Evaluation of LP-WAN Technologies for Fire Forest Detection Systems

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***Abstract*—Low Power Wide Area Networks (LP-WAN) are receiving a lot of attention because of their ability to communicate using radio frequency in long distances, with low-power consumption and low-cost devices. In this paper, we provide a comparison between the two LP-WAN platforms that are leading the market, the Sigfox and the LoRaWAN, based on the literature. Both platforms are analyzed considering the context of the forest fire detection and verification systems. Many aspects are being considered to identify which LP-WAN is more adequate to be used in this kind of systems, such as battery lifetime, coverage range, business model and costs. The comparison shows that both platforms are very similar in most of the aspects, although LoRaWAN is more flexible than Sigfox on the deployment and management of the network infrastructure. LoRaWAN allows customers to implement and manage their own infrastructure network, which is essential in systems which monitor vast forest areas.**

Keywords–IoT; LoRaWAN; Sigfox; Fire detection.

I. Introduction

Forest is one of the most important resources of the earth that protects the ecological balance. It has a huge impact on reducing the emission of greenhouse gases, soil erosion, atmospheric carbon absorption, moderating the temperature, and regulating rainfall. A forest fire is considered one of the most dangerous natural accidents, caused by natural forces or human activities. It can affect practically all the forests in the world, having many consequences such as physical, biological and environmental [1]–[3]. In the last decade, with the advent of the Internet of Things (IoT), many forest fire detection and verification systems based on Wireless Sensor Network (WSN) technology were being proposed. In fact, these identified technologies represent an advance in comparison with traditional forest fire prevention [4]. But, most of those systems used short-range radio communication with mesh network protocols, and long-range communication based on Global System for Mobile Communications (GSM). In general, this approach contributes to an increase of the energy consumption and the cost of the system [5], [6].

Recently, a new concept of wireless telecommunication wide area network has arisen to attend the need to develop highly scalable systems with low-cost, low-power consumption, with the capacity to communicate in long distances using radio frequency [7]. Nowadays, there are many platforms and technologies based on this new paradigm called Low-Power Wide Area Networking (LP-WAN). In this article, we will compare two of those platforms, commercially available, that are leading the market: LoRa and Sigfox [8]. The goal is to identify which of them is more adequate to be used in forest fire detection and verification systems, as depicted in Figure 1. More specifically, this system should cover an area of $6600\,\mathrm{km}^2$, involving urban, rural and forest spaces (Figure 2, Bragança District, Portugal).

Besides Sigfox and LoRa being the most popular LP-WAN platforms, they were also chosen to be compared in this article because both operate in unlicensed bands, reducing the final cost of the solution [9]. Sigfox is a closed platform and LoRa is an open platform [6]. The two platforms are available for the customers as Network-as-a-Service (NaaS). But, LoRa allows customers to create their own infrastructure without the need to contract any service [10], [11].

The rest of the article is organized as follows: Section II presents the state of the art on LP-WAN technologies and platforms, section III describes the LoRaWAN and Sigfox low power wide area networks where the business model, the architecture, the technical aspects and the costs are stressed. Section IV performs

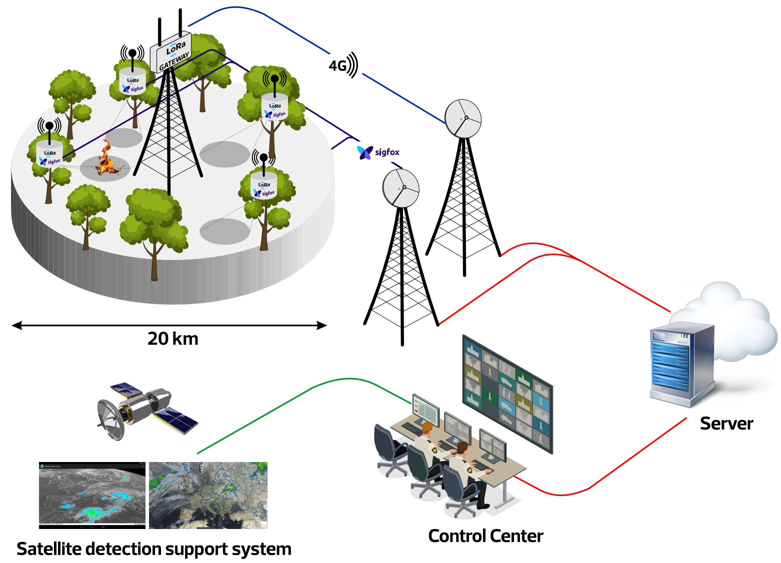

Figure 1. Overview

a comparison between the presented platforms. Conclusion is described in Section V.

Figure 2. Case study - Bragança, Portugal

II. Related Work

Marco Centenaro *et al.* [6] make a presentation about the main characteristics of the LP-WAN paradigm, focusing on the platforms that operate in the unlicensed spectrum. They compares three platforms commercially available: LoRaWAN, Sigfox and Ingenu. These platforms are analyzed in terms of efficiency, effectiveness, and architectural design, especially for smart city applications. Also, they present practical results of experiments and deployments with IoT networks based on LoRaWAN, developed in the city of Padova, Italy. Raza *et al.* [7] presents the most important Low Power Wide Area (LPWA) platforms and technologies available in the market, the standardization activities developed by different standards organizations and the industrial consortia built around some LP-WAN technologies. They point that LP-WAN technologies have similar approaches, limitations and challenges. Also, they highlight the need for standards because of the variety of LP-WAN solutions which is resulting in a fragmented market. They provide an overview of many standardization efforts. Also, they make a comparison of the following LP-WAN platforms: LoRaWAN, Sigfox, Ingenu, Weightless-N and NB-IoT. The comparison is based on business and technical aspects. Sinha *et al.* [9] analyze and compare two LP-WAN platforms based on licensed and unlicensed bands, respectively, NB-IoT and LoRaWAN. They provide a survey on both technologies, describing the technical differences in terms of physical features, network architecture and MAC protocol. The comparison shows that LoRaWAN has advantages in terms of battery lifetime, capacity and cost. NB-IoT also has advantages , like QoS, latency,

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reliability and range. They consider application scenarios and show the current status of these technologies in Korea, Japan, and China. Mekki *et al.* [8] provide a comprehensive and comparative study of the three LP-WAN platforms that are competing for large-scale IoT deployment worldwide: Sigfox, LoRaWAN and NB-IoT. The first two, based on unlicensed bands, and the last one, on licensed bands. The platforms are compared, showing the technical differences between Sigfox, LoRaWAN and NB-IoT in terms of IoT success factors such as quality of service, coverage, range, latency, battery life, scalability, payload length, deployment and cost. The result of the comparison shows that Sigfox and LoRaWAN have advantages in terms of battery lifetime, capacity and cost. NB-IoT offers benefits in terms of latency and quality of service.

III. SIGFOX AND LORA PLATFORMS

This section addresses the business models, the architecture and the technical aspects for both Sigfox and LoRa low power wide area networks.

A. Business Model

Sigfox is a company and a LP-WAN network operator that commercializes its own IoT solution as Network and as a Service (NaaS) in around 57 countries. To cover all these countries, the company has partnership with various network operators. In the Sigfox's business model, customers can implement their own application in a fast and easy way, because they are only concerned about the end-devices. All the costs and management related to the infrastructure is Sigfox responsibility [10].

LoRa is a technology that was developed by a start-up called Cycleo in 2009. Three years later, Cycleo was purchased by Semtech, a company from USA. In 2015, LoRa was standardized by LoRa-Alliance that makes it an open software and IoT platform hardware. Furthermore, LoRa is deployed in around 100 countries. In LoRas business model, customers can use a public network offered by LP-WAN network operator (e.g., Orange in France, KPN in Netherlands, and Fastnet in South Africa), or create their own LoRa infrastructure. A network infrastructure based on LoRa can use hardware from many different manufacturers with a low cost [11].

B. Architecture

In terms of architecture, both platforms are very similar. Their architecture can be divided into four layers, as shown in Figure 3. In the first layer are presented the end-devices, which collect the monitored data. The end-devices send the collected data to the gateways or base stations, into the second layer. In the third layer, the network server receives the data from the gateways, process and stores the data into the databases. At the upper layer, the application layer the end-users access the information acquired by the end-devices, through specific applications, such as industrial monitoring, home automation, smart city applications, smart grid and smart metering applications. End-devices and gateways communicate using radio frequency. The Network layer communicates with the Gateway and Application layers using a TCP/IP based communication [10], [11].

TABLE I. LORA END-DEVICES CLASSES

	Class A	Class B	Class C
Communication	Bidirectional	Bidirectional	Bidirectional
Power consumption	Low	Medium	High
Latency	High	Low	Low
Messages	Unicast	Unicast and Multicast	Unicast and Multicast

C. Technical aspects

Regarding the radiofrequency, both Sigfox and LoRa use unlicensed Industrial, Scientific and Medical (ISM) radio bands (868 MHz in Europe, 915 MHz in North America, 433 MHz in Asia)

At Sigfox network, the end-devices connect to the base-stations using Binary Phase-Shift Keying (BPSK) modulation in an ultra-narrow band sub-GHZ ISM band carrier. Sigfox supports bidirectional communication, uplink (from the end-device to the base station) and downlink (from the base station to the end-device). The number of messages over the uplink is limited to 140 messages per day, and the maximum payload length for each uplink message is 12 bytes. The number of messages over the downlink is limited to four messages per day. Sigfox permits encrypted messages using the the algorithm AES-128. Accordingly with the company, the communication is up to 30–50 km in rural areas and 3–10 km in urban areas [6], [10]. The battery lifetime for each end-device is around 8 years [7].

On the other hand, LoRa also supports a bidirectional communication but provided by the chirp spread spectrum (CSS) modulation. It uses six spreading factors (SF7 to SF12) to adapt the data rate and range trade off. The data rate is between 300 bps and 50 $kbps$. It depends on the spreading factor and on the channel bandwidth. The maximum payload length for each message is 243 bytes. The LoRaWAN communication protocol is used by the LoRa platform. In this protocol, each message transmitted by an end-device is received by all the base stations in the coverage range of the system. Messages can be encrypted using the algorithm AES-128b. The communication range is between 15–20 km in rural areas and between 3–5 km in urban areas. LoRaWAN considers three classes of end-devices as presented in Table I [11], [12]. The battery lifetime is around 10 years for each LoRa end-device [7].

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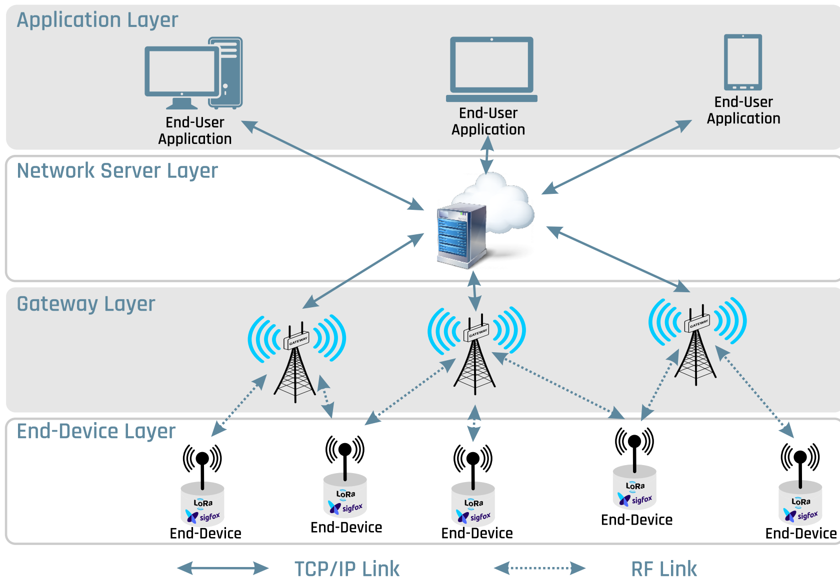

Figure 3. Lora and Sigfox architecture

TABLE II. COMPARISON OF SIGFOX AND LORA COSTS

	Spectrum cost	Network infrastructure cost	End-device cost
Sigfox	Free	Not Applicable (Network as a Service)	\$1–\$5
LoRa	Free	\$100–\$1000/gateway	\$1–\$5

D. Costs

For both platforms, is possible to find into the market, end-device hardware with low prices from \$1 to \$3, in average. The connectivity subscription per unit is around \$1 per year, when applicable. Besides these items, there are other cost aspects like spectrum and network infrastructure that impacts an implementation [8], [9]. Table II shows a comparison for these topics.

IV. COMPARING THE PLATFORMS

Some relevant aspects for an IoT project will be compared, considering the presented Sigfox and LoRa characteristics as show in Table 3. The compared characteristics are:

Implementation time:
Necessary time until to get the project on production;

Initial investiments:
Initial monetary resources to create the IoT infrastructure;

Adaptative Data Rate (ADR):
Configurations to adjust the size of the message, and control the coverage range of the devices impacting on the power consumption;

Uplink messages:
Messages sent from the end-devices to the network server;

Downlink messages:
Messages sent from the network server to the end-devices;

Maximum payload:
Maximum size of the uplink messages (in bytes);

Coverage and range of the gateways:
The maximum distance of communication between an end-device and a gateway in urban and rural areas.

In addition, other IoT comparison factors may be added [8]. These factors include the quality of service, battery life, latency, scalability, deployment and cost. The spider web diagram presented in Figure 4 summarizes the comparison between these factors for Sigfox and LoRaWAN low power wide area networks.

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TABLE III. COMPARISON OF SIGFOX AND LORA

	LoRa	SigFox
Implementation time	Higher	Lower
Initial investiments	Higher	Lower
Adaptative Data Rate (ADR)	Yes	No
Uplink messages	Unlimited	140 per day
Downlink messages	Unlimited	4 per day
Maximum payload	243 bytes	12 bytes
Coverage and range of the gateways	15 – 20 Km (Rural) 3 – 5 Km (Urban)	30 – 50 Km (Rural) 3 – 10 Km (Urban)

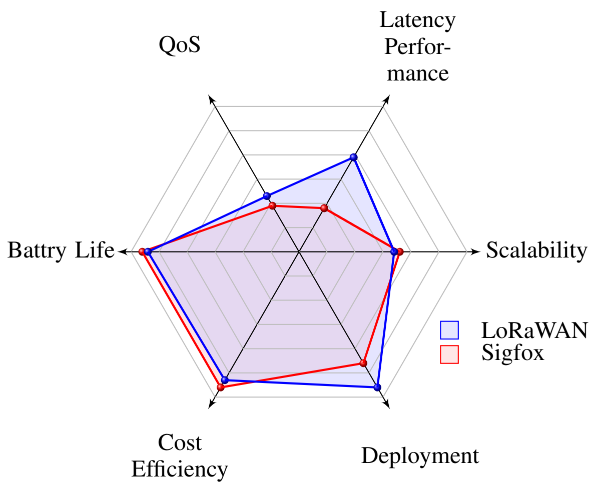

Figure 4. Spider web Diagram

V. CONCLUSION

This article analyzed and compared some aspects of LoRa and Sigfox low power wide area networks platforms. In all aspects, both platforms are very similar and could be used to implement forest fire detection and verification systems. However, Sigfox is limited in the regions of the world where the service is available. This is a great advantage showed by LoRa, because, if the system has to be implemented in a region where there is no LoRa public network available, the customers can implement their own networks. In terms of coverage, the considered area of the $6000\,\mathrm{km}^2$ could be covered by one or two LoRa base stations, based on the experience related in Belgium, where a LoRa network covers the entire country ($30\,500\,\mathrm{km}^2$) with seven base stations [9].

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