Omni: Data Science Platform for Evaluate Performance of a LoRaWAN Network

Emanuele A. Solagna, Ricardo S, Tozetto, Roberto dos S. Rabello

Abstract—Nowadays, physical processes are becoming digitized by the evolution of communication, sensing and storage technologies which promote the development of smart cities. The evolution of this technology has generated multiple challenges related to the generation of big data and the active participation of electronic devices in society. Thus, devices can send information that is captured and processed over large areas, but there is no guarantee that all the obtained data amount will be effectively stored and correctly persisted. Because, depending on the technology which is used, there are parameters that has huge influence on the full delivery of information. This article aims to characterize the project, currently under development, of a platform that based on data science will perform a performance and effectiveness evaluation of an industrial network that implements LoRaWAN technology considering its main parameters configuration relating these parameters to the information loss.

Keywords—Internet of Things, LoRa, LoRaWAN, smart cities.

I. Introduction

IN the context of Smart Cities, the Internet of Things has promoted the experimentation and analysis of urban infrastructures that allow innovation [1], enabling the emergence of new data communication technologies. These new technologies are usually composed of devices that have sensing, processing and communication capabilities with other devices. They can perform tasks, automate processes, which enable them to learn common behaviors and identify eventualities across many types of systems and infrastructures. These devices can be called Smart Objects [2]. However, such objects have recurrent processing and energy limitations, making wireless communication a major challenge.

LoRaWAN networks aim to solve this challenge by being a Low Power Wide Area Network (LPWAN), a low power and long range network. They are implemented using LoRa (Long-Range) technology, a radio-frequency technology that enables low power long-distance communication [3]. In addition, LoRa devices configuration comprises a few main parameters, one of them, which is the radio signal modulation technique, called Spread Spectrum Modulation (SSM) [4]. In this technique, the original signal is spread in the frequency field, increasing the signal robustness. In the LoRa specification, the SSM is related to a parameter called *Spreading Factor*(SF).

The SF can be set as six different values, from SF7 to SF12 [5]. Each value causes variation between the robustness of interference modulation and the bit rate. On the one hand, depending on the configured value, the transmission rate may increase, which also increases the communication flow rate. However, on the other hand, the value of the parameter may imply loss of resistance to interference, which induces packet loss and decreases the flow.

Because LoRa technology is relatively new, little is known about the impact of SF value configuration, assuming that this parameter is one of the main factors that directly affect network performance and effectiveness. Thus, this paper proposes to present the project, under development, of the development of a web platform to perform an evaluation of the performance and communication effectiveness of LoRa technology. The analysis will be performed according to the Spreading Factor parameter, since this is a particularity of the technology, its value is configurable via software and because it is a parameter that significantly implies the network performance. The parameters of signal strength, gateway latency, packet loss rate, and communication flow rate will be analyzed to evaluate the efficiency of the defined spreading factor.

The network to be evaluated will be an industrial network using LoRaWAN technology, which was built by OPTIM, a customized hardware/firmware developer company, integrate at UPF Planalto Mdio Science and Technology Park, at University of Passo Fundo (UPF), located in the city of Passo Fundo - Rio grande do Sul, Brazil. The company has the demand to obtain a performance and effectiveness assessment of its network, aiming to use the maximum capacity and efficiency of the devices that are in operation. Thus, was proposed the development of a web platform for data collection regarding packet traffic on the network and the use of Data Science (interdisciplinary area focused on study and data analysis), aiming at the extraction of knowledge or insights, based on the data that will be obtained.

II. Scientific Foundation

Since 3,000 B.C., cities have developed as a means for the strengthening of human life and housing. The emergence of cities was a natural response to life circumstances, but they also had a profound and lasting impact on the evolution of the human species as a whole [6].

Currently, cities are challenged with issues related to economic development, social inclusion, security, sustainability, infrastructure, transportation, housing, etc. At the same time, the advent of new information and communication technologies has allowed the democratization

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of the production capacity of citizens, who are empowered to participate in the innovation dynamics of their cities [7]. Thus, they can be conceptualized as complex ecosystems, where different actors with different interests collaborate with each other. And from the emergence of new media *Information and Communication Technologies* (ICTs), performance indicators such as knowledge-based social capital gained ground [8] and concepts such as *smart cities* were developed and put into practice.

Smart cities are generally characterized by the widespread use of ICTs in traditional infrastructures, as well as to enhance the active participation of human and social capital [7], [9]. This technology-based approach is considered capable of dealing with different problems[10], [11], while ensuring the quality of the urban environment and the sustainability of its development. Thus, a smart city can be described as a city that uses ICTs to improve the quality of life of its population [7]. The formation of smart cities, widely connected to the Internet, makes use of the Internet of Things to transform the life and work of the community.

For the use of IoT solutions, technologies with long battery life and communication over long distances are required as shown in Fig. 1.

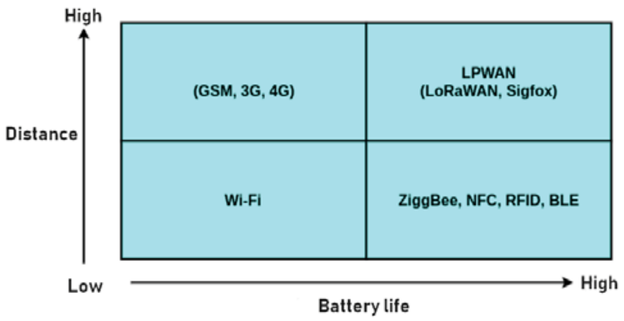

Fig. 1 Communication distance x battery life of each communication technology [12]

A promising solution is low power long range networks (LPWAN). They where created specifically focused on low-level IoT applications, in other words, low cost devices, long battery life and low transmission rates [13]. Devices on the LPWAN network use LoRa technology, which is a radio frequency technology that enables long distance communication with minimal power consumption and follows the Internet of Things paradigm.

LoRa technology defines a physical layer, which seeks to attempt the low power requirements of Smart Objects and is used to implement the LoRaWAN protocol. LoRaWAN is the protocol that defines system architecture and communication and access parameters. The protocol also defines the rates of data transmission speed, support for two-way communication and provision of mobility services and location of network devices.

The LoRaWAN network consists of four components: end-devices, gateways, network server and application server. End-devices are the Smart Objects, usually with energy restrictions, they can be sensors or other types of smart devices. Gateways act as relays that forward messages sent by any end device to the network server, after adding some reception quality information. The Network Server is responsible for filtering out unwanted and duplicate packets and responding to an end device by choosing a particular gateway according to the quality of the [14] radio connection. End devices are associated with the network server, so they can ”move” along the network being served by different gateways [4], [15]. Application servers are specific programs that receive (via request or automatically) packets from network servers and according to the information perform one or more specific actions.

The LoRaWAN protocol uses authentication, data integrity and packet duplication mechanisms characterized as MAC (Media Access Control). Thus, every packet of information that circulates on a LoRaWAN network is protected with Advanced Encryption Standard (AES) cite Singh encryption. In the physical layer, LoRa technology has chirps-based modulation, which are signal frequency changes at predefined times. These chirps can be separated between base-chirps and down-chirps, depending on whether the frequency ranges from $f_{min} = \frac{-BW}{2}$ to $f_{max} = \frac{+BW}{2}$ for base-chirps and $f_{max} = \frac{+BW}{2}$ up to $f_{min} = \frac{-BW}{2}$ for down-chirps , assuming that BW (Bandwidth) is the signal bandwidth. Thus, for different digital signal inputs for modulation different chirps with different time offsets are produced. In addition, for signal demodulation to occur, there must be alignment of time references between the transmitter and the receiver. From there, the demodulator determines the displacement of each chirp by multiplying it by itself and searching for the Fast Fourier Transform (FFT) of the result, and in this power spectral diagram performing a search for the maximum signal, thus determining The demodulated digital symbol. Another important feature of this modulation is the SF (Spreading Factor) which is given by $\log N$, where N is chirp length, considering that there may be different cyclic changes in this value and characterizing the factor. spreading communication [16]. Also, we can mention the Symbol Rate (SR) and Data Rate (DR) that depend directly on the Spreading Factor and determine the transmission rate of the communication system. Fig. 2presents the spectrum of a LoRa packet.

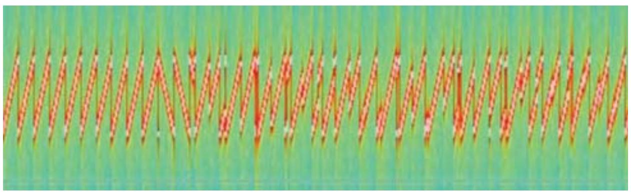

Fig. 2 Power spectral density of a LoRa packet (adapted from [16]

As for topology, LoRaWAN networks are typically defined as tree cluster topology, as can be seen in Fig. 3. Gateways are connected to the network server over an Internet Protocol (IP) connection, while end devices connect to one or more gateways using single hop communication. As shown, the proposed platform lies between the network server and the [15] application server.

The LoRaWAN network specification defines three classes

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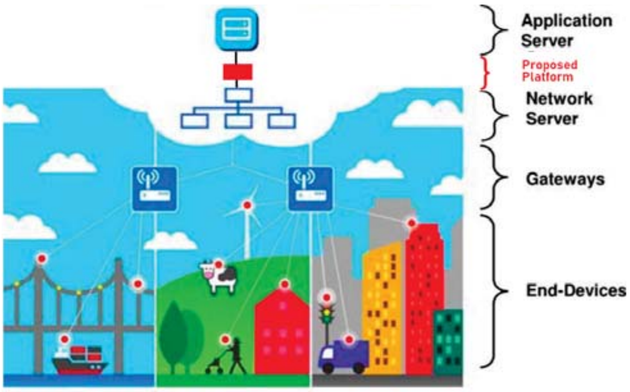


Fig. 3 LPWAN network architecture, where devices, gateways, network server, and application servers are present (adapted from [4])

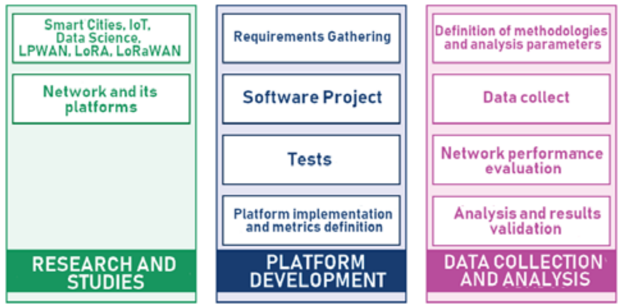


Fig. 4 Phases and activities that are being followed to complete the project, which is currently in the data collection

of end devices in its architecture to achieve different types of service: class A, class B, and class C [15]. On Class A devices, they can send messages to the gateway at any time. However, they are only available for reception during time windows called reception windows. During these windows, the gateway can send messages to devices. A class A device initiates communication with the gateway and, after transmission, initiates a receive window, waits for a certain amount of time, and initiates a second receive window. A new receive window will only open after a new transmission from the same class A device. This mode of operation must be implemented by all LoRa devices. On class B devices, the process is similar. The class B device also opens two receive windows after performing a transmission. However, additionally, Class B devices open reception windows with scheduled times, configured through messages issued by the gateway. On class C devices, terminal devices are always available for receiving [14] messages.

III. Material and Methods

The execution of this project aims to achieve as a final result the implementation of a web platform, integrated with the LoRaWAN telemetry [1] network developed by OPTIM. And based on this integration, apply data science concepts and perform an evaluation of performance and effectiveness of the LoRaWAN network.

The project development is divided into phases, which are: research, platform development, data collection and analysis, which are further subdivided into smaller steps. Fig. 4 gives an overview of the phases and their activities:

The project began with a literature review and study of the general topics covered, smart cities, communication technologies (LPWAN, LoRa and LoRaWAN) and data science, including books, journal and congress articles and the study of the network, its platforms and integration APIs.

The functional structure of the platform, already implemented, is divided into four layers: Data Source, Data Collection, Web Layer and Interaction forms. Fig. 5 shows the schematic diagram of the developed architecture.

The first layer is the data source layer, basically the LoRaWAN network where end devices collect and send data obtained from their sensing to a gateway. Data is temporarily stored by *Orbiwise* [2], Which was OPTIM's own chosen network server. At this point, the data set stored on the network server is considered to be in JSON document format. JSON is an acronym for "JavaScript Object Notation", it is a compact format for fast and simple data exchange between open standard systems, independent of the JavaScript [17] derived programming language. This format has unique specifications that need to be considered while handling.

The second layer is the Data Collection layer, where JSON documents are "harvested", modeled on a Java object (language chosen by the company for platform development) and, using the Java Persistence API (JPA) with Hibernate 4, the data will be persisted into the database. Both technologies were chosen to compose the project because they are already consolidated technologies and have a satisfactory performance.

Once stored, the data are available for use by the Web Layer. In this layer, the repository built by the Data Collection step will be mined using data science technology, which will still be chosen. In order to extract information about the collected packages, which will be presented as dynamic dashboards in the platform. In addition, the Web layer is also responsible for all navigation and interactivity logic devised for the tool. Several technologies were necessary to build the Web layer, the main ones being the Java Server Faces (JSF) frameworks with PrimeFaces and the HTML5, Javascript and CSS3 technologies. And finally, the Interaction Layer is where access to the platform's web layer is provided via the web browser.

Methodologically the tests and evaluations performed will be based on the Ishikawa Diagram, also known as Cause and Effect Diagram, presented in Fig. 6. A tool that helps to root out the root causes of a problem by analyzing all the factors surrounding the process execution.

In the case of this project, as already commented, the following parameters will be considered: Spreading factor, Gateway latency, signal strength and frequency. The purpose

[1] Automated communication process in which measurements are taken and other data is also collected at remote or mobile points where there is usually difficult to access, or impossible to establish cabling.

[2] Swiss network company that develops advanced technologies for the IoT industry. It has a network server (Orbiwan) for networks based on LoRa technology.

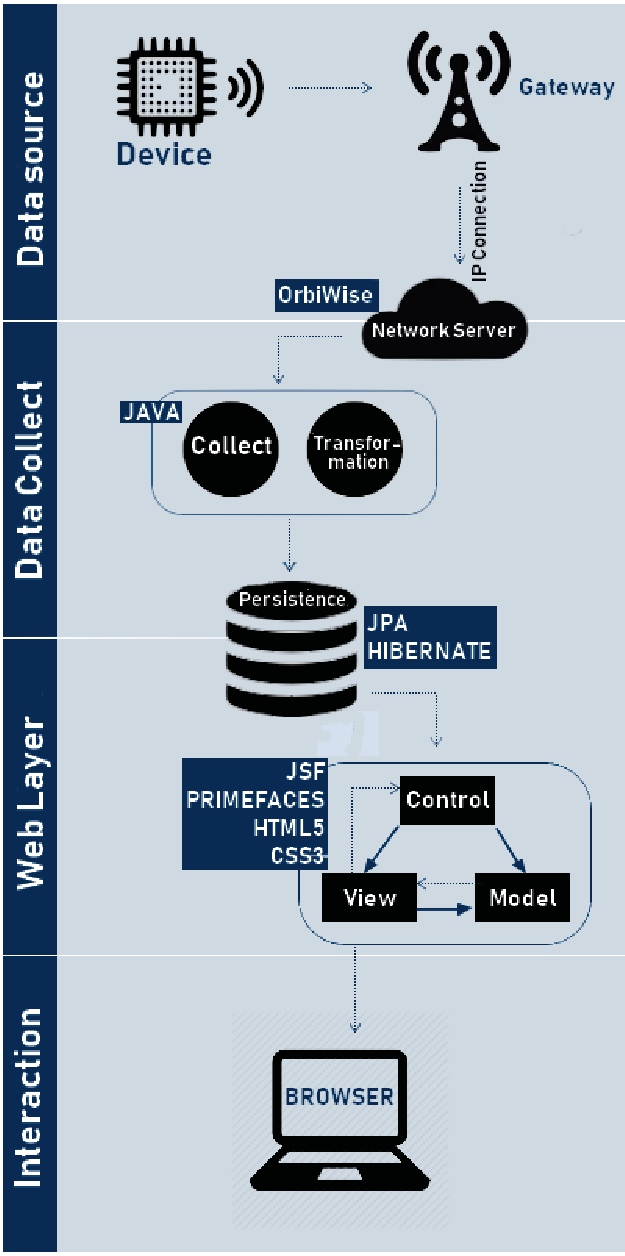


Fig. 5 Developed subdivided platform architecture

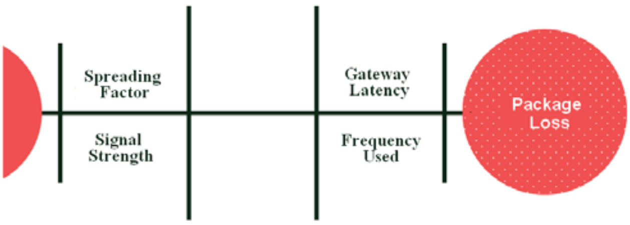
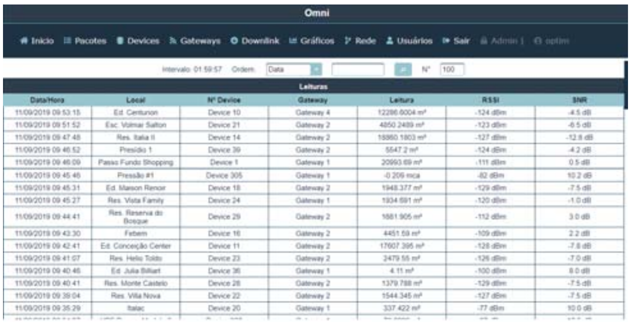


Fig. 6 Ishikawa diagram presents the possible causes for packet loss on the network

of using this methodology is to find out what is the influence of these parameters on the packet losses that happen in the network and which one of them have more action in this problem.

Currently the project is in the last phase, this happens the data collection, cleaning them so that the performance and effectiveness of the network can be performed considering the previously defined metrics, analysis and validation of the results obtained. The necessary cleaning of the 112.000 stored packages is currently being carried out. Since the network has 40 devices in operation, with standard communication every 1 hour from April 23, 2019 and data collection was done until August 21, 2019 (120 days), that was the amount expected packets that would be received.

Fig. 7 presents the packages at the platform and with some storaged parameters. In addition to the presented parameters, gateway latency data, SF used for each packet, other signal strength data, and standard data provided by the LoRaWAN protocol are also being stored.



Data/Hora	Local	Nº Device	Gateway	Leitura	RSSI	SNR
11/09/2019 09:53:15	Ed. Centurion	Device 10	Gateway 4	12286.6004 m³	-124 dBm	-4.5 dB
11/09/2019 09:51:52	Esc. Volmar Salton	Device 21	Gateway 2	4850.2489 m³	-123 dBm	-6.5 dB
11/09/2019 09:47:48	Res. Italia II	Device 14	Gateway 2	18860.1803 m³	-127 dBm	-12.8 dB
11/09/2019 09:46:52	Presidio 1	Device 39	Gateway 2	5547.2 m³	-124 dBm	-4.2 dB
11/09/2019 09:46:09	Passo Fundo Shopping	Device 1	Gateway 1	20993.69 m³	-111 dBm	0.5 dB
11/09/2019 09:45:46	Pressão #1	Device 305	Gateway 1	-0.209 mca	-82 dBm	10.2 dB
11/09/2019 09:45:31	Ed. Maison Renoir	Device 18	Gateway 2	1948.377 m³	-129 dBm	-7.5 dB
11/09/2019 09:45:27	Res. Vista Family	Device 24	Gateway 1	1934.691 m³	-120 dBm	-1.0 dB
11/09/2019 09:44:41	Res. Reserva do Bosque	Device 29	Gateway 2	1881.905 m³	-112 dBm	3.0 dB
11/09/2019 09:43:30	Febem	Device 16	Gateway 2	4451.59 m³	-109 dBm	2.2 dB
11/09/2019 09:42:41	Ed. Conceição Center	Device 11	Gateway 2	17607.395 m³	-128 dBm	-7.8 dB
11/09/2019 09:41:07	Res. Helio Toldo	Device 23	Gateway 2	2479.55 m³	-126 dBm	-7.0 dB
11/09/2019 09:40:46	Ed. Julia Billiart	Device 36	Gateway 1	4.11 m³	-100 dBm	8.0 dB
11/09/2019 09:40:41	Res. Monte Castelo	Device 28	Gateway 2	1379.788 m³	-129 dBm	-7.5 dB
11/09/2019 09:39:04	Res. Vila Nova	Device 22	Gateway 2	1544.345 m³	-127 dBm	-7.5 dB
11/09/2019 09:35:29	Italac	Device 20	Gateway 1	337.422 m³	-77 dBm	10.0 dB

Fig. 7 The platform that was called Omni Platform shows already stored packages and displaying some values from each package

IV. Final Considerations

This paper aimed to present the project of developing a web platform to evaluate the functionality and effectiveness of a LoRaWAN industrial network. The project was based on OPTIM's need for a performance appraisal of its LoRaWAN network. It was discussed about the spreading factor, a parameter defined as the basis for the network evaluation to be performed, which is a very important factor in the network configuration. The idea of measuring packet loss rate and communication flow was established in order to evaluate the efficiency of the spreading factor defined for the network in question.

The steps and phases that divide the project were exposed, so that the proposed objectives can be successfully achieved. And currently the project is at the end of the data collection stage, which will be used to start the performance and effectiveness analysis of the network. From this project it is expected to demonstrate that LoRaWAN technology meets the expectations of being a solution with good performance and significant effectiveness, proving to be reliable for use in the context of smart cities.

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