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INDUSTRIAL PARAMETERS MONITORING WITH LORA TECHNOLOGY IN NEXT GENERATION WIRELESS COMMUNICATIONS

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ABSTRACT

The growing development of advanced wireless communications and internet of things expanded its field of Applications improving the technology not only for people but to communicate Machine to Machine (M2M) and Industrial parameters monitoring.The most important communication parameters and design aspects like scalability, controller latency time andcost of the equipment design. So in this article we propose best ease of sending can be exploitedusing LoRa Nodes and as well as LoRa WAN gateway technology is introduces with low cost with low power consumption like in terms of micro amperes (µA) as the part of Industry 4.0. In this article we propose the characteristics and behavior models of LoRa and LoRa WAN Communications to monitor the industrial parameters monitoring in IoT Platform.To differentiate the outcomes, tests were acted in clear metropolitan conditions, where it was seen that the conditions inside the Commercial buildings and industrial Buildingsto establishment of the link with radio frequency (RF) conditions. At first, short-range situations (<100 m) have been considered in which a view is kept up between the transmitter and the Receiver. Nowadays the LoRa range evaluated very long distances like 8 Km to 15 Km without LOS (Line of Sight) with LOS to achieve maximum distances up to 100 to 150 Km range is possible. Finally we will control and monitoring the industrial parameters even long distances also with low cost with low power consumption.

Keywords: IoT, Cloud, Industry 4.0, LoRa,GPS, Cloud Platform.

1. INTRODUCTION

In the competitive industrial market, companies face the growing need to improve the efficiency of your processes, comply with environmental regulations and achieve financial goals. Due to old age of many of the industrial systems and dynamic manufacturing that forces the market, industrial automation systems low cost, are an alternative to optimize the productivity and efficiency. One possible option is proposing integrations to existing hardware (PLCs (Programmable Logic Controller) and Panel HMI (Human-Machine Interface)), without the need to update equipment or stop the process of production [1]. Traditionally, systems of industrial automation are carried out by wired communications medium (Ethernet industrial, RS-232, RS-485). However, these require expensive, invasive and complex lines, or it is even necessary to adapt systems when the hardware is outdated. The collaborative and spontaneous nature of wireless sensor networks (WSN, Wireless Sensor Network), provides great advantages over traditional systems wired monitoring and control, including auto organization, rapid deployment, flexibility and reduced cost. In this regard, WSNs have an important role in creating reliable systems and resistant that respond quickly to real-time events. In this context, current advances in low-power and long-range networks (LPWAN, Low Power Wide Area Network), and the implementation of embedded systems automation and data collection, have become more feasible for interconnection of the "islands" of industrial monitoring [2]. For industrial applications there are several alternatives. In some specifications like ZigBee and Wireless HART, IEEE standard is used 802.15.4 [3]. In LoRa technology, for its part, the specification is mostly used LoRa-WAN, although it is possible to also use the 802.15.4 standard. LoRa technology was developed by The LoRa-Alliance and has had a greater acceptance in the market in recent years due to its characteristics higher in parameters such as scope, robustness and low energy consumption [4]. A) Yes, LoRa technology is expected to also be satisfactorily adapt to requirements of applications focused on Industry 4.0 with LPWAN, a perspective opens different industrial, thanks to the launch continual of new equipment. Among these are those developed by the manufacturer stand out semiconductor company SEMTECH with its line of Long-Range Products (LoRa). LoRa makes use of advanced technologies spread spectrum using pulses linear frequency modulated band wide to achieve better frequency [5].

LoRa-WAN, for its part, defines the communication protocol (link layer data of the OSI model) and the architecture of the system, on the physical layer defined by LoRa. LoRa-WAN uses a star topology long-range in which gateways are used to switch messages between end devices (nodes) and the core of the network [6]. In a LoRa-WAN network the nodes can transmit the data to multiple gateways and not necessarily just one. In turn, each gateway will address the received packets from the end node to the network server, which can be local or it can be located in the "cloud". This is done through some kind of backhaul, traditionally via: GSM, LTE, Ethernet, satellite, or Wi-Fi [7]. Today the industry shows special interest in the connection of the physical part (floor equipment) and digital infrastructure, in order to optimize the production and provide interoperability to different entities involved, satisfying Industry 4.0 guidelines. In this work the evaluation is proposed of a LoRa-WAN network and its applicability in industrial environments. Campaigns were carried out of measurements, in addition to controlled tests in environments free of obstacles and sources of interference. The data collected shows than quality parameters: RSSI (Received Signal Strength Indication), SNR (Signal toNoise Ratio) and packet loss rate, show little degradation caused by equipment and machinery within the environments industrial, obtaining more favorable levels than in clear urban environments. The data acquisition was performed by a process sampling for each measurement point. The rest of the document is organized as follows. Section II analyzes the related jobs. In Section III a general review of the most relevant aspects of the LoRa physical layer and the LoRa-WAN protocol. For its part, Section IV presents the proposed methodology for evaluation. The Section V shows the results obtained and finally in Section VI the main conclusions of this work.

2. RELATED JOBS

In recent years, various jobs have been have focused on the technologies used to IoT deployments, recently highlighting LoRa and LoRa-WAN. Of the latter, in several works, its applicability has been analyzed and performance in environments with factors adverse to radio transmissions (interference, noise, and reflection). One of the main shortcomings of IoT technologies, is to provide data in real time. In strategies are described to optimize the access layer (MAC), both for regular broadcasts in real time and occasional non-periodic transmissions. For this, it seeks to synchronize the transmission of end nodes in order to avoid collisions.

These optimizations allow you to continue exploiting the advantages of WSNs, such as high scalability and reduced infrastructure, necessary for its deployment. On the other hand, in [8]the LoRa technology's ability to long-range communications, being possible to achieve maximums of up to 10 km with line of sight conditions. The work of shows how LoRa is long-range capabilities can be used in industrial applications short-range, in which the main mitigating is the interference produced by high power equipment. Performance of LoRa technology is not equivalent to that of wired systems, but with an error rate of packages close to 0.2%, this is shown as a solution for industrial systems not critical. Deploying a LoRa-WAN network inside the facilities of a military ship it is exposed in [9]. In this case, the conditions are adverse due to the metal frame that causes reflections of the signals of radio, plus no line of sight for the transmission of sensor nodes. The network achieved acceptable performance using a spreading factor (SF, Spreading Factor), with a value of 12. A rate of packet loss (PER, packet error ratio) less than 5% over a length of 110 m between ship compartments. In this studio, LoRa-WAN is presented as an alternative to deployment of copper or fiber optic cable, which in the case of ships it implies great complexity and high costs.

LoRa-WAN allows the network to be scalable and facilitates node mobility sensors. In [10] the performance of a WSN inside a mine. Is considered that this environment undergoes constant changes in its structure, in addition to variations in levels of gases, humidity and temperature. For Therefore, continuous monitoring is required, both of the machinery as of the conditions environmental conditions to which personnel are exposed. In such work reduces delay and latency in packet transmission. This improves the network performance in case of transmissions emergency, requiring the leastnumber retransmissions in the event of loss or errors in the packages. The capabilities of technology LoRa for long-range communications has been deeply analyzed in multiple jobs, achieving distances greater than 10 km with line of sight. For this, the networks base their architecture on a topology in star using the LoRa-WAN protocol. On the other hand, [11] analyzes that this type of network structure is dependent on the line of seen between devices, however, this does not It is always possible. Specifically, the work focuses on the detonation of explosives inside of mines using LoRa technology for the transmission in a multi-hop network, capable of overcome obstacles in uneven environments.

3. PROPOSED METHODOLOGY

3.1 LoRa and LoRa WAN Technologies

3.1.1 LoRa

LoRa is a type of modulation of CSS spread spectrum physical layer (Chirp Spread Spectrum) [12]. This modulation consists of the use of a chirp signal that varies constantly with frequency. This allows in a way that increases your capacity of resistance to interfering signals and also reduces signal fading due to multi-path propagation [13]. This in turn implies that, the nodes that are more close to the Gateway will have a data rate greater than that of the most distant nodes [14]. In addition, being an LPWAN standard it is possible reduce the effective rate of transmission of data when there are more communication ranges broad that require a more robust link as shown in figure 1 the LoRa node.

Fig.1. E32 EBYTE 868M Hz LoRa Node.

Low energy consumption and its powerful, make LoRa one of the standards most used in the development of Industrial IoT applications (IIoT). Which it's allows the devices used in this type of industrial developments increase your life time. However, in some LoRa cases have certain drawbacks in as for latency. At present, there are other protocols that could provide a lower latency and faster data rate high, for example NB-IoT (Narrow Band IoT) [15]. On the other hand, one of the biggest Advantages of LoRa lies in the use of a wide range of frequencies that do not require license, as they belong to the ISM spectrum (Industrial, Scientific and Medical). This facilitates interoperability worldwide [16].

3.1.2 LoRa WAN

The LoRa-WAN specification is a low power and long network protocol scope, LPWAN [17]. Its operation relies on low-power devices energy generally used in development of applications related to IoT and IIoT. A LoRa-WAN network has a topology known as Star of Stars (Star of Stars), composed of four elements main: end devices, gateway, a network server and an application server. The end devices are generally found made up of sensors or actuators, which share the information with the gateway acquired, making use of the LoRa physical layer. For its part, the gateway is in charge of receiving said information and share it with the server network via communication based on the IP protocol as shown in below figure 2 the LoRa WAN Single channel from DRAGINO Company.

Fig.2. Single Channel LoRa Gateway (DRAGINO).

The LoRa-WAN protocol has features that allow data to be collected in a single Gateway from multiple nodes located at different distances, even kilometers, through one-way communication [18]. However, in some cases it has been chosen by bidirectional communication between node and gateway, and there is also the possibility of have more than one gateway. The role of gateways lies in sending the information collected from each end device, raw, to a server network using a higher-end backhaul interface performance such as Ethernet, 3G / 4G, satellite or Wi-Fi [19]. For its part, the network server receives information sent in the form of packages from the nodes, it decodes them and performs its security protocol. In this way, each one of the applications running on the application servers, can receive the data from the network server, and can use said information at your convenience [20]. In Figure 3 you can see each one of the architecture components described. This LoRa-WAN architecture based in the star topology of stars allows ensure effective communication between all devices, in addition to generating a low power consumption in end devices.

4. METHODOLOGY

For the deployment of the LoRa-WAN network designed in this work, systems were used open source and low cost equipment, suitable for scenario conditions studied. Measurement campaigns are carried out in two industrial settings and two controlled environments, in order to contrast results as shown in figure 3 LoRa WAN Architecture.

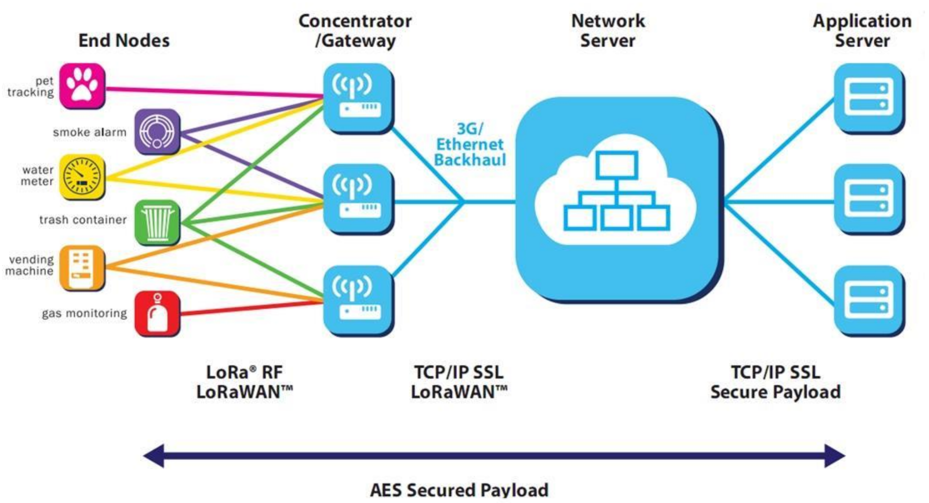

Fig.3. Structure of ESP32 Module.

Industrial scenarios count with different machinery and connections located inside metallic warehouses, while that the controlled scenarios are green areas free of obstacles, located in sectors urban.

4.1 Equipment

Heltec Wi-Fi-LoRa 32: The Heltec team Wi-Fi LoRa-32 is an IoT oriented device, designed and produced by Heltec Automation. The development board bases its operation on the ESP32 microcontroller and uses the SX1278 integrated chip for the functions of LoRa communication. These two devices interact through an SPI interface (Serial Peripheral Interface) [21]. Despite being designed to operate as a sensor node, the Heltec device can also be configured as a gateway LoRa-WAN, communicating to the server by means of the TCP / IP protocol. This limits its operation, preventing you from performing transmissions on the downlink to sensor nodes.

4.2 Raspberry Pi 3 Model B

Raspberry Pi 3 Model B Raspberry Pi 3 is a computer of reduced dimensions, originally designed for educational purposes by the Raspberry foundation Pi. Can support avariety of systems operating with an architecture processor ARM (Advanced RISC Machine). The computer has peripherals that include GPIO (General Purpose Input / Output), allowing communication and control external devices [22]. In this work we used the Raspberry Pi 3 model B, as network administrator LoRa-WAN and web server, for connection to applications and graphical interfaces as shown in figure 4 the Raspberry Pi Model B physical view.

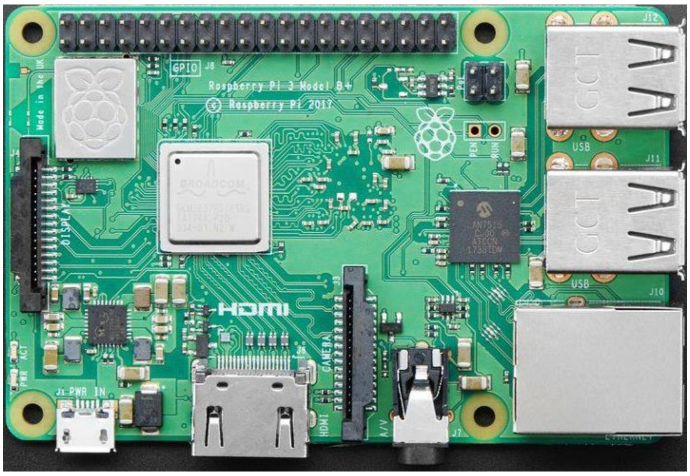

Fig.4. Raspberry Pi 3 Model B Development Board.

4.3 Equipment Layout

Figure 5 shows the block diagram of computers on the LoRa-WAN network. The sensor node is composed of a microcontroller in charge of collecting measurements of the environment, and communicate them through a port serial to Heltec Wi-Fi-LoRa 32 module for transmission through technology LoRa. In the gateway (receiver), it is used, as in the transmitter, the SX1278 module in the Heltec card. The data received by it is transmitted to the server by means of the Wi-Fi module. The server is mounted on the Raspberry Pi, which complies with both LoRa-WAN network administrator functions as the web server role for the interface of user as shown in figure 5 the sequence flow diagram.

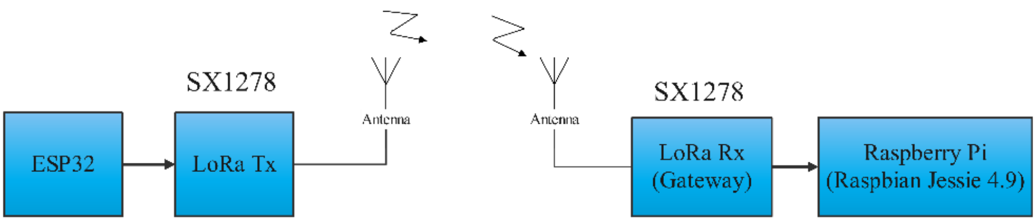

Fig.5. Equipment block diagram.

4.4 Equipment Configuration

Equipment configuration used in this work is based on the LoRa Alliance [23] guidelines for topology of a LoRa-WAN network. In the cape physical, a frequency of 433 MHz is used, using SEMTECH's SX1278 chip, both for the transmitter as well as for the receiver. The network server was mounted on a computer Raspberry Pi for network management.

- ***Sensor Node:***The data to be transmitted from the sensor node are recompiled via an Arduino NANO board connected as a peripheral via a serial port to the Heltec Wi-Fi module LoRa 32. Information from sensors and peripherals is encrypted using the method Cayenne LPP [24]. This in order to reduce message size (payload) and send various measurements by message. The ESP32 microprocessor the Heltec card handles the SX1278 chip and transmission parameters as well as security credentials.

- ***Gateway:***The SX1278 chip on the card Heltec Wi-Fi LoRa-32, takes care of receive LoRa transmissions. These are processed by the microcontroller ESP32, which packages and transmits them over the IP network using your Wi-Fi module integrated. The programming was based on the [25] work for a channel gateway simple.

- ***Server:*** The LoRa-WAN server is mount on a Raspberry computer Pi 3 model B. A MQTT server for communication with external applications and a web server for the user interface. The server and the gateway communicate over a Wi-Fi network. The data processed by the server are stored in a database at .csv format.

5. SCENARIOS

The contribution of this work focuses on evaluate the behavior and applicability of LoRa technology in industrial environments therefore two facilities were chosen with different machinery and production processes. The measurements were developed keeping a line of sight between the sensor node and the gateway. Additionally, controlled tests in two environments free of obstacles and sources of interference.

5.1 Industrial Environment 1

The warehouse main industrial environment 1 (KL University) has an approximate height of 20 m, a length greater than 150 m and consists of two levels. On the ground floor are located, in its most high power motors (50-120HP). Furthermore, this surface functions as area storage and product preparation finished. On the upper floor there are two lines production lines spread throughout the warehouse. Both floors are divided by a central corridor that communicates the environments and allows access to machinery. For the first group of tests in the upper floor, the gateway was placed on the south end of the corridor, shown in Figure 6, with a height of 1.5 m from the ground, while the sensor node was located at different distances along the corridor (Figure 6). On the second floor of the ship main, the gateway was placed at the southern end at a height of 1.5 m above the ground, and the node was placed a distance of 90 m from the gateway.In measurements upstairs and low, he kept a line of sight between the sensor node and the gateway. In the areas of measurement, a reduced traffic of people and heavy machinery (forklifts). It is important to mention that due to the security restrictions, it was not possible perform measurements within the limits of the production lines.

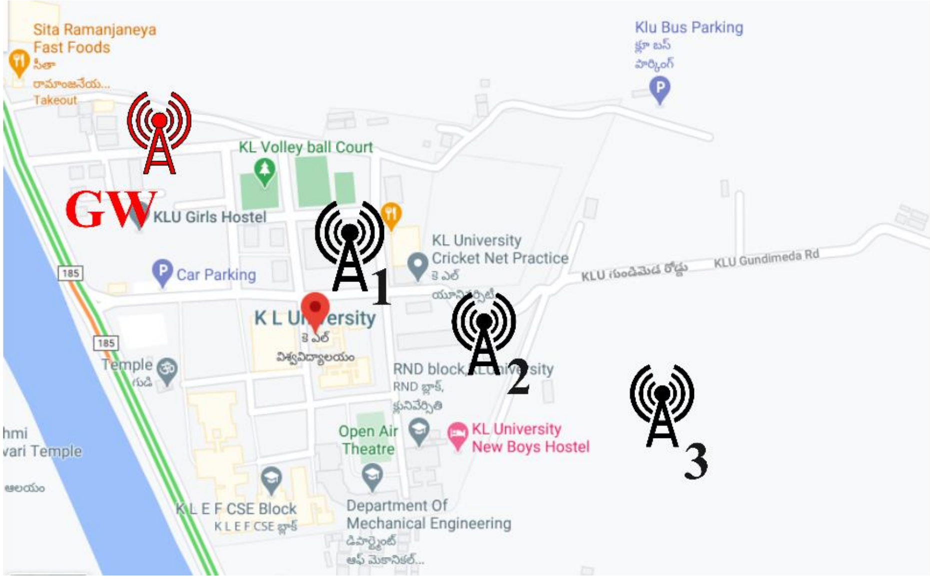

Fig.6. Distribution of the industrial environment 1.

5.2 Industrial Environment 2

Factory of industrial environment 2 (KL University) is made up of a main ship divided into two wings as shown in Figure 7. Each of these has a length greater than 100 m and an approximate height of 20 m. The factory consists of several lines of production, in which each stage of the process is has a different machinery, having as main actuators to high-speed motors power (50-120HP).

Fig.7. Distribution of industrial environment 2.

The gateway was located in the second plant of the technical area offices to a height of four meters from the ground. From this point it was possible to maintain a line view to node locations sensors.

The first group of tests was performed in the north wing, placing the sensor node at a height of 1.5 m above the ground. In this part from the factory there is moderate traffic personnel and forklifts, while there is a large amount of machinery to production and packaging. The second group tests were carried out in the south wing, locating the sensor node at the east end of the ship, and keeping the gateway position as in the previous measurements. In this part of the factory, the production machinery has variable heights, reaching up to 10 m in height. In the south wing, the transit of personnel and machinery is reduced.

5.3 Open Urban Environment 1

The Control tests were performed in order to contrast them with measurements in environments industrial, and evaluate their variations. He was chosen the urban environment area 1indicated in the Figure 8. This shows an extension in a KL University Vijayawada campus, without obstacles and a low gradient, allowing you to maintain a line of sight from the sensor node to the gateway.

The gateway was placed at a height of three meters and the sensor node was located different distances as shown in the Figure 8. In the vicinity of the park there are no visible interference sources (machinery, cell towers, and HF antennas). The traffic of pedestrians was reduced during the period of the tests.

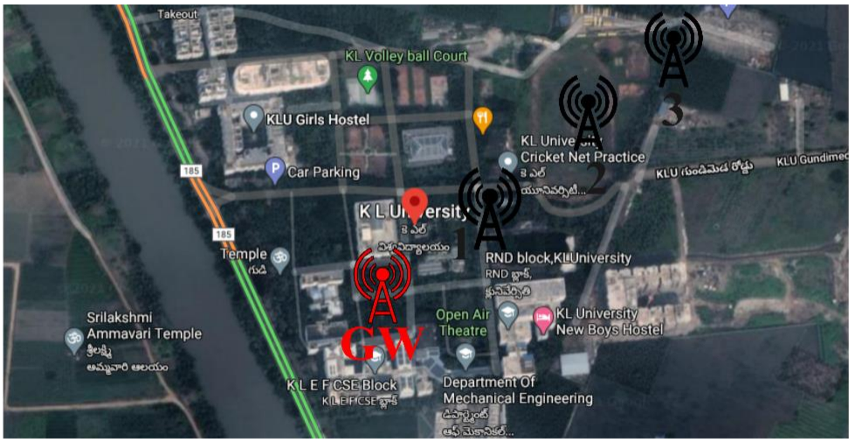

Fig.8. Open Urban Environment 1.

5.4 Open Urban Environment 2

The second control test was performed in another Location in the KL University Hyderabad campus, located in an urban area southeast of the city of Cuenca. The park has an approximate length of 130 m and a gradient reduced by allowing to maintain a line of view between the gateway and the sensor node.The gateway was placed at the end south of the park at a height of 3 m. The node was placed at different distances at a height 1.5 m as shown in Figure 9. In the vicinity of the property no sources of interference were present. The pedestrian and vehicle traffic in the area was moderate.

Fig.9. Open Urban Environment 2.

5.5 Procedures

The measurement processes consisted in sending packets from the sensor node (transmitter), maintaining a factor of spreading, SF of 7, and a frequency constant transmission of 433.175 M Hz. used a power value of 16 dB, the maximum allowed by the chip. The transmitting equipment is placed at a height of 1.5 m above the level of the ground. The gateway was placed at different heights to maintain a line of sight with the sensor node, this depending on the environmental conditions, as indicated in Section IV-E. At each point 100 packages, of which the RSSI was collected, the SNR and packet number to determine loss percentage. Due to the limitations of the equipment used could not vary the SF, as well as jumps of frequency, because this is not supported by the receiver chip (SX1278) [26].

The transmitter and receiver were equipped with a 1 dBi gain antenna and powered by lithium batteries connected to the respective micro-USB connectors. The factories in which the measurements in industrial environments limited access to the facilities, due to strict security measures. This reduced the amount of measurements and the points to be analyzed.

The wireless sensor network employing the LoRa physical layer and architecture LoRa-WAN was evaluated in two environments industrial with different facilities and equipment distribution. So also carried out measurements in two environments control, in which there are no obstacles or nearby sources of interference. Because that this is a work in progress, the results preliminaries of the first campaigns of measurement are presented below. The SNR results as shown in Figure 10 and RSSI as shown in Figure 11 collected by the server LoRa-WAN, show similar levels for the two industrial environments. This despite differences between your machinery and layout of its infrastructure. The values of SNR and RSSI are similar to those measured by in urban environments and by in environments forestry. In these cases, the levels for a distance of approx. 100 m border an SNR close to 10 units and the RSSI levels close at 80 dBm. SNR and RSSI values allowed a stable link in which the percentage of packet losses stayed below 6% for all cases as shown in Figure 12.

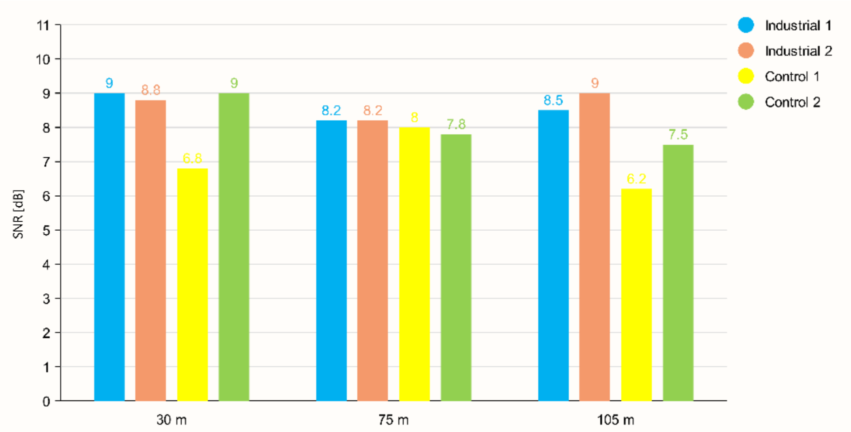

Fig.10.SNR results for industrial control.

In the measurements for the scenarios of control, equal parameters of configuration both in the sensor node and in the gateway. The SNR values obtained in control measurements show levels of noise higher than those obtained in environments industrial as shown above Figure 10. RSSI measurements indicate greater attenuation in all distances analyzed, this compared to the values obtained within the factories.

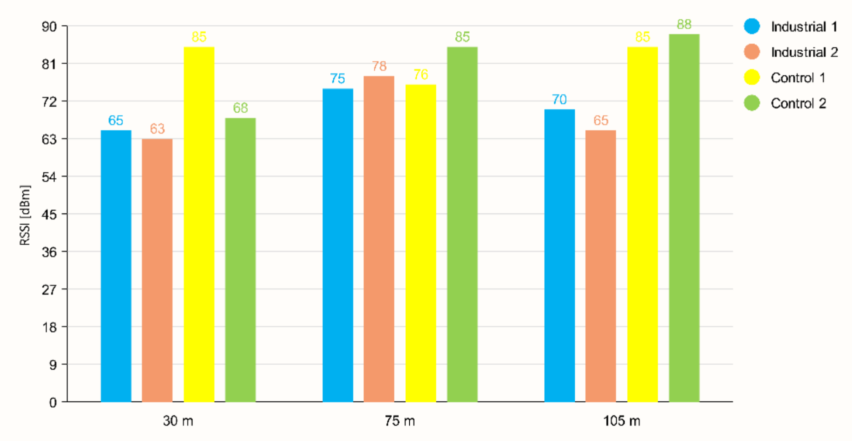

Fig.11.RSSI results for industrial control.

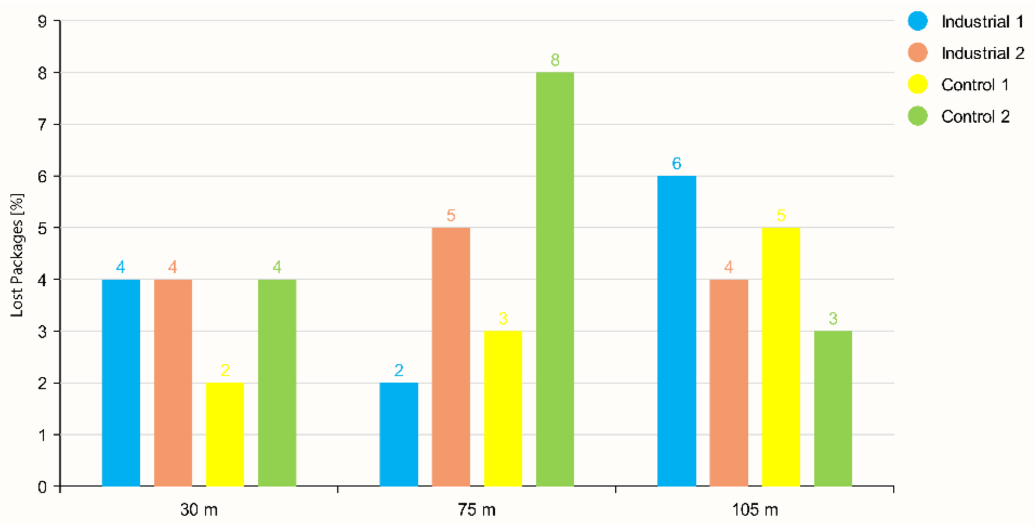

Fig.12. Packet Loss Rate Result.

Despite the conditions obtained in open urban environments, it was possible establish a stable link with loss of packages less than 6% in most cases. The SNR levels measured in the open industrial and urban environments, indicate possible signal overlap due to multi-path propagation. In industrial settings, this overlap seems to constructively affect the signal received, due to dimensions and materials of the industrial buildings where they were carried out tests. In the case of the parks of the open urban settings, an overlap with cancellation effects, causing the low SNR levels measured. The park chosen as the second scenario urban open, showed better levels of SNR and RSSI, in contrast to the first scenario of control. The second park had a less clear area, being surrounded by a residential urban area. These conditions less affected the lag and delay of the signal. Due to the limitations of the equipment employees, only a SF of 7 was used, according to this configuration allows great sensitivity for the purposes of multi-path propagation in a Rayleigh channel.

6. CONCLUSION

The first results presented in this work show important evidence of the applicability of LoRa technology and LoRa-WAN architecture, in communications short range for industrial environments. WSN provides robustness and scalability suitable for event monitoring recurring and random influencing production and maintenance processes. Low cost, low complexity and security of sensor nodes and gateways, facilitate their deployment and interoperability, without need for an existing infrastructure.

Sources of noise and interference (three-phase AC motors, high connections voltage, metallic structures, WAN networks) identified in test environments, not significantly influenced the quality of the link, even though both the sensor node as the gateway were located at nearby heights at ground level. The parameters of SNR, RSSI and PER, show little degradation in the quality of the link within industrial environments analyzed. In contrast, in the tests control, it was observed that the environments open urban 1 and 2, have levels considerably higher SNR, and values. Similar to RSSI and PER. This leads to intuition that the metal warehouse of the factories attenuates interference and noise from outside, as well as reduce destructive effects of spread multi-path, to which the link is more sensitive configured with an SF of 7. SX1278 chip met the transmitter functions satisfactorily at the sensor node. Being configured as gateway, the reliability of the Heltec card chip Wi-Fi LoRa, may decrease, due to not it is designed to fulfill these functions. In future works they will be complemented the initial measurement campaigns, analyzing control scenarios in greater detail and the number of packages and repetitions per measurement. The analysis is also appropriate of multi-path dispersion effects inside warehouses and metallic structures like this as in urban environments, especially for SF higher than the one analyzed in this work. Other aspect, it would be to evaluate the location of gateways at higher levels in industrial buildings that provide a line of sight from any facilities point. This job too is a first step in evaluating the feasibility of implement concrete industrial solutions based on LoRa technology in industries local.

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