SigFox Communication Protocol: The New Era of IoT?

Alexandru Lavric, Adrian I. Petrariu and Valentin Popa
Computers, Electronics and Automation Department, Stefan cel Mare University of Suceava, Romania
lavric@eed.usv.ro

***Abstract*—The IoT (Internet of Things) concept is in a state of continuous development, being an important subject for many research centers. The main contribution of this work comes to evaluating the performance level associated to the SigFox technology. From the gathered results one can conclude that the SigFox technology represents a handy candidate in the implementation of the IoT concept. However, the effects of the collision triggered by the lack of a verifying mechanism of the degree of occupation of the channel still need to be analyzed.**

Keywords— SigFox, IoT, wireless communication, UNB

I. Introduction

The IoT Concept (Internet of Things) finds itself in a continuous development, being of utmost importance to many research centers. This expansion is supported by the will to introduce connectivity capabilities to simple objects that are around us on a daily basis.

The main goal of the IoT concept is the increase of the quality of life, contributing to the protection of the environment. Depicted in this context, there is a multitude of protocols and mechanisms of communication which promise a solution for the IoT problem. Within this work, the focus will be the protocols of a low-power narrow-band (LP-NB). The IoT concept which includes offering of IP connectivity of various objects that surround us is showcased in Fig. 1.

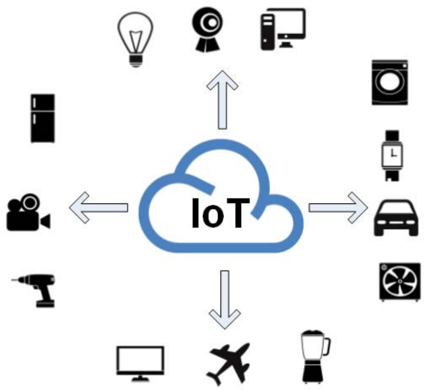


Fig. 1. IoT concept.

The paper is organized as follows: first, a brief introduction related to the state-of-the-art, followed by Section II, where the main challenges of sensor power management are presented. The SigFox communication mechanism and requirements are discussed in Section III. In Sections IV, the experimental results are presented. The final section of the paper, is represented by the conclusions.

The main contribution of the work is when it comes to evaluating the performance level associated to the SigFox technology. Within the specialized literature, there are a series of scientific papers which attempt to analyze the SigFox sensor networks, oftentimes at a review or survey level. This paper comes to fill in the gap and tries to materialize a study that allows for the analysis of the performance level, by the attempt of developing an objective standpoint.

II. Challenges

Whenever we are to correlate the IoT concept with the field of sensor networks, we can see that a series of issues arise, those being of maximum actuality. Firstly, an IoT sensor particular to IoT applications needs to fulfill more requirements such as:

1. Low cost. The cost needs to be as low as possible so that mass deployment is possible. To allow for the IoT concept to integrate a high number of sensors, the initial cost of the sensors needs to be the lowest possible.

2. The life span of the battery needs to be the longest possible, the goal being that a source of energy should have a lifetime of the order of decades. Fulfilling this goal will not be possible without the development and the perfecting of the algorithms and of the management systems of the electric energy consumption. At the same time alternative such as renewable energy sources need to be integrated, which can allow for the maximization of the lifetime of the sensors.

3. The utmost spread communication range. The environment in which these sensors will work is oftentimes represented by the urban environment. Thus, one needs to take into account the non-LoS (Line of Sight) communication conditions. The communication mechanism needs to be capable of ensuring of maximum communication ranges, so that the architecture of the whole system would be as simple as possible.

4. No spectrum licenses. To streamline the initial implementation costs the sensors need to operate within an unlicensed frequency band. Thus, we need to direct ourselves towards technologies which make use of the ISM frequency (Industrial, Scientific and Medical) or SRD (Short Range Devices).

5.High Density Large Scale. The communication protocol needs to support the possibility of integrating of a large number of sensors (e.g. hundreds, thousands or even hundreds of thousands) spread on great geographical area. This requirement implies the creation of complex network type topology. In order to keep the cost of devices in check the communication mechanism needs to be as simple as possible so that the hardware structure of the nodes and the architecture of the sensor networks to be the simplest.

6. Architecture coverage. The network architecture that includes GW (Gateways) or BS (Base Stations) would ideally be of any open-access type. An illustrative example in this direction is represented by the LoRaWAN technology

978-1-7281-1022-6/19/$31.00 ©2019 IEEE
Authorized licensed use limited to: Danmarks Tekniske Informationscenter. Downloaded on March 04,2021 at 08:39:32 UTC from IEEE Xplore. Restrictions apply.

[1]. This architecture involves installing a Gateway, whose access of the users isn't restricted. In the eventuality in which there is LoRa technology coverage in a particular area, any sensor can be connected to the already existing infrastructure.

Another handy candidate that shouldn't be ignored is represented by the SigFox communication protocol. Unlike the LoRaWAN architecture, SigFox [2] is vendor-locked with the system being oft implemented by the mobile network operators. In this situation, the user pays a small sum of money which allows one's access to the mobile network. Depending on the numbers of packages which one wants to send the paid fee can increase. Up next, we will focus upon the SigFox protocol, which is characterized by a high degree of flexibility.

III. SigFox Technology

SigFox uses a new strategy when it comes to tackling the IoT Concept, becoming a characteristic business model of a network operator, in the last few years. The technology was developed by a group from Labège, France, bearing the same name. The applications that can make use of this technology are the ones that ask for a small transfer of data, its base being represented by a technology of an UNB (Ultra Narrow Band) type. The bandwidth of the communication is about 100 bps (e.g. 100 Hz bandwidth) and of 600 bps (e.g. 600 Hz bandwidth) for the ETSI and FCC region, respectively [3]. In other works, published by the authors [4]-[8] different aspects of the IoT concept, as well as other communication protocols are analyzed and evaluated.

Fig. 2 depicts the SigFox communication stack. One can observe the physical layer, the medium access control, and the application layer.

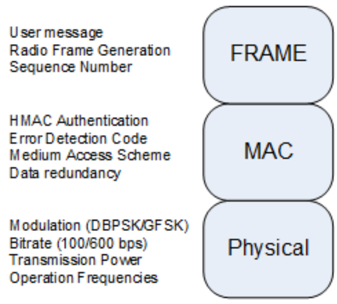


Fig. 2. SigFox communication protocol stack.

In Europe, the maximum power being sent is of 14 dBm for a 2 second timespan. The sensor can transmit up to 40 packets. In the geographical area where the FCC regulations are respected, the utmost power emitted by the Base Stations is of roughly 30 dBm.

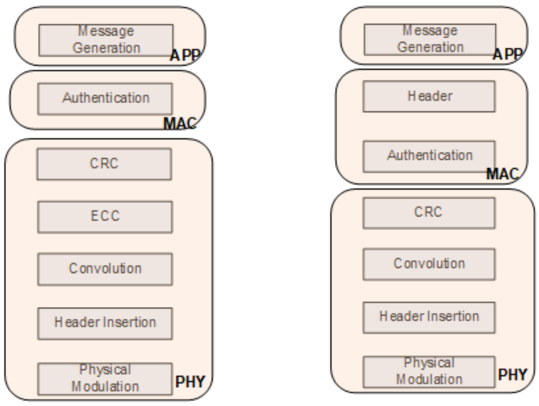
The main advantage of the technology is represented by its resistance to interferences and collisions, made possible by the implementation of a diversity mechanism when it comes to both time as well as frequency. Thus, each sensor sends each data packet on three communication channels at a pseudorandomly selected moments of time.

This mechanism involves the introduction of redundancy at communication level, but also has a major disadvantage through the increase of the degree of occupancy of the channel and implicitly of the number of eventual collisions. A worthwhile mention is that the MAC level doesn't have any algorithm of verification of the degree of occupancy implemented and implicitly no CSMA (Carrier-Sense Multiple Access) mechanism with collision detection (CD).

Alongside these innovative mechanisms the SigFox architecture proposes the utilization of a spatial diversity. Thus, the sent packet by each sensor should be received by at least 3 Base Stations. By offering this level of performance, the number of sensors can theoretically be increased even further by the realization of load balancing. As BS is implemented by the use of SDR (Software Defined Radio) technologies, many of the communication stack levels are closed, being proprietary to the manufacturer. The vast majority of information presented in specialized literature is presented at a commercial level [9] - [12], with an utter lack of an objective manner of the performance level. In a previous work published by the authors [7] the performance level was analyzed in conditions of a large-scale, high-density type associated to the SigFox networks.

At a physical level, the SigFox protocol uses D-BSK (Differential Binary Shift Keying) modulation to allow for the modulation of downlink and of GFSK (Gaussian frequency shift keying) for the downlink packets. The modulation technique uses downlink in order to send a bit on a 1 Hz bandwidth. On these grounds, the technology is tailored to the applications that send data at a reduced transfer rate. At a physical level as well, we have the control mechanism of power and the pseudorandom allocation of communication frequencies being integrated.

In Fig. 3, the SigFox frame creation procedure uplink and downlink mechanisms are represented.



a) uplink b) downlink

Fig. 3. SigFox Frame creation procedure.

The means of accessing the communication channel is of an ALOHA type, particular to the sensor networks of a Random Frequency and Time Division Multiples Access (RFTDMA) type. Another further advantage is the lack of a synchronization mechanism between the emitter and the receiver, a fact that generates the further reduction of implementation costs, because no high-performance hardware oscillators are needed. A major disadvantage that cannot be overlooked and needs analysis is the influence of the number of collisions over the performance level of the network, because at protocol level, there isn't any mechanism tasked with the verification of the degree of occupancy of the communication channel.

Authorized licensed use limited to: Danmarks Tekniske Informationscenter. Downloaded on March 04,2021 at 08:39:32 UTC from IEEE Xplore. Restrictions apply.

In Fig. 4 the SigFox architecture containing the SigFox Base Station, the SigFox Cloud and the Application Server is presented. The uplink and downlink communication mechanisms are implemented.

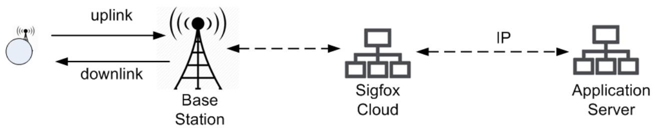


Fig. 4. SigFox arhitecture.

IV. Performance Evaluation

In Fig. 5 the setup is depicted, whose goal is the evaluation of the performance level associated to the SigFox communication. Thus, a local SigFox BS has been emulated by using the SigFox SDR dongle [13]. This instrument was developed to make the development of SigFox easier, by offering the possibility the developer the possibility to realize the initial SigFox conformity tests. The initial design can be altered by verifying the conformity of the developed module with the SigFox specifications nowadays in effect. Moreover, the module can work in the spectrum analyzer configuration, whose functionality is implemented under the UBUNTU Linux operating system.

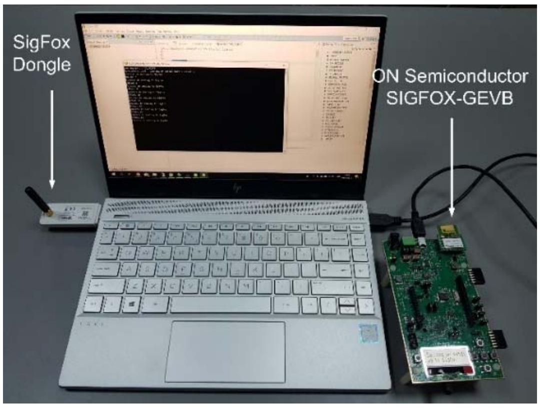


Fig. 5. RTL-SRD Spectrum.

To achieve the setup, one software application was realized, implemented and tested, whose role is to run on the ON SigFox-GEVB [14] evaluation board module. The application implies the sending of a packet whose payload is an utmost dimension of 12 bytes. The first section of the performed analyses implies the use of the spectrum analyzer mode.

Represented in Fig. 6 is the Ultra Narrow Band FFT – Nominal Voltage for the sensor under test. From the gathered results one can see that the frequency shift is within the nominal deviations. It has to be mentioned that in this experimental scenario, in order to bring the interferences as close to a minimum as possible, the sensor is connected directly to the dongle module by using a 40 dB attenuator.

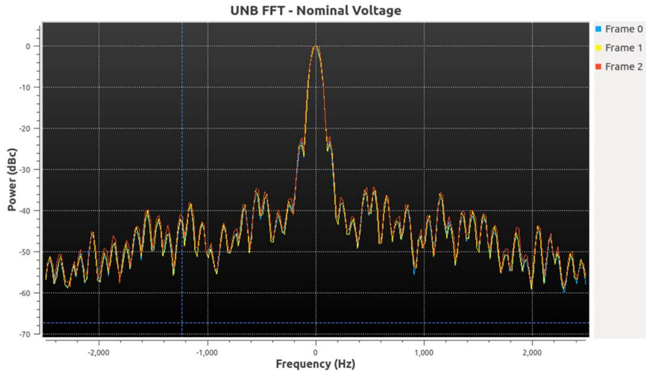


Fig. 6. Ultra Narrow Band FFT – Nominal voltage.

In Fig. 7, FFT or full analysis for the sensor under test is being shown. One can observe that beside the in-band SigFox transmission there is some out of band harmonics that are emitted by the sensor.

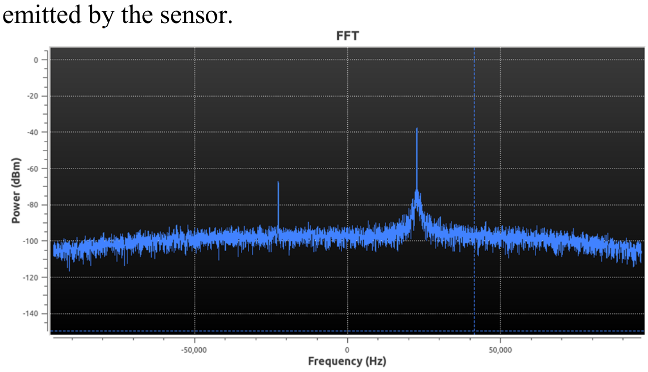


Fig. 7. FFT analysis for the senzor under test.

The power spectral density for the sensor under test is represented in Fig. 8. One can see the spectral power mask defined within the frames of the SigFox specification. From the gathered results one can gather that the sensor tested, that being the ON SigFox-GEVB follows the SigFox specification when it comes to spectral power.

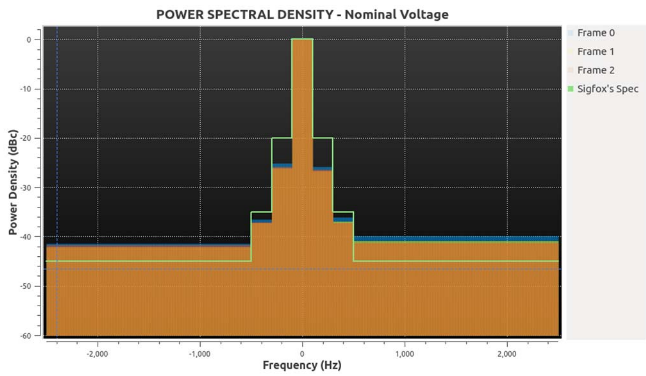


Fig. 8. Power spectral density analysis of the SigFox node.

Presented in Table 1 is the EIRP (Effective Isotropic Radiated Power) output power expressed in dBm for different regions regulated by SigFox specifications. The RC 1 region corresponds to EMEAI region, RC 2 for US and RC 3 for Japan, South Korea.

TABLE I. Output Power

Authorized licensed use limited to: Danmarks Tekniske Informationscenter. Downloaded on March 04,2021 at 08:39:32 UTC from IEEE Xplore. Restrictions apply.

Region	RC 1	RC 2	RC 3
Power (dBm EIRP)	16	24	16

The Nominal Voltage for the extra symbol after transmission is presented in Fig. 9.

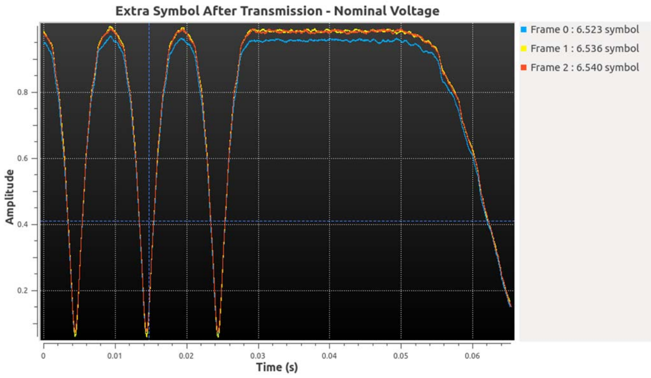


Fig. 9. Nominal Voltage for the extra symbol after transmission.

From the results gathered results, one can conclude that the sensor abides by SigFox specifications. The second part of the test scenario implies the emulation of a SigFox BS. Thus, the sensor sends packets towards the BS. The SigFox Network Emulator is shown in Fig. 10, it allows the observation and analysis of the received packets. Thus, local-laboratory debugging can be done without the need of an BS that is most often employed by the mobile network operator. The packets sent by the SigFox sensor are correctly received by the SDR dongle. The information present at a platform level include: the device ID, the sequence number, the data decoding and the LQI (Link Quality Indicator).

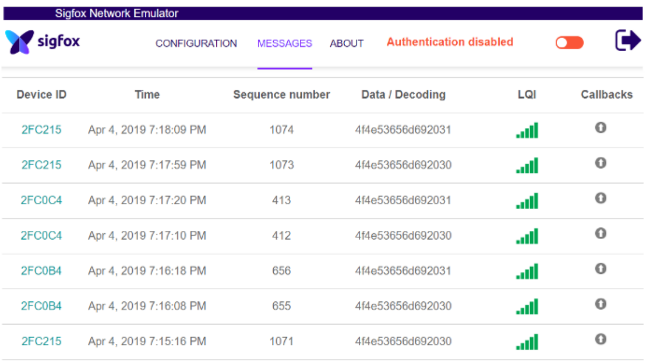


Fig. 10. SigFox Network Emulator.

V. Conslusions

The SigFox communication protocol is classified within the frame of UNB type of communications. From commercial information which oftentimes have a marketing characteristic, one can think that all of these technologies are able to solve the issue of the IoT concept. Thus, within the first part of this paper, the challenges that the IoT concept comes up against are analyzed and evaluated. Within specialized literature, there are a series of works which attempt the analysis of the SigFox networks of sensors, oftentimes at a review or survey level. This paper comes to fill in the gap and tries to realize a study that can allow for the analysis of the level of performance, by attempting to develop an objective standpoint. The main contribution of this work lies itself within the evaluation of the performance level associated to the SigFox technology. This level of performance is associated with a greater range of communication, increased sensitivity and the possibility of integrating of a great number of sensors.

From the obtained results one can conclude that the SigFox technology represents a handy candidate in implementing the IoT concept. However, the effects caused by the absence of a verification mechanism that deal with the degree of occupancy require further analysis.

Acknowledgment

This work was supported by a grant of the Romanian Ministry of Research and Innovation, CCCDI-UEFISCDI, project number PN-III-P1-1.2-PCCDI-2017-0776/No. 36 PCCDI/15.03.2018, within PNCDI III.

References

[1] LoRaWAN™ Specification v1.1, Online: https://lora-alliance.org/resource-hub/lorawantm-specification-v11

[2] Patents: Method for analyzing frequency resources and selecting transmission frequency in a wireless communication system, Online: https://patents.justia.com/patent/20180242333

[3] SigFox Specifications, Ref.: EP-SPECS Rev.: 1.3 Date: Feb. 2019, Online: https://build.sigfox.com/sigfox-device-radio-specifications

[4] Alexandru Lavric, Valentin Popa, LoRa Wide-Area Networks from an Internet of Things Perspective, ECAI 2017 - International Conference – 9th Edition Electronics, Computers and Artificial Intelligence, 2017.

[5] Alexandru Lavric, Valentin Popa, Internet of Things and LoRa Low-Power Wide-Area Networks Challenges, ECAI 2017 - International Conference – 9th Edition Electronics, Computers and Artificial Intelligence, 2017.

[6] Alexandru Lavric, Valentin Popa, „A LoRaWAN: Long Range Wide Area Networks Study", 11-th Electromechanical and Power Systems (SIELMEN 2017), pp. 435-438.

[7] A. Lavric, A. I. Petrariu, V. Popa, "Long Range SigFox Communication Protocol Scalability Analysis under Large-Scale, High-Density Conditions," IEEE Access, 2019, DOI: 10.1109/ACCESS.2019.2903157;

[8] A. Lavric, "LoRa (Long-Range) High-Density Sensors for Internet of Things," Journal of Sensors, 2019, DOI: 10.1155/2019/3502987;

[9] Gomez, C., Veras, J.C., Vidal, R., Casals, L. and Paradells, J., 2019. A Sigfox energy consumption model. Sensors, 19(3), p.681.

[10] Ruckebusch, P., Giannoulis, S., Moerman, I., Hoebeke, J. and De Poorter, E., 2018. Modelling the energy consumption for over-the-air software updates in LPWAN networks: SigFox, LoRa and IEEE 802.15. 4g. Internet of Things, 3, pp.104-119.

[11] M. Aernouts, B. Bellekens, R. Berkvens and M. Weyn, "A Comparison of Signal Strength Localization Methods with Sigfox," 2018 15th, 2018, pp. 1-6. doi: 10.1109/WPNC.2018.8555743

[12] Chung, Y., Ahn, J.Y. and Du Huh, J., 2018, October. Experiments of A LPWAN Tracking (TR) Platform Based on Sigfox Test Network. In 2018 International Conference on Information and Communication Technology Convergence (ICTC) (pp. 1373-1376). IEEE.

[13] SigFox SDR Dongle, On-line https://build.sigfox.com/sdr-dongle

[14] Test Procedure for the ON SIGFOX-GEVB Evaluation Board, Online: https://www.onsemi.com/pub/Collateral/SIGFOX-GEVB_TEST_PROCEDURE.PDF.

Authorized licensed use limited to: Danmarks Tekniske Informationscenter. Downloaded on March 04,2021 at 08:39:32 UTC from IEEE Xplore. Restrictions apply.