LoRaWAN Gateway: Design, Implementation and Testing in Real Environment

Adrian I. Petrariu[1,2], Alexandru Lavric[1], Eugen Coca[1]
[1]Department of Computers, Electronics and Automatics
[2]MANSiD research center
Stefan cel Mare University of Suceava
apetrariu@eed.usv.ro

***Abstract*— The interest in developing systems working with IoT platforms is increasing nowadays. Thus, many smart sensors can communicate over the Internet without human mediation using LPWAN networks. This paper presents a low-cost high-performance multi-channel Gateway for LoRaWAN technology. In order to validate the Gateway performances, the TTN cloud data network it's used. The configuration of the Gateway consists of a Raspberry Pi 3B+ and an iC880A concentrator LoRa Gateway board. The Gateway is certified by LoRaWAN Alliance and supports multichannel communication. Also, the system integrates a 2.2 dBi Omnidirectional antenna. From the performed measurements, the Gateway ensures a high level of performance and a maximum communication distance of 2.5 km in rural areas, and 1.3 km in urban areas with a PER of less than 20%.**

Keywords*— *IoT, LPWAN, Gateway, LoRaWAN

I. Introduction

Nowadays, the need for long range communications with small power consumption is possible by using LPWAN (Low Power Wide Area Network) technologies [1]. These kinds of technologies are essential for IoT (Internet of Things) cloud platforms that collect data from sensors which are typically battery powered (can operate for years without maintenance) [2]. Moreover, when we need to consider the development of smart cities [3]-[4], smart parking lots [5] or smart agriculture [6]-[7] for example, the need of transmitting low data rate at high distances with low power consumption is crucial. These types of requirements are hard to fulfill using traditional machine-to-machine (M2M) technologies such as 2G/GSM/GPRS or WPANs (Wireless Personal Area Networks) [8].

LPWAN systems use end-devices that are connected directly to one (or more) Gateway(s), in a very similar way as a classic cellular network topology. Also, they use unlicensed spectrum to transmit data and most of them are open source [9]. Another important aspect is that they are designed to fill the traditional technology gap by reducing power consumption at long communication distances for the end-devices in the network.

Some of the LPWAN technologies such as NB-IoT (NarrowBand-IoT), uses the existing cellular infrastructure, combining low energy usage with long range communication for the development of large-scale connectivity devices for the IoT network [10]. The bandwidth is only 180 kHz for both, uplink and downlink, and can cover up to 18 km in the cities and 25 km in the rural areas. Some other important aspects of this technology are the low manufacturing costs (keeping in mind the existing infrastructure of the cellular networks) and the long service life of the Nodes.

SigFox is another technology proposed for the IoT market since 2009. The coverage range for the rural areas can reach up to 50 km, while in the cities can go up to 10 km. Also, the number of connected devices per Gateway can go to millions, being the most efficient technology from this point-of-view. One disadvantage of this technology is the low data rate, being the smallest one, only 100 bps for EU region and 600 bps for US region [11].

Another technology, like LoRaWAN uses specialized Gateways and a standardized LoRa modulation scheme, developed by Semtech, in order to connect devices in the IoT network with LPWAN facilities. This is the most advanced technology from LPWANs and it's used in many applications due to the simplicity and low cost of the entire system.

Also, this technology opens an active and an interesting research domain. Thus, many issues are related to the scalability of large-scale configuration in real environments for Nodes and Gateways [12] and to the imperfect orthogonality [13]-[16].

In this paper a LoRaWAN Gateway is analyzed by mean of the design and the implementation, being tested in real environment with different configuration scenarios. Thus, a DIY model using a well-known development board is brought into spotlight.

The paper is organized as follows: Section I presents a short introduction of the most important LPWANs technologies. In Section II the LoRaWAN Gateway is brought into discussion, being analyzed as the hardware and the software components. Section III presents the tests and measurements of the Gateway in real operating conditions, using different scenarios. Section IV is reserved for conclusion part.

II. LoRaWAN Gateway

A. General description

The Gateways are essential in the LoRa technology, forming a bridge between the end-devices (named Nodes) and the user application, where the messages are delivered and displayed. These bridges will forward the data packets, after adding some information regarding the quality of the reception, to the IoT platform like TheThingsNetwork, ThingSpeak, AdafruitIO, Ubidots, etc., from where the user can obtain the requested data from the field, where the Node is placed. The Gateways uses high bandwidth networks like Wi-Fi, Ethernet or Cellular to connect to the IoT platform due to the large traffic that can be collected from the connected Nodes. A basic LoRaWAN architecture is related in Figure 1.

A Gateway can communicate with hundreds or thousands of Nodes. If more Gateways are in the Node coverage area, all the Gateways will receive the messages and forward them to the IoT platform. Thus, using a specialized algorithm, the IoT platform will filter the duplicated or unwanted messages and will select the best Gateway to forward any messages queued for downlink (for example choosing best radio connectivity with the Node).

B. Hardware and software design

In this paper, the LoRaWAN Gateway uses a certified LoRaWAN Alliance concentrator board (iC880A) [17], having two transceivers (SX1257) [18] and one baseband processor (SX1301) [19]. All the components are Semtech manufactured, one of the few licensed LoRa chip manufacturers. Some of the important characteristics of the LoRa chips are listed below:

SX1257

- RF front-end to digital I and Q modulator/demodulator Multi-PHY mode transceiver
- Maximum signal bandwidth of 500 kHz
- Working frequency range between 862 MHz to 960 MHz
- Supports modulation schemes as LoRa, MR-FSK, MR-OFDM, MR-O-QPSK
- Maximum RF input power of +6 dBm

SX1301

- Multi-channel high performance TX/RX
- Can emulate 49x LoRa demodulators and 1x (G)FSK demodulator
- Supports dynamic data-rate adaption (ADR)
- Up to -142 dBm sensitivity

The concentrator can receive up to 8 LoRa packets simultaneously having different spreading factors and different receiving channels, supporting thousands of Nodes per Gateway.

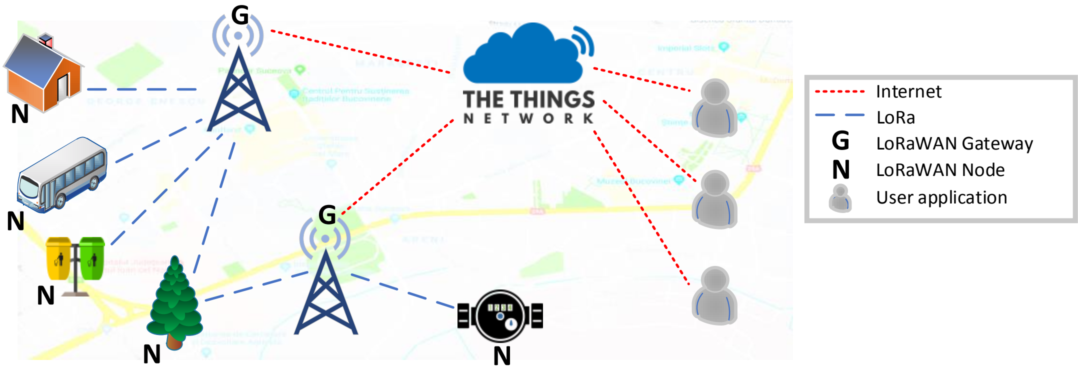

Fig. 1. The LoRaWAN basic architecture

Spreading factor 7 (SF7) means a physical bit rate of 5.4 kbps, while spreading factor 12 (SF12) means a physical bit rate of only 250 bps, in the configuration where 125 kHz bandwidth is used. The spreading factor can be adjusted according to the distance between the Gateway and the Node, to ensure a small PER (Packet Error Rate). Also, can be obtained different data rates due to the combination between the signal bandwidth and the spreading factor. In this case, the Nodes with high distances from the Gateway must use higher spreading factor and therefore have a lower data rate. In the same way, the Nodes placed closer to the Gateway will increase the data rate and will lower the spreading factor.

These types of LoRaWAN multi-channel Gateway can provide better coverage for the entire IoT services worldwide, improving indoor building applications or asset tracking solutions.

In Figure 2 is presented the hardware setup of the Gateway. In order to connect the iC880A concentrator board to the Raspberry PI 3B+ development board, an adapter board is made in the University laboratory. The antenna for the system is a standard one, having a gain of 2.2 dBi with omnidirectional radiation pattern.

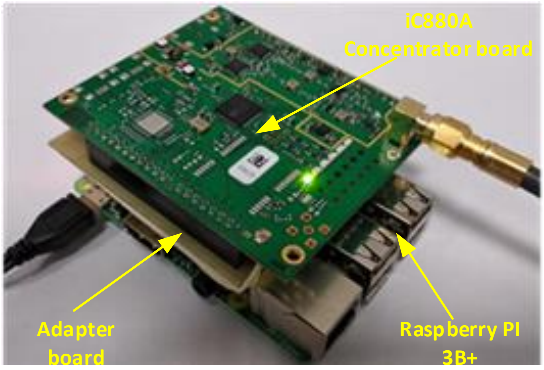

Fig. 2. The LoRaWAN Gateway – hardware

The LoRaWAN Gateway is configured using the open source files from [20]. The system files must be modified according with the TTN (TheThingsNetwork) IoT platform. Thus, the DIY LoRaWAN Gateway can be registered successfully as a compact certified multi-channel device in the LoRa community. The registering window from the TTN can be observed in Figure 3.

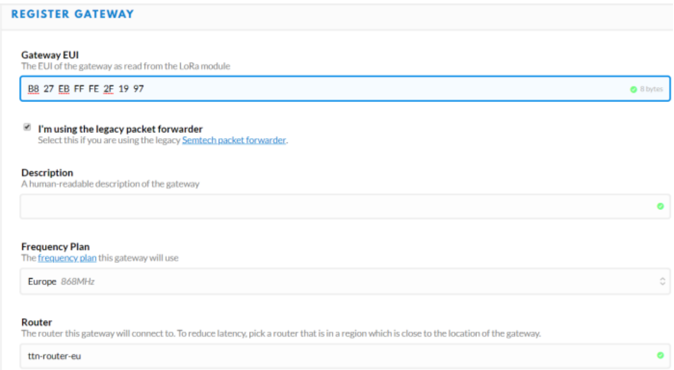

Fig. 3. Registering the LoRaWAN Gateway in the TTN platform

The results in the TTN platform regarding messages transmitted from the Nodes to the LoRaWAN Gateway are depicted in Figure 4. The TTN provides a user-friendly interface in order to analyses the received data.

We can see that for a payload of 23 bytes, the airtime is calculated as 61.7 ms, while for 21 bytes using the same spreading factor and the same coding mechanism, the airtime drops to 56.6 ms. This is an important aspect if large data packets need to be sent at long distances.

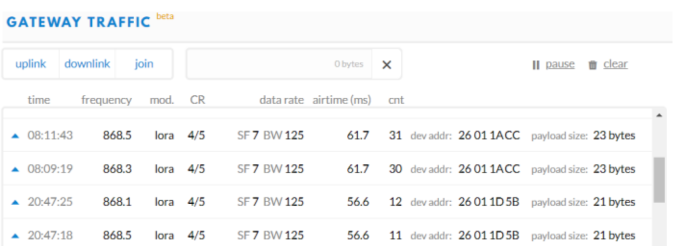

Fig. 4. Gateway traffic received in the TTN platform

For performance testing, some LoRaWAN Nodes are placed at different distances from the Gateway having different packet length. One we can see that the packages can be received on different frequencies, allocated for SRD 860 frequency band, from 868.1MHz to 868.5MHz. For this test setup are used only 3 of the LoRaWAN communication channels.

The TTN platform allows to view all the received data packets from each node that is connected to the cloud interface. Due to the security reasons, the information from the data packet can't be decoded, this aspect being possible at the end-user application level through the security key.

III. Measurements and Tests Performed

The performance tests for the LoRaWAN Gateway are made using 2 scenarios: placing the Gateway in a rural and an urban area, respectively, using the same LoRaWAN Node configured with the same spreading factor (SF7).

The data packet used has a length of 23 bytes, so the airtime will be each time the same, of 61.7 ms according to the TTN platform interface. The packets will be sent with a delay of 30 seconds between them and each time will be sent 100 packets. Thus, for the mentioned configuration, will be analyzed the PER (Packet Error Rate).

Each geographical position of the Node is recorded using the Google Maps API, so for both configurations will be kept approximately the same distances between the Gateway and the Node. The obtained values of the PER analyzed in both situations are depicted in Table 1 and in Figure 5, respectively.

TABLE I. Measurements of the PER for urban and rural placement of the Gateway

Distance (km)	PER (%) rural	PER (%) urban
0.3	0	0
0.4	0	0
0.9	0	9
1.2	0	14
1.4	0	32
1.6	3	53
1.9	8	72
2.1	9	92
2.5	17	100

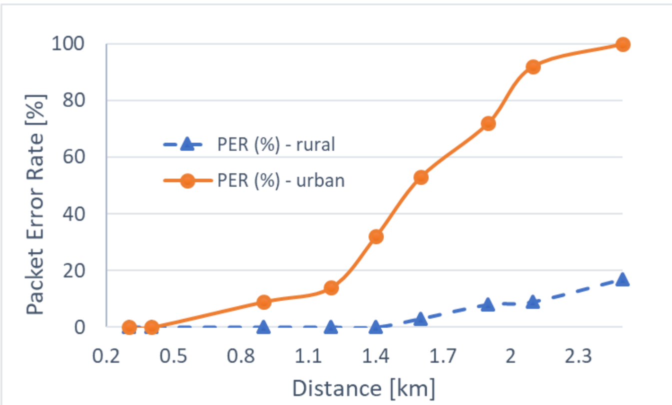

Fig. 5. Packet Error Rate parameter

If we take into account a value of the PER of maximum 20%, the maximum coverage area of the Gateway in the presented testing setup is about 2.5 km in the rural area and of 1.3 km in the urban area. This coverage area value can be increased if the system will use a better antenna with a high gain placed at a high elevation point from the ground. For these tests, the antenna is placed at approximately the same elevation, for both scenarios.

Figure 6 and Figure 7 respectively, depict the PER values obtained for the Node with the Gateway placed in the rural and urban areas. Due to the lack of buildings and other signal perturbing objects, the signal will be received by the Gateway with a higher success rate in the rural area.

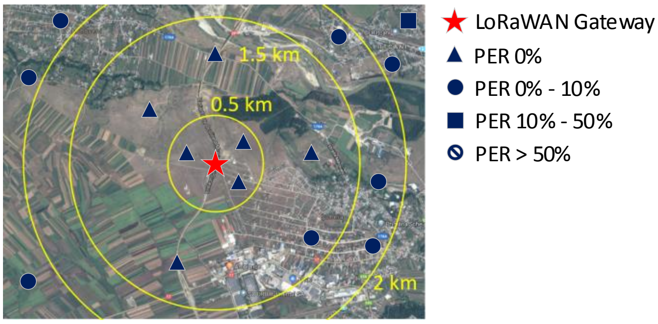

Fig. 6. PER for the LoRaWAN Gateway in rural area

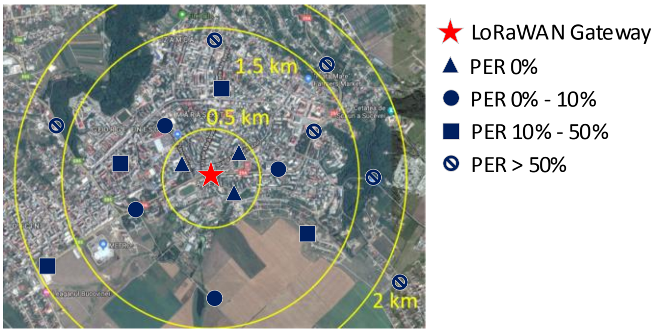

Fig. 7. PER for the LoRaWAN Gateway in urban area

IV. CONCLUSIONS

In this paper a multi-channel LoRaWAN Gateway is designed, implemented and tested in real environment condition with 2 scenarios: using the placement in rural and urban areas respectively. Using the same configuration test and the same number of data packets sent from the Node, the system is analyzed from the PER point of view. Thus, measurements performed in rural area are much better due to the lack of buildings or other signal perturbing objects that interferes with the LoRaWAN Node. Using only a 2.2 dBi gain omnidirectional antenna and SF7, the LoRaWAN Gateway can cover 2.5 km in rural areas and 1.3 km in urban areas.

ACKNOWLEDGMENT

This paper was partially made using the infrastructure from the project “Integrated Center for research, development, and innovation in Advanced Materials, Nanotechnologies, and Distributed Systems for fabrication and control (MANSiD)”, Contract No. 671/09.04.2015, Sectoral Operational Program for Increase of the Economic Competitiveness co-funded from the European Regional Development Fund and by a grant of the Romanian Ministry of Research and Innovation, CCCDI-UEFISCDI, Project Nos. PN-III-P1-1.2-PCCDI-2017-0776 and 36 PCCDI/15.03.2018, within PNCDI III.

REFERENCES

[1] A. Lavric, A. I. Petrariu, “LoRaWAN communication protocol: The new era of IoT,” 2018 International Conference on Development and Application Systems (DAS), 2018, DOI: 10.1109/DAAS.2018.8396074;

[2] H.-C. Lee, K.-H. Ke, “Monitoring of Large-Area IoT Sensors Using a LoRa Wireless Mesh Network System: Design and Evaluation,” IEEE Transactions on Instrumentation and Measurement, vol. 67, no. 9, pp. 2177-2187, 2018, DOI: 10.1109/TIM.2018.2814082;

[3] K. Tzortzakis, K. Papafotis, P. P. Sotiriadis, “Wireless self powered environmental monitoring system for smart cities based on LoRa,” 2017 Panhellenic Conference on Electronics and Telecommunications (PACET), 2017, DOI: 10.1109/PACET.2017.8259970;

[4] E. Bingol, M. Kuzlu, M. Pipattanasompom, “A LoRa-based Smart Streetlighting System for Smart Cities,” 2019 7th International Istanbul Smart Grids and Cities Congress and Fair (ICSG), 2019, DOI: 10.1109/SGCF.2019.8782413;

[5] P. Gotthard, T. Jankech, “Low-Cost Car Park Localization Using RSSI in Supervised LoRa Mesh Networks,” 2018 15th Workshop on Positioning, Navigation and Communications (WPNC), 2018, DOI: 10.1109/WPNC.2018.8555792;

[6] Terteil A.A. Ali, V. Choksi, M. B. Potdar, “Precision Agriculture Monitoring System Using Green Internet of Things (G-IoT),” 2018 2nd International Conference on Trends in Electronics and Informatics (ICOEI), 2018, DOI: 10.1109/ICOEI.2018.8553866;

[7] Z. Wenju, L. Shengwei, H. Jiwen, X. Rongtao, L. Hou, “Design and Implementation of Smart Irrigation System Based on LoRa,” 2017 IEEE Globecom Workshops (GC Wkshps), 2017, DOI: 10.1109/GLOCOMW.2017.8269115;

[8] M. Centenaro, L. Vangelista, A. Zanella, M. Zorzi, “Long-Range Communications in Unlicensed Bands: The Rising Stars in the IoT and Smart City Scenarios,” IEEE Wireless Communications, vol. 23, no. 5, pp. 60-67, 2016, DOI: 10.1109/MWC.2016.7721743;

[9] https://github.com/lorabasics/basicstation, accessed on 27.08.2019;

[10] Z. Xihai, Z. Mingming, M. Fanfeng, Q. Yue, X. Suijia, H. Senghout, “A Low-Power Wide-Area Network Information Monitoring System by Combining NB-IoT and LoRa,” IEEE Internet of Things Journal, vol. 6, no. 1, pp. 590-598, 2019, DOI: 10.1109/JIOT.2018.2847702;

[11] A. Lavric, A. I. Petrariu, V. Popa, “Long Range SigFox Communication Protocol Scalability Analysis Under Large-Scale, High-Density Conditions,” IEEE Access, vol. 7, pp. 35816-36825, 2019, DOI: 10.1109/ACCESS.2019.2903157;

[12] F. Van den Abeele, J. Haxhibeqiri, I. Moerman, J. Hoebeke, “Scalability Analysis of Large-Scale LoRaWAN Networks in ns-3,” IEEE Internet of Things Journal, vol. 4, no. 6, pp. 2186-2198, 2017, DOI: 10.1109/JIOT.2017.2768498;

[13] A. Mahmood, E. Sisinni, L. Guntupalli, R. Rondon, A. H. Syed, M. Gidlund, “Scalability Analysis of a LoRa Network Under Imperfect Orthogonality,” IEEE Transactions on Industrial Informatics, vol. 15, no. 3, pp. 1425-1436, 2019, DOI: 10.1109/TII.2018.2864681;

[14] L. Amichi, M. Kaneko, N. El Rachkidy, A. Guitton, “Spreading Factor Allocation Strategy for LoRa Networks Under Imperfect Orthogonality,” ICC 2019 - 2019 IEEE International Conference on Communications (ICC), 2019, DOI: 10.1109/ICC.2019.8761235;

[15] A. Waret, M. Kaneko, A. Guitton, N. El Rachkidy, “LoRa Throughput Analysis With Imperfect Spreading Factor Orthogonality,” IEEE

***2019 IEEE** 25th International Symposium for Design and Technology in Electronic Packaging (**SIITME**)*

Wireless Communications Letters, vol. 8, no. 2, pp. 408-411, 2019, DOI: 10.1109/LWC.2018.2873705;

[16] D. Croce, M. Gucciardo, S. Mangione, G. Santaromita, I. Tinnirello, "Impact of LoRa Imperfect Orthogonality: Analysis of Link-Level Performance," IEEE Communications Letters, vol. 22, no. 4, pp. 796-799, 2018, DOI: 10.1109/LCOMM.2018.2797057;

[17] WiMOD iC880A concentrator module datasheet, accessed on 27.08.2019;

[18] SX1257 - Low Power Digital I and Q RF Multi-PHY Mode Transceiver datasheet, accessed on 15.08.2019;

[19] SX1301 - Digital Signal Processing Engine datasheet, accessed on 01.08.2019;

[20] https://github.com/ttn-zh/ic880a-gateway/wiki, accessed on 20.08.2019.