamic environments, bridging the gap between theoretical machine learning approaches and practical IoT network requirements.

References

[1] Gewu Bu, Nancy El Rachkidy, Gateway-Side Distributed Frame Deduplication for LoRaWAN, MobiWAC, in Proceedings MSWiM 2025.

[2] Anaïs Durand, Nancy El Rachkidy, Alexandre Guitton, MADERE: Mobile Adaptive Datarate for LoRaWAN, in Procedings IEEE WCNC 2023.
[3] Fall, Ndeye Penda and Marot, Michel and Diallo, Cherif and Bernard, Antoine and Roujanski, Gatien, Optimizing mobility in LoRaWan: a resource reservation approach, in Proceedings IEEE GLOBECOM 2023

Desired Profile:

- Solid programming skills in C, C++, and Python
- Strong background in networking and machine learning
- Proficient in English, both written and spoke