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Laboratoire d'accueil : LEAT

Description du sujet :
Advisors : Alain Pegatoquet, Fabien Ferrero and Benoit Miramond

Motivation
The number of physical objects connected to the internet is constantly increasing. According to some expectations, this number will reach the 50 billions by 2020 [EVA11].
The result is the diffusion of an Internet-of-Things (IoT) that completely changes the way people interact with their environment. The huge amount and variety of data generated by these objects allows the development of new applications and services in many different domains such as smart homes, transportation systems, healthcare, agriculture, etc...
The amount of information that must be transmitted is usually very limited, typically the physical parameters collected by a sensor (temperature, pressure, etc.) or the geolocation data. This allows a strong reduction of the bandwidth requirements and leads to the
development of ultra-sensitive modulation schemes. Moreover, new protocols capable of dealing with the tremendous number of connected objects and enabling compatibility between heterogeneous devices are needed. However, most of IoT standards (LoRa, Sigfox, NB-IoT) are now using the narrow ISM band around 900MHz, leading to a high risk of packet collisions as well as network saturation. The medium access is usually based on a random use of the available channels and periodic communications, resulting in a non-optimal use of the spectrum. The massive number of active devices will also generate a large amount of interferences, which results in data packet losses, causing latencies and high energy consumption in the entire network. Spatial filtering could be used to mitigate this issue. As an example, a study on the use of reconfigurable antennas @2.4GHz for a M2M network has shown that spatial filtering can reduce the overall network energy consumption by a factor of 3 [LE16].

Objectives
Cognitive radio carries bright prospects for a more efficient use of the spectrum. The underlay paradigm encompasses techniques that allow communication by the cognitive radio assuming it has knowledge of the interference caused by its transmitter to the receivers of all non-cognitive users. The decision making is mainly based on the continuous sensing of the spectrum and will also depend on different parameters such as the urgency of the information to be sent, the available energy and the localization of the transmitter and receiver. The continuous sensing of the spectrum, done by the gateways (GW), leads to a huge amount of data hard to analyze. The different gateways (GW) can indeed gather over the cloud the spectrum sensing information. In that context, machine learning techniques could be used to extract relevant decisions to improve the spectrum efficiency (i.e. medium access). The objective is then to propose new MAC protocols that could be shared efficiently with all the network nodes. At the node level, machine learning algorithms with lower complexity could be used to combine information from the GW with local RF sensing, and taking into account available energy as well (i.e. the state of charge of the battery). Nodes could also integrate reconfigurable antenna capabilities on directivity and/or polarization. This adaptability will enable a more efficient use of the channel parameters.

The PhD will focus on the development of advanced MAC layer to optimize the spectrum usage for use cases in the ISM band. The PhD student is expected to investigate and develop this concept both theoretically and experimentally.

Work description
The study will be applied to LP-WAN network and some experiments will be realized to assess the performance. LoRa communication standard could be used as a first use case for several reasons:
The SX1301 chip used by LoRa gateway can simultaneously sense 8 different channels, and some gateways can integrate several SX1301 chips to further increase the number of channels or to sense different polarization.
LoRa technology can provide localization information based on OTDOA technique. LoRa nodes based on SX1276 are energy efficient and can be thus powered using energy harvesting. LoRa can perform both up-link and down-link communications. This bidirectional capability could be used to update nodes MAC strategy. LoRa technologies enable tuning several independent RF parameters such as the spreading factor, the channel frequency, the bandwidth or the transmit power, thus offering a lot of degrees of freedom for optimization. A node can integrate reconfigurable antenna with directional and/or polarization tunability.

The proposed MAC solution will be directly compared with the LoRaWAN standard used in LP-WAN communication. Criteria such as packet error, latency, collisions or spectral efficiency will be used for comparison. In order to outperform current MAC standard, the PhD will have to classify and/or predict the spectral usage in the ISM band from the gateway. Different machine learning algorithms will be investigated to perform classification and/or prediction at the gateway level. In a second phase, the PhD student will try to improve the access to the ISM spectrum at the node level. To do so, the nodes will have to combine in an efficient way the information available from the gateway and at the node level.

Requirements

The successful PhD candidate is expected to hold or be about to receive a MSc degree in Telecommunication or Electronic Engineering, embedded software or an equivalent degree with a strong mathematical background. Some knowledge in electromagnetics and/or antennas is an asset. Good command of English orally and in writing is required to publish and present results in international conferences and journals.

References


English version:

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References


