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Title of PhD subject: Improvement of the LoRaWAN throughput based on physical characteristics of LoRa frames

Short summary:
LoRa is a low-power wide area network wireless technology, which enables battery-powered devices to communicate over very long distances (typically, up to about ten kilometers outdoor). LoRaWAN networks, that are based on the LoRa technology, have numerous applications for environmental monitoring or smart cities.

However, the main drawback of LoRaWAN is its very limited throughput.

In this thesis, our objective is to **improve LoRaWAN throughput** by leveraging physical characteristics of frames. Several approaches are considered, including the **suppression of the source node address** from the frames (which also improves the privacy of the transmitted data, as an attacker is not able to directly obtain the address of the transmitter), the use of (imperfect) **orthogonal properties** of the transmissions, as well as the **recovering of colliding frames**.

Long summary:

Context:
Low-power wide area networks (LPWAN) enable battery-powered devices to communicate over long distances, typically up to about ten kilometers outdoor. These networks have numerous applications, including environmental monitoring (monitoring of forests, rivers, mountain fauna, etc.) [1].

LoRa is a physical layer developed by the Semtech company, and based on a very efficient modulation called CSS. This modulation has a high robustness, which enables it to correctly decode signals, even when they are received below the noise level. The LoRaWAN open standard [2] is built upon the LoRa physical layer and defines a network architecture and a MAC layer protocol. The combination of LoRa and LoRaWAN is the most common protocol combination in LPWAN.

Main research issue:
However, LoRaWAN has a very small throughput of a few bits per second in practice. It is thus critical to develop techniques that enable to improve LoRaWAN throughput.

Objectives of the PhD:
The objective of this PhD is to leverage the physical characteristics of LoRa frames in order to improve the LoRaWAN throughput. This is especially challenging: indeed, LoRa is enable to decode frames even when the reception power is about 100 times lower than the noise level. With such very weak signals, the physical characteristics of the frames are very hard to obtain accurately. The questions we are addressing are thus: Can we identify the transmitter of a frame without using the address integrated in the frame header? Can we determine if two frames detected by two gateways correspond to the same transmission? Can we leverage orthogonal properties of LoRa in order to transmit several frames in collision, without impacting the decoding capabilities at the gateways? By answering to these questions, it becomes possible to identify LoRa nodes based on the physical characteristics of the transmitters, which enables to remove the source address from the header of the frames, thus saving a few precious bytes. This also improves the privacy of the communications, as it becomes more challenging for an attacker to determine the actual transmitter of an unsourced frame. A first proof of concept has already been achieved [3], but it is necessary to extend this preliminary work. Other research directions are also envisioned, including the decoding of colliding LoRa frames [4] by using multi-gateway or spreading-factor-based information. All the concepts proposed in this

PhD will be validated by real hardware implementation, by using both commercial LoRa end-devices as well as highly configurable software defined radios.

Novelty of the approach compared to the literature:
The part on recovering colliding frames is the extension of a PhD which was defended in Clermont-Ferrand in June 2023 [5]. This work lead to several high-level publications (including [4]). The other parts of this work are novel: to the best of our knowledge, no research paper deals with these ideas.

References:
[1] M.S. Hidayat, A.P. Nugroho, L. Sutiarso, T. Okayasu. « Development of environmental monitoring systems based on LoRa with cloud integration for rural area », IOP Conference Series : Earth and Environmental Science, volume 355, the 3rd International Symposium on Agricultural and Biosystem Engineering, 2019.
[2] LoRa Alliance. « LoRaWAN L2 1.0.4 Specification », Technical standard, TS001-1.0.4, 2020.
[3] Weixuan Xiao, **Alexandre Guitton**, **Megumi Kaneko**, **Nancy El Rachkidy**. « Local Identification of Devices from LoRa Preambles: a Preliminary Feasibility Study », work in progress, 2023.
[4] Weixuan Xiao, **Megumi Kaneko**, **Nancy El Rachkidy**, **Alexandre Guitton**. « Integrating LoRa Collision Decoding and MAC Protocols for Enabling IoT Massive Connectivity », IEEE Internet of Things Magazine, 2022.
[5] Weixuan Xiao. « Techniques de décodage pour annuler les collisions dans LoRaWAN ». PhD thesis of Université Clermont Auvergne, 2023. Supervision: **Alexandre Guitton** (main supervisor) and **Nancy El Rachkidy** (co-supervisor). In French.