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LoRaWAN Communication Protocol: The New Era of IoT

[1]Alexandru Lavric, [1,2]Adrian loan Petrariu

[1]Computers, Electronics and Automation Department, Stefan cel Mare University of Suceava, Romania
[2]Integrated Center for Research, Development and Innovation in Advanced Materials, Nanotechnologies, and Distributed Systems for Fabrication and Control (MANSiD), Stefan cel Mare University, Suceava, Romania
lavric@eed.usv.ro

Abstract— **The LoRaWAN communication protocol is more and more used in the Internet of Things (IoT) concept. Many research centers have addressed the problem of wireless sensor networks, thus making a sustained effort in increasing the performance of WSN networks. The IoT concept promises to revolutionize and change the way we do our daily business and allow us to overcome current challenges such as the energy crisis, resource depletion and environmental pollution. The potential of the IoT concept is immense and comes to solve the major challenges of the M2M (Machine-to-Machine) industry. LPWA (Low-Power Wide-Area) wireless networks come to complete the traditional wireless and short-range wireless communications technologies in order to fulfill the various requirements of IoT applications. LoRa modulation is using a chirp (Compressed High Intensity Radar Pulse) spread spectrum (CSS) technique which offer resilience to interference, great communication link budget, performance at low power while being resistant to multi-path propagation fading and Doppler effect. The main contribution of this paper is the performance evaluation and sustainability analysis of LoRa technology.**

Keywords— LoRaWAN; LPWAN; LoRa (Long Range) modulation; WSN; Internet of Things

I. Introduction

In recent years, emphasis has been put on the Low Power Wide Area (LPWA) technology, which gains ground in the implementation of the Internet of Things (IoT) concept. Many research centers have addressed the problem of sensor networks, thus making a sustained effort in increasing the performance of WSN networks [1]. The IoT concept promises to revolutionize and change the way we do daily business and allow us to overcome current challenges such as the energy crisis, resource depletion, globalization effects and environmental pollution. The potential of the concept is immense and comes to tackle the major challenges of the M2M (Machine-to-Machine) industry.

LPWA networks come fill in the gap of traditional wireless short-range communication technologies and to meet the different requirements of IoT applications [2]. These technologies have many advantages ensuring a long-distance communication of one volume of reduced data. LPWA networks have a number of particularities compared to other short-range wireless technologies suitable for the IoT concept. For example, an alternative could be represented by short-range WSN network technologies such as ZigBee (IEEE 802.15.4), Bluetooth, Z-Wave or cellular GSM networks.

LPWA networks aim is to provide long-range communications, connecting devices distributed over a large geographic area. LPWA networks practically represent an alternative to M2M (Machine-to-Machine) communications using 2G/3G/4G technologies. Support for 2G technologies is announced to be stopped in the near future, this will cause a distress in ensuring connectivity to low-power sensors and modules [3].

The main advantages are ensuring a communication distance in the order of tens of kilometers [4] and a ten-year battery life, LPWA technologies are perfect for achieving low maintenance costs. The large radius of communication is obtained at the expense of the transfer rate (which typically in the order of tens of kilobytes per second). Also, the latency is usually high in the order of seconds or even minutes. Thus, IoT applications in which delays are not tolerated or a high rate of data transfer is required are not suitable for LPWA technologies.

Most LPWAN (Low-Power Wireless Area Networks) operate in the ISM (Industrial, Scientific and Medical) unlicensed frequency band at 169 MHz, 433 MHz, 868/915 MHz and 2.4 GHz, depending on the operating region. Some examples in this regard are communication protocols like: SigFox, LoRa, Weightless and Ingenu.

The main contribution of this work is the performance evaluation and sustainability analysis of the LoRa technology. The paper is structured as follows: after a brief introduction, in Section II, some general considerations regarding LoRa modulation and LoRaWAN communication protocol. The obtained measurement, followed by a presentation of the CupCarbon simulator and simulation results are discussed in Section III; conclusions conclude the work.

II. LoRaWan Technology

The physical layer of LoRaWAN communication protocol uses LoRa modulation [5], that is patented by Semtech [6]. In Fig. 1 is presented the LoRaWAN communication protocol stack. It can be observed that the LoRaWAN specifications defined by LoRa Alliance are defined on top of the LoRa modulation and LoRa MAC (Medium Access Control) layer.

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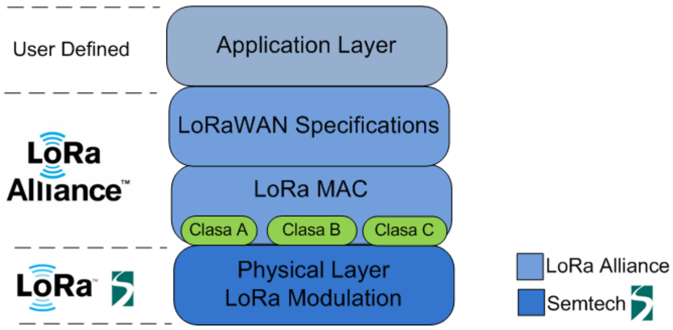

Fig. 1. LoRaWAN communication protocol.

LoRaWAN defines the MAC communication protocol and the system architecture for the WSN network that is being standardized by the LoRa Alliance [7]. LoRaWAN communication represents a solution for the IoT concept. The protocol uses a star-of stars type network topology, in which every Lora node can communicate directly with the Gateway module (the sink node).

One of the main advantages of LoRaWAN is that it uses the unlicensed ISM (Industrial, Scientific and Medical) frequency so no license is needed. The only limitation is enforced by the duty cycle parameter that is regulated depending on the different geographical area. Lora devices are battery powered.

LoRa Alliance defines three classes of devices: class A, class B and class C. In order to achieve power efficiency a LoRa node besides the duty cycle regulation has the ability to receive a packet from the Gateway module only in restricted time slot.

Fig 2. presents the LoRaWAN architecture that includes: the Lora Gateways, the Lora end modules, the Lora Server and the Application Server. The LoRa Gateway can receive messages from thousands of LoRa End Nodes, so it can serve a large geographical area. The packets are sent at different data rates using the specific of the spreading factor technique. The separation of the physical channels using the spreading factor mechanism is very efficient. Thus, two packets sent at the same time on the same channel using different spreading factors will not interfere with each other and will be received correctly [8].

When a packet is sent from the End LoRa node is received by the Gateway module which retransmits it to the Network Server. The user accesses the information from this data service aggregator.

Table I shows the sensitivity of the Gateway module for different SFs used. As can be observed the sensitivity is improved if the Spreading Factor (SF) is increased, this aspect determines a longer communication range.

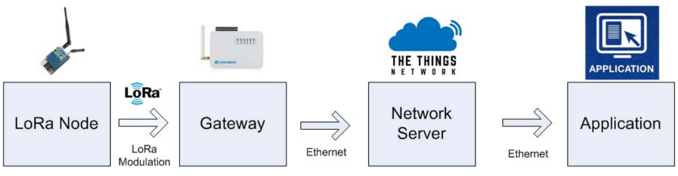

Fig. 2. LoRaWAN arhitecture.

LoRa modulation proposes a compromise between the communication distance and the data rate by modifying the SF parameter.

In the [9] - [18], various aspects regarding the performance level of LoRa communication are presented and analyzed. Previous recent works published by the authors [10], [11] address different aspects of the LoRaWAN technology ranging from challenges to different performance evaluations and simulations.

TABLE I. RECEIVER SENSITIVITY

Spreading Factor	Sensitivity [dBm]
7	-130,0
8	-132,5
9	-135,0
10	-137,5
11	-140,0
12	-142,5

In [10] is presented a LoRaWAN communication model implemented in Pothosware. From the obtained results even if the noise level is increased the received signal is successfully decoded. The main obstacles addressed are: connectivity, efficient energy management, security and the complexity of the IoT concept. In [11] the influence of the SF parameter on the time spent in the air by the LoRaWAN packet is discussed. From the obtained results if the SF is increased the data rate drops. Also, the influence of the channel bandwidth is analyzed.

III. RESULTS AND DISCUSSIONS

CupCarbon is a WSN network simulator. The framework offers the possibility of developing, implementing and testing WSN algorithms, allowing data collection from the environment. The utility can be used in the development and testing of communications protocols by integrating different network topologies [19].

CupCarbon allows simulation of WSN mobility scenarios. The utility allows the simulation of discrete events within the sensor network, the user can model the behavior of the WSN nodes [17]. The programming language used at the node level in CupCarbon is called SenScript. This allows the user to implement, develop and test new communication protocols and mechanisms. In the simulation scenario, a number of 500 LoRa nodes connected to a Gateway module were integrated. The CupCarbon utility can be used for the first phase of the initial deployment operation. CupCarbon has integrated a wave propagation model which, along with the integrated building recognition module (used in parallel with the geographical map) provides the ability to simulate the network performance level.

Fig. 3 one shows a section of the simulated network where the coverage map of the LoRa network can be seen. Using propagation module offers the advantage of configuring and simulating the LoRa network before the initial implementation of the network. The planning possibility reduces the initial deployment costs and installation time.

Fig. 3. CupCarbon propagation model for the simulated scenario.

In Table II is presented the node script implemented in the CupCarbon simulator. LoRa nodes sent random packets to the Gateway module that monitors and records the packets.

TABLE II. SENSCRIPT OF THE NODES

//Receiver	//Transmitter
loop	loop
radio radio2	send A 0 12
wait	randb x 10 1000
read v	print $x
mark $v	delay $x
delay 500	send B 0 12
	delay 1000

Thus, the initial implementation costs can be significantly reduced, and the time associated with the implementation phase significantly minimized. The final physical location of the nodes can be determined by assessing the network load level, also taking into account the surrounding urban environment (e.g. buildings, obstacles).

Fig. 4 shows the LoRa device used, which include the microcontroller and the wireless module. In the developed tests the LoRa Semtech SX 1276 [20] transceiver was used. The nodes transmit packets with a payload of 5 bytes in the test scenario.

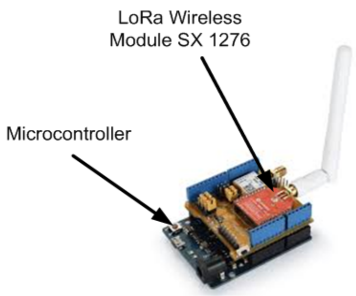

Fig. 4. The LoRa transceiver.

Fig. 5 presents the signal spectrum of a LoRa transceiver operating in the 868 MHz ISM frequency band. The communication mechanism ensures a high resistance to noise and interferences, allowing to obtain a long communication range. Also, because of the reduced complexity of the transceivers the implementation costs are low.

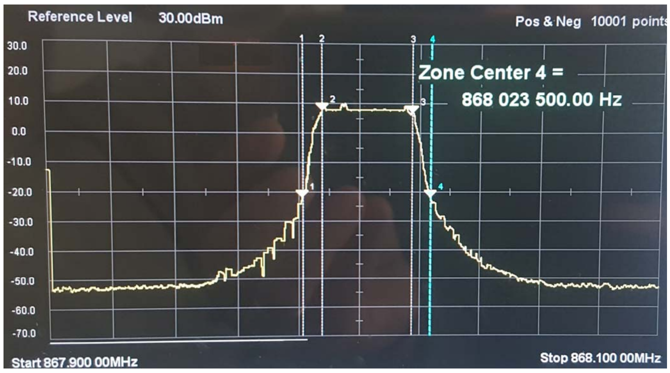

Fig. 5. The spectrum of the LoRa transceiver.

Table III shows the obtained results. The Gateway station is installed on the ground floor. Three LoRa End Sensor are placed on each floor. The recorded RSSI values are presented in the table below. The used spreading factor is 12, the channel bandwidth is 125kHz and the coding rate is 4/8.

TABLE III. RSSI VALUES

Location	RSSI Values
Ground Floor	-40
First Floor	-45
Second Floor	-48
Third Floor	-57

Fig. 6 shows the spectrogram of the captured LoRa signal using an RTL-SDR SDR (Software Defined Radio) module [21]. We can observe the signal frequency distribution over time, this characteristic is specific to LoRa modulation.

Frequency variation over time of a sample signal emitted by LoRa can be observed. The figure shows the LoRa signal after the chirp (Compressed High Intensity Radar Pulse) sequence is applied to the modulated signal.

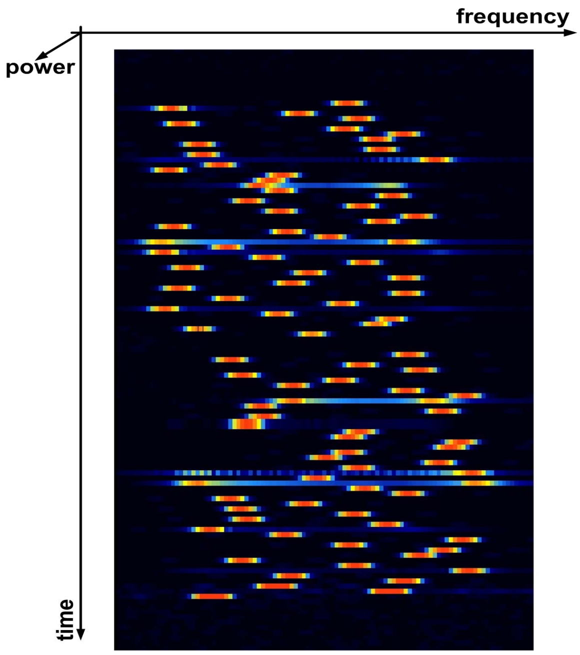

Fig. 6. LoRa signal frequency vs. Time.

Fig. 7, presents the LoRa modulation signal for a packet with a 5 bytes payload.

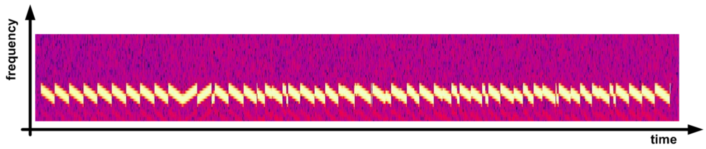

Fig. 7. LoRa signal frequency shifting.

From the obtained results we can see that the frequency is continually increased and decreased. We can observe the upchirp that states an increase of the frequency and the downchirp which suggests a decrease in frequency. The LoRa modulation uses a spread spectrum technique, so more energy is put on a wider frequency band. The modulated signal is injected in the noise floor.

IV. Conclusions

LoRa technology is a candidate for the implementation of the IoT concept. From the obtained results LoRaWAN communication protocol provides a high level of performance. The CupCarbon simulator offers the opportunity to model the LoRa network by reducing the implementation costs and evaluate any problems that may arise relating to the way of transmitting packages that comply with an ALOHA mechanism. LoRa modulation is using a chirp spread spectrum (CSS) technique which offer resilience to interference, great communication link budget, performance at low power while being resistant to multi-path propagation fading and Doppler effect. Also, the LoRa technology offers support for localization techniques.

The paper was organized in two directions as the main stated contributions. The first one addressed the scalability problem of the LoRa emphasizing the initial LoRa network deployment. The proposed solution is the use of the CupCarbon simulator environment. The second part of the paper presents the experimental measurement results. From the obtained results we can observe the frequency variation of the LoRa modulated signal by using a SDR module.

Thus, in the case of a large-scale distributed network over a large geographic area with thousands of nodes, the number of collisions can be elevated, thus negatively affecting the capacity of the communication channel. This aspect will be analyzed in a future work.

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