Genetic Algorithm For LoRa Transmission Parameter Selection

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Abstract—The exponential growth of Internet of things (IoT) applications in both industry and academic research raises many questions in wireless sensor networks. Heterogeneous networks of IoT devices strongly depend on the ability of IoT devices to adapt their data transmission parameters to each application requirement. One of the most important problem of the emerging IoT networks is the limitation in terms of energy consumption and computation capability. These limitations could be addressed by using the edge computing to unload IoT devices from additional computation tasks. Our work is motivated by the idea of matching each transmission configuration with a reward and cost values to satisfy applications constraints. Our goal is to make IoT devices able to select the optimal configuration and send their data to the gateway with the QoS required by IoT applications. In this work, we use LoRa network to evaluate the efficiency of our algorithm. Determining the best configuration among 6720 LaRa transmission settings is challenging. The difficulty is mainly due to the lack of tools that could take all applications requirements into account to select the best settings. To address this problem, we use a genetic algorithm in an edge computing to select the transmission parameters needed by the application. Each LoRa configuration represents a feature that needs to be selected to match better the QoS criteria. Particularly, we analyze the impact of selecting one configuration in 3 kinds of applications: text, voice and image transmission by modeling a new adaptive data rate selection process.

Keywords—Genetic algorithm; Fuzzy logic; LoRaWAN; Adaptive Data Rate (ADR).

I. INTRODUCTION

The need of Low Power Wide Area Networks ($LPWAN$) increased significantly these five last years. The main factor is that IoT devices require low power consumption to transmit data in a wide area. LoRa, Sigfox and Narrowband IoT ($NB - IoT$) are the most known technologies that satisfy these requirements. Applications like smart building and smart environment are one of hundreds use cases that need to be deployed with such technologies. Unlike Sigfox and NB-IoT, LoRa is more open for academic research because the specification that governs it is relatively open. The transmission could be configured with 4 parameters: Spreading Factor (SF), Transmission Power (Tx), Coding Rate (CR) and Bandwidth (BW), to achieve better performance.

The main LPWAN research directions are about link optimization, adaptability and large scale networks to support massive number of devices. The selection of an appropriate transmission parameter for IoT networks typically depends on the nature of the application. In this paper, we investigate the performance of heterogeneous networks (i.e., when each IoT device selects its LoRa transmission parameters according to its link budget and the application requirements). For that purpose, we have developed a LoRa transmission adaptation mechanism. Both ns-3 simulator and the Low cost LoRa Gateway [1] are used to validate our approach. The computation tasks of the selection process will run on the Gateway device (Raspberry-pi) and the required settings will be sent to nodes for the next transmission.

This paper is organized as follows. Section II elucidates summary of related works. In Section III, we propose our approach to solve LoRa parameter selection problem. Our experiments is presented in Section IV. Section V concludes this paper.

II. RELATED WORK

Transmission parameter configuration mechanisms, such as Adaptive Data Rate (ADR) scheme [2] need to be developed to fit each application requirement in terms of power consumption, delay and packet delivery ratio. Solutions running on LoRa node should be less complex to match computation limitation of IoT devices as required in LoRaWAN specification. However, LoRa network server could run complex management mechanism, which can be developed to improve network performance. In this paper, we focus on the server-side mechanisms.

The basic ADR scheme [2] provided by LoRaWAN predicts channel conditions using the maximum received Signal Noise Rate (SNR) in the last 20 packets. The basic ADR scheme is sufficient when the variance of the channel is low, it reduces the interference compared with the static data rate [3][4]. However, their simplicity causes many potential drawbacks. First, the diversity of LoRa Gateway models that measures SNR make the measurement inaccurate as a result of hardware calibration and interfering transmissions. Second, selecting the maximum SNR each 20 packets received could be a very long period in many IoT applications that require less uplink transmission. Third, transmission parameters adjustment considers only the link of a single node. If many LoRa nodes are connected to the near gateway, all nodes connected to this one will use the fastest data rate. In this case, the number of

LoRa nodes using the same data rate will increase and the probability of collisions also increases dramatically.

For example, the authors in [4] slightly modify the basic ADR scheme by replacing the maximum SNR with the average function. In this paper, we focus on building a framework that help IoT devices to adapt their transmission parameters to the application requirements in a server side.

III. PROPOSED FRAMEWORK

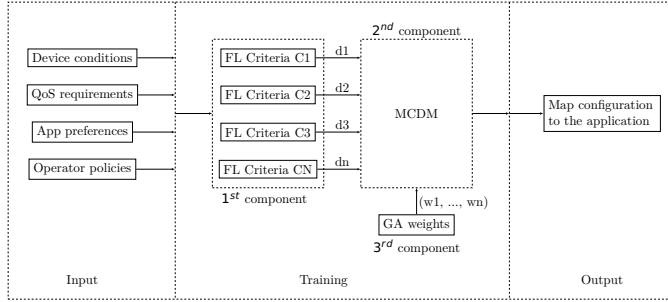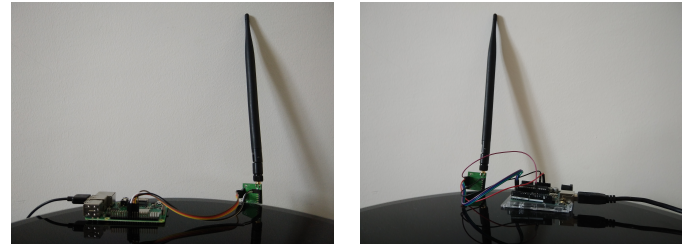The selection process scheme illustrated in Figure 1 can be described following these five steps:

Figure 1. The proposed scheme for LoRa transmission parameters selection based on GA, FL and Multi-Criteria Decision Making $MCDM$.

1) According to the Semtech SX1276 LoRa transceiver [5], there are 6720 possible settings (s_1, ... , s_{6720}) and the framework has to select the most optimal one or to rank them according to their relevance.
2) The first step of the selection process depends on multiple criteria up to i (c_1, ... , c_i). Different type of criteria can be measured from different sources to cover the maximum point of views, as an example, the network server requirements, the applications requirements and the devices conditions.
3) The Fuzzy Logic (FL) based subsystem gives an initial score for each configuration that reflects its relevance. The different sets of scores (d_1, ... , d_i) are sent to the $MCDM$ in the 5th step.
4) At the same time, the GA [6] assigns a suitable weight (w_1, ..., w_i) for each initial selection decision, this selection is made according to the objective function that is required by the application.
5) Using the initial scores coming from the 3rd step and the weights using the 4th step, the multi criteria decision making $MCDM$ will select the most relevant settings and rank them according to their reward.

IV. EXPERIMENTS

For our experiments we use both real environment (Figure 2) and ns-3 simulator with SX1276 LoRa module. However, to test the scalability of genetic algorithm with numerous IoT devices in a real environment, we use FIT IoT-LAB platform among other platforms presented in [7]. This choice is motivated by the number of devices supported by this platform (up to 2000 nodes).

(a) Gateway (Raspberry-pi). (b) Sensor node (Arduino).

Figure 2. Gateway & Sensor node.

Figure 2a presents the LoRa gateway that we build using a low cost LoRa gateway [1] on a Raspberry-pi. Figure 2b presents one of the two Arduino boards equipped with an antenna that cover both 868 and 433 MHz band with a SX1276 LoRa Transceiver.

Due to the energy constraints of LoRa nodes of class A that we use, our framework will send commands through the FCtrl fields to ask nodes to adapt their transmission behavior to the new application or the new environment conditions.

V. DISCUSSION

Our main contribution was to build 3 applications that requires 3 different levels of QoS, such as text, sound and image transmission. We used a low cost LoRa gateway on a Raspberry-pi with 2 Arduino boards equipped with 2 LoRa Transceivers based on the Semtech SX1276 specification. The main challenge addressed in this work was to explore the application of genetic algorithm in LoRa transmission parameter selection. To measure the accuracy of applying genetic algorithm in an edge computing we expect to compare our approach with other adaptive data rate solutions.

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