The Implementation of a Solution for Low-Power Wide-Area Network using LoRaWAN

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***Abstract*—In recent years, there has been an increasing emphasis on low-power wide-area network also knowns as LPWAN (Low-Power Wide-Area Networks) technologies that allow efficient and fast data transfer, thus desiring a large-scale integration of various devices facilitating long-distance communications in various fields such as agriculture, logistics, or infrastructure. This category of technologies includes SigFox, LoRa, NB-IoT and others. One area where these low-power technologies can be used successfully is agriculture, in which monitoring the humidity and temperature are crucial. The social-economic context of 2022 highlights as one of the main priorities the security of the food and the raw materials provided by the agriculture field, so the desire is to obtain a large, efficient, and traceable production. Starting from this context, in this paper an architecture based on LoRa (Long-Range) technology and the LoRaWAN protocol it is proposed. We will place special emphasis on monitoring the extremely important parameters in agriculture, namely temperature, humidity and pressure. Although there are multiple works of research in this direction or in similar directions in other fields of activity, we should mention that each of them focuses on certain strictly geographical area and most of the times the results are purely theoretical. The gain that comes with this paper consists first in the fact that there is a practical support implementable and secondly the solution described can be adapted to different geographical regions. Moreover, at the end of this paper, we will focus on the comparison and analysis at the architectural level of two LPWAN technologies, namely SigFox vs. LoRa implemented in the same context in order to find the best results.**

Keywords*—LoRa; low-power; LoRaWAN protocol; SigFox; LPWAN

I. Introduction

In the current social and economic context, the field of agriculture is once again proving to be an area of great global importance. With the onset of the COVID 19 pandemic in 2020, agriculture returned to the table of global discussions and thus brought up the issue of crop efficiency and how agriculture is divided globally into different production sectors. The main problem that deepened in this sector started with the COVID 19 pandemic and was related to the food supply chain and the level of agricultural productivity in each country [1]. Another problem facing the agricultural sector today is related to the military conflict between Ukraine and Russia. Both countries have a critical role to play globally in producing cereals and vegetable oils. Thus, with the sanctions imposed by the West on Russia and the fact that Ukraine can no longer export and produce the usual quantities of agricultural products [2], we can say that agriculture needs particular attention, and the need to research in this field is justified. Investments in research in this field usually have technologies such as the Internet of Things (IoT) as a starting point.

When we refer to the IoT, we refer to the billions of devices interconnected by certain communication technologies that ensure the collection and exchange of data between them remotely without the need for a person's direct presence or intervention. IoT includes the family of low-power wide-area networks (LPWAN), which consists of several technologies such as LoRa, SigFox, NB-IoT (Narrow Band - Internet of Things), LTE-M (Long Term Evolutions for Machines), and so on [3]. These LPWAN technologies aim to reduce or even cushion the disadvantages of traditionally used communications networks, such as Zig-Bee, WiFi, Bluetooth, or even LTE. The applications of LPWAN technologies cover a wide range of fields. Still, the main ones are agriculture, logistics applications, infrastructure monitoring, personal and commercial applications, medical, etc. LoRa is a complex technology composed of two main components. The LoRa alliance [19] specifications present these components as two distinct levels: the physical LoRa level and the MAC protocol level, namely LoRaWAN [4].

A. LoRa Physical Layer

LoRa is based on a radio modulation technique developed and patented by Semtech [5], which operates in the unlicensed spectrum of frequency bands. This technique is used especially when the power consumption is low and extended coverage is needed. The name refers to the long-distance data links covered by this technology. LoRa is one of the best choices when communication requires a very high range. LoRa covers up to 5 km in urban areas and 15 km or more in rural areas.

A vital feature of this type of technology is that it does not require considerable power resources, so devices that are operated on batteries can be used. The energy needed to transmit a data packet is very low, and this is because the data packets are small and are not transmitted continuously but only a few times a day. Moreover, when the end devices are asleep, the power consumption is of the order of mW and thus allows the operation of the same battery even for several years. LoRa uses the proprietary of spread spectrum modulation technology derived from Chirp Spread Spectrum technology, providing a trade-off between sensitivity and data rate while operating in a 125 kHz fixed bandwidth channel. In addition, LoRa uses orthogonal spread factors. This technique allows the network to preserve the battery life of connected end devices by making adaptive optimizations based on each node's power level and data transmission at the individual level. The higher the spreading factor, the higher the processing gain and the reception sensitivity, but the data transmission rate will undoubtedly be lower [4][5].

B. LoRaWAN MAC Layer

LoRaWAN is standardized by the LoRa Alliance and defines a MAC protocol and a system architecture for networks based on the physical LoRa layer. LoRaWAN provides an environment access mechanism that allows multiple end devices to communicate with a LoRa modulation gateway.

LoRa communications networks operate under a star-like topology where communication between end-devices and a central network server is done through gateway nodes that transparently transmit messages. The final devices communicate data taken from sensors to gateways, and these gateways will connect to a server through a network connection other than LoRaWAN. Usually, this connection is made through the WiFi protocol. Communications are bidirectional under this protocol, and uplink messages have priority. The LoRaWAN protocol operates in the free frequency band, between 863MHz and 870 MHz in Europe and 433 MHz in the United States [4].

In Fig. 1, it is presented the main stack layers of the LoRa architecture that are related to each other and how the ISM bands are used based on the geographical area. The Application layer does not directly relate to the MAC layer and the physical layer, so it is realized at a higher level based on the data saved on the server.

This paper presents a study about LoRa architecture with practical implementation in agriculture. Section II reviews state of the art in this area, while Section III describes the architecture we proposed. In Section IV, we made a comparison about LoRa vs SigFox, and the conclusions are drawn in Section V.

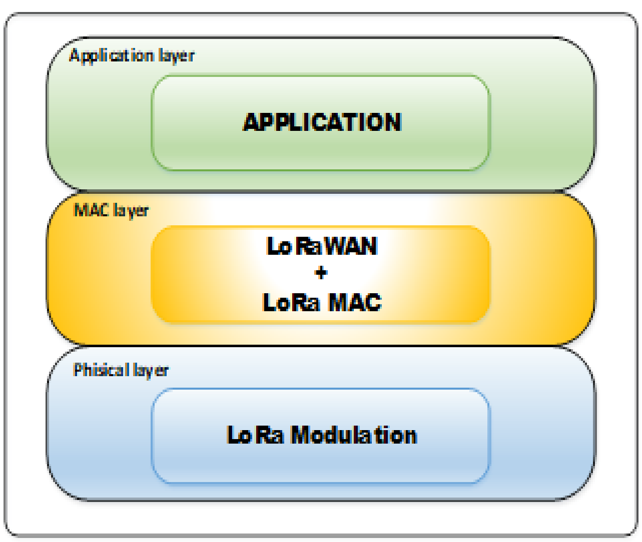

Fig. 1. The Main Stack Layers for LoRa Architecture.

II. Related Work

Integrating IoT technology into agriculture is not new; it has been introduced and implemented repeatedly but not on a vast scale but usually at the prototype level. The geographical areas with the greatest need for these technologies typically do not have people specialized in this direction or financial support. Interest in IoT technologies in agriculture has continued an upward trend in recent years, evidenced by outstanding research. One such work is [6], where the authors implemented a system based on a WSN architecture. In this paper, the researchers focus on real-time monitoring of temperature, light intensity, and humidity parameters. Once collected, this data is transmitted further through the LoRa-based gateway, and then visual processing and tracking are performed using a cloud tool. They concluded that the proposed architecture did not cover more than 600 meters following their research.

In [7], Klaina et al. propose a multi-scenario-focused approach to large-scale monitoring using multiple LPWAN technologies. This paper focuses on a network of sensors and various communications links. These sensors are mounted on both tractors and farmers. They came up with this proposal to evaluate and improve the equipment's performance and to monitor and manage them as efficiently as possible. At the level of this paper, different data links were tested to take into account the impact of soil, spatial distribution and infrastructure elements present. Their study showed that LPWAN networks provide better performance in the range covered. Still, better communication links were observed than in the traditional ZigBee network.

The study by Miles et al. [8] presents an evaluation of the performance of a LoRaWAN network using an NS-3 simulator. The authors propose and validate in this paper a mathematical model that focuses on estimating as accurately as possible the successful delivery of data packets on the network presented in a pilot farm starting from the transmission intervals and the number of nodes that make up the network. The conclusion they reached after conducting this study, consisting of a single network gateway and up to 1000 nodes, is that the proposed LoRaWAN architecture is suitable for various implementations in agriculture.

The performance and implementation of LoRa technology are not limited to agriculture, so there are many areas in which this technology has been successfully addressed. An example of such an implementation is made in [9], which proposes a street lighting monitoring system in a smart-city approach. Remote management and control of LED lights are done through LoRa technology. In another research paper [10], the authors propose a system for remote monitoring of forest fires in areas that are difficult to access through LoRa technology. The authors of this paper emphasize the importance of the distance covered by the system but also the reliability of the implementation.

Another proposal in which LoRa technology occupies a prominent place is the authors of Maftei et al. [11], in which a health application is implemented. In this paper, the authors designed a device to monitor the main health parameters such as heart rate, body temperature, blood oxygen saturation, and the battery level that powers this system. This information is transmitted to a gateway via the LoRaWAN protocol, and then this information is processed and stored in a blockchain network. The achieved conclusion of this study shows that the LoRa protocol can be integrated well into the remote healthcare system but also in applications based on blockchain technologies.

In this section we have noticed that the LoRa technology and LoRaWAN protocol have multiples areas of application but although each study adds to the whole research ecosystem it should be noted that there are gaps. Some of these would be the fact of the distance covered; can this technology cover the expected distance in the agricultural sector as well? Or the values remain valid only for other types of applications in different fields, so this paper addresses and disseminates this fact. Another question that arises as a result of the research is how accurate is the data? Thus, even if the data obtained in the mentioned studies fall within reliable data, in the agricultural sector there is a danger that depending on the device used, the data will not correspond to reality, so in this study, we want to combat this phenomenon.

III. System Description

To demonstrate the reliability of the LoRaWAN communications protocol in terms of implementation in agriculture, we propose a system architecture consisting of three main blocks: the final device or end node, the gateway, and the application server. The functionality of each component that composes our system will be described below.

A. The End Node

In our paper the development board from STMicroelectronics, namely the NUCLEO-L973RZ board [12] represents the end node. This board is especially notable for its low-power MCU. This tool can also be used with other development boards such as Arduino or other similar devices. In our case, we used this board together with the expansion board I-NUCLEO-LRWAN1 [13]. This board contains the LoRaWAN USI WM-SG-SM-42 module and the ST HTS221 temperature and humidity sensor but also the ST LPS22HB pressure sensor as well as the sensor that incorporates both an accelerometer and an ST LSM303AGR gyroscope; however, in this paper, we focused only on the use of the temperature and humidity sensor as well as the pressure one.

In Fig. 2, we can see the end node device, which is in use in this application.

LPS22HB [14] is an ultra-compact piezo resistive sensor that works like a digital barometer. This device consists of a sensitive element that detects absolute pressure consisting of a suspended membrane. By certain specific STMicroelectronics methods, which are not open-sourced, it measures the desired values and then communicates them further to the main application via either I2C (Inter-Integrated Circuit) or SPI (Serial Peripheral Interface) interface. LPS22HB operates at -40 ° C to + 85 ° C and can measure pressure values between 260 hPa to 1260 hPa.

ST HTS221 [15] is an ultra-compact sensor for measuring relative temperature and humidity, and it consists of a sensitive element such as a polymeric dielectric planar capacitor. The temperature detection range is between -40 ° C and +120 ° C, and a mixed-signal ASIC (application-specific integrated circuit) is used to transmit the measured information further to the main application via digital serial interfaces.

B. The Gateway

The gateway includes two boards supplied by the same manufacturer, namely STMicroelectronics. The first board is the NUCLEO-F746ZG development board [16], which is the support on which the LoRa protocol-specific gateway expansion board will be attached, developed by Semtech.

C. The Server

The server used in this implementation and to which data is transmitted through the gateway is from The Things Network (TTN) [17]. This IoT server is designed especially for the LoRaWAN protocol, being a free tool that promises maximum security, is used globally in over 151 countries and whose members exceed the number of 168 thousand.

D. System Functionality

For the application to become functional, each of the three main components has to be configured, so the software utilities offered by STMicroelectronics were used for the development boards, namely, STM32CubeProgrammer and STM32CubeIDE.

For the gateway configuration, the devices used must be set in gateway mode, a setting done by programming the firmware. This operation is done as seen in Fig. 3.

Once the gateway firmware is programmed, it has to be configured in such a way that the parameters related to the frequency in which the device will work match the geographical area we are located. At this level, particular attention should be paid to the MAC address parameter of the device. The address is required later in establishing the connectivity with the server.

Fig. 4 presents the main parameters of the gateway as seen from a connection to the TeraTerm terminal. In this terminal, we have the opportunity to modify the main specifications, such as the MAC address or the frequency band.

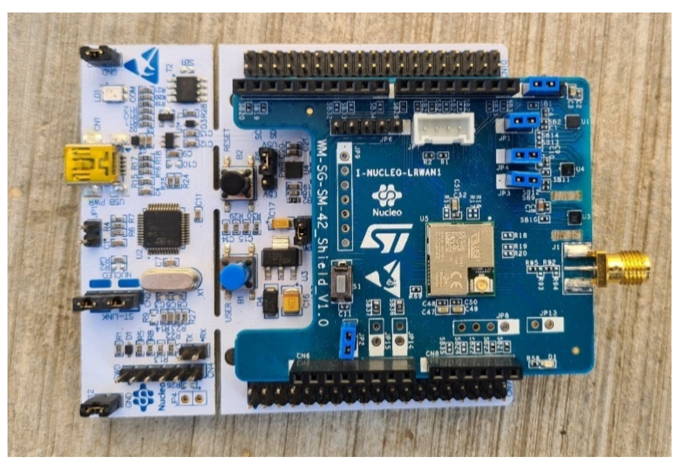

Fig. 2. The End Node Device used in this Application.

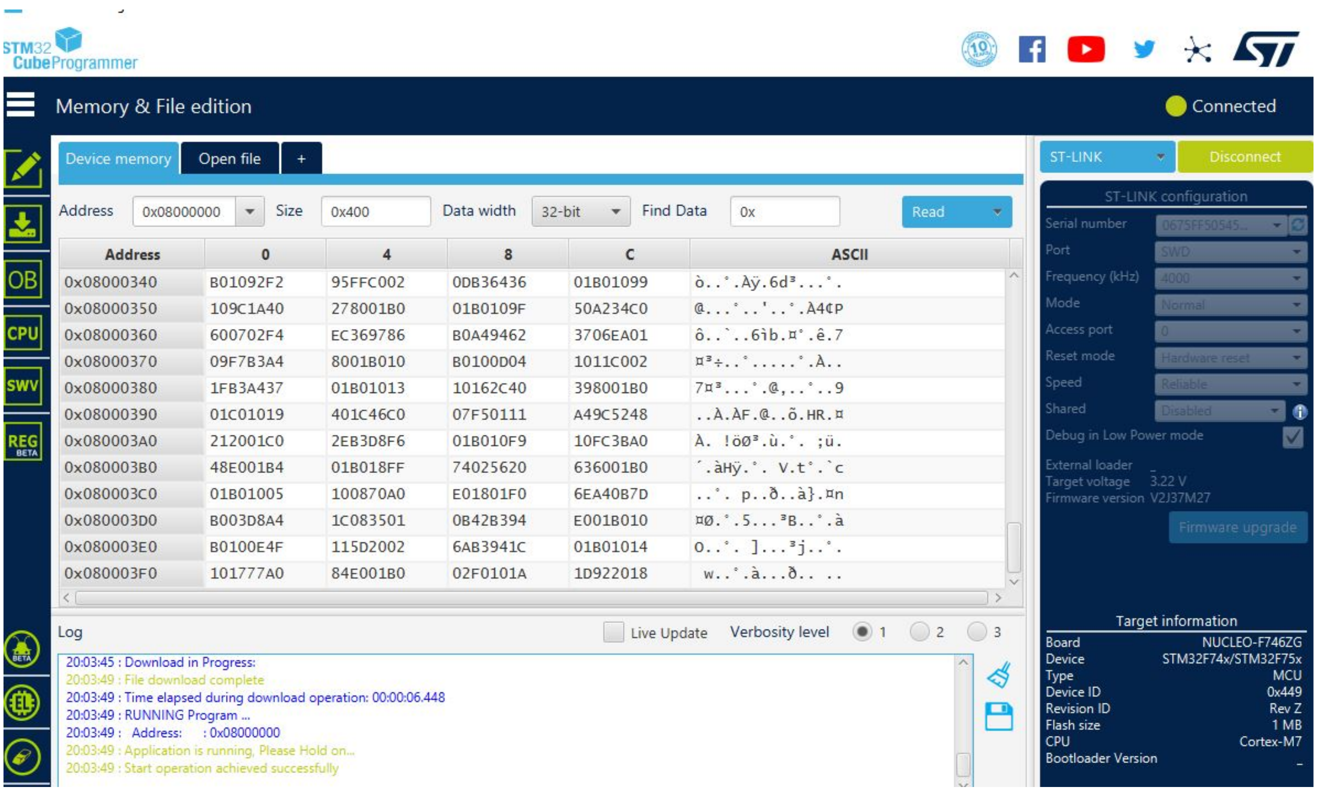

Fig. 3. The Firmware Programming in STM32 Cube Programmer.

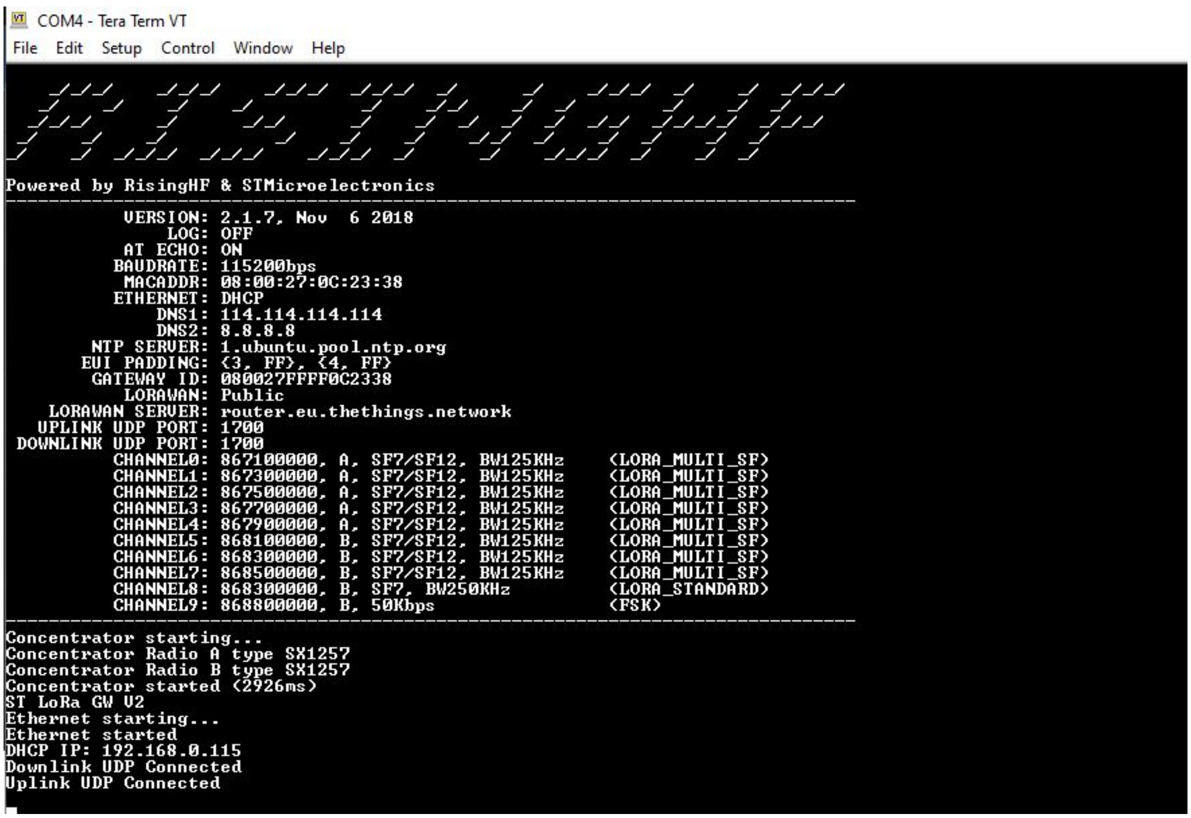

Fig. 4. The Gateway Configuration Terminal in TeraTerm.

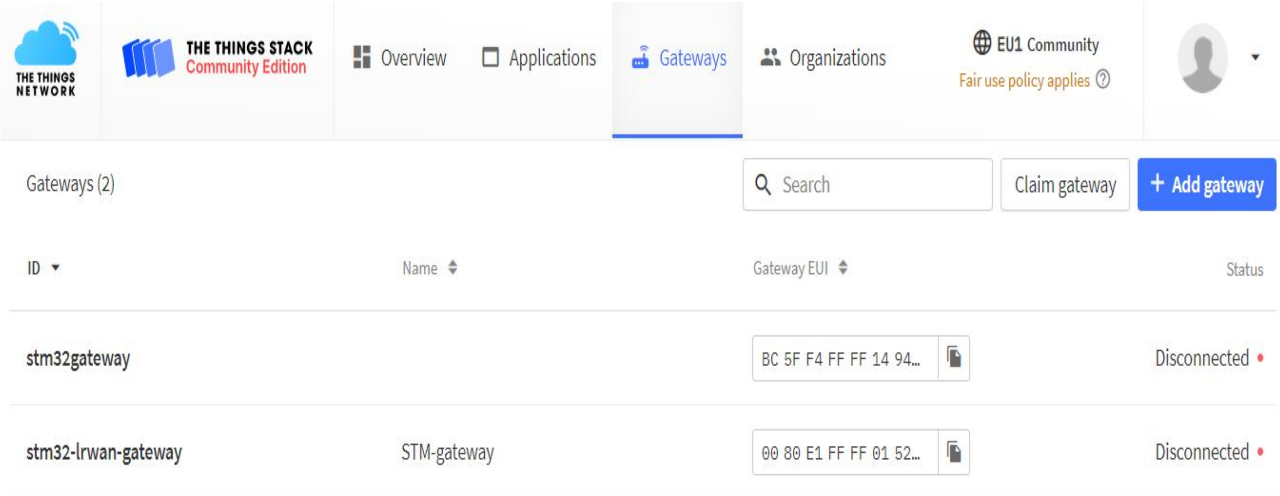

Fig. 5. The Gateways Registered on TTN Server.

In order to be able to connect the application to the server, firstly, it is necessary to create an account on the server site and then add a device either as an end node or as a gateway. After completing these steps and verifying the connection functionality, the values received from the end node located in the remote area can be viewed and processed from the final application in TTN.

In Fig. 5, it can be seen the main interface of the gateways registered on the server. Here we can add another gateway or end device, and we can see the status at the time being. The gateways are displayed based on the MAC addresses enrolled initially.

IV. LoRa vs SigFox

Both the LoRaWAN protocol and SigFox are part of the same category of IoT technologies, namely LPWAN technologies, but the principle of operation differs. Our paper started from the premise of using such a system in agriculture. In this paper and in the previous one [18], both devices were integrated into the environment, but the particular emphasis was placed on how the data was transmitted and processed.

Thus, after making and completing all the necessary connections, we could see a significant advantage that the LoRaWAN protocol has compared to SigFox, namely, the coverage.

If in the previous paper, due to our geographical position, namely the northeastern region of Romania, we could not connect the system to a gateway and then to the actual SigFox server, this time using LoRa, we were able to configure our gateway. We also connected to a server that would allow the recording and processing of transmitted data. In addition to connecting to an already created server, the advantage of LoRa is that with the necessary hardware components, we can create our own server and integrate it into an application.

In this study, the emphasis was on creating a complete system for the agricultural sector for implicit monitoring of the main factors influencing the evolution of various crops, starting with the network node or end device and creating the final application as a result of data obtained from the server. This system was created to see how the LoRa infrastructure, which consists of the LoRa modulation technique and the LoRaWAN communication protocol [19][20], relates to the environment in which it is used and the additional benefits that this technology brings.

V. Conclusion

In the introduction of this paper, we started from the premise of comparing it with another work conducted in a different paper in the same field of agriculture but which is based on a different communication protocol, namely the LoRaWAN protocol compared to the SigFox protocol. The conclusion we have reached is that LoRa technology has a clear advantage ensuring a better connection. Once a gateway is configured, the data transmission does not depend strictly on the manufacturer's servers, as in the case of the SigFox protocol. Still, it can use open-source servers or even you can set up your own servers.

Another aspect that should be mentioned is that using the development boards mentioned in this paper, STMicroelectronics offers considerable support when it comes to configuring, programming and viewing the code used in different instances of the application.

Finally, we can conclude that as a LPWAN technology, LoRa, is a reliable solution in the field of agriculture and offers advantages from superior to traditional technologies. Also, an important thing to note is that this protocol allows users from everywhere to contribute to the development of its effectiveness.

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