Smart Mobile LoRa Agriculture System based on Internet of Things

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***Abstract*—Agriculture represents the main source of food in the world, but it also represents challenges such as population growth, urbanization and aging, global economic growth, investment, trade, and food prices and competition for natural resources. The development of technology can help us cope with these challenges. The internet of things (IoT) technology represents the future of computing and communications. These can be useful to improve traditional agriculture methods around the world. By implementing these modern technologies is possible to reduce costs and maintenance and, to increase the performance of our agriculture processes and goods. Particularly, one of this relatively new technology is the LoRa communication protocol that uses long wavelengths for the communication link to obtain long ranges. This is extremely useful in agriculture where the communicating areas are extensive crop fields and greenhouses. This paper proposes and presents the development of a mobile LoRaWAN gateway device that can be applied to increase greenhouses' productivity and accuracy. The presented development includes the use of a Heltec's Mini LoRa Gateway controlled by a Raspberry Pi 3 B+. It is powered by an external Li-On battery and uses a defined number of LoRa nodes with sensors. Sensors will measure humidity and temperature and send the data, which are gathered by the mobile LoRaWAN gateway. These data are processed using third-party free online services. This document illustrates and explains the development and application of data collectors for agriculture and their advantages.**

Keywords—Internet of Things, LoRaWAN, mobile communication, precision agriculture, wireless LAN

I. Introduction

The IoT technology has the capability of influencing the world in which we live improving the industry, connecting vehicles, creating smart cities [1]. However, applying such technology to the agriculture industry, the impact can be even greater than in other fields. One of the current biggest problems is the world population and the food availability. The IoT technology can make a real improvement, but the success of the IoT requires a service provision attributed to ubiquity, reliability, high-performance, efficiency, and scalability [2]. There have already been studies of end-to-end reliability [3], in which their results have reflected a great reliability in simulations. Greenhouse agriculture is a methodology that helps to improve the quality of vegetables, fruits and crops using controlled parameters. The environment has controlled mechanisms using real-time data from sensors [4], and processing tools such as cloud computing to increase accuracy and efficiency [5-7].

The main improvement that IoT technology brings to the agriculture area. There are some models, such as the one that works together with image data analysis and MSM messages to send alerts [8]. In addition, some architectures are based in *low-cost* equipment and using meteorological stations [9]. Another popular architecture uses a three-layer model proposed in China which uses Bluetooth communication to capture the data from the sensors and send them to a smartphone. There, the data will be processed and sent to the internet using the 4G-telecom network [10], or any other smart monitoring systems [11]. The IoT technology is not only for agriculture, it can also be applied to monitor and improve animal's ecosystems [12] [13].

It is a challenge to cover a large area using IoT, as usually needs in agriculture and farming. To achieve a reliable communication, Low Power Wide Area Network (LPWAN) protocols such as LoRa are a great solution [14].

A new agricultural information technology, called intelligent agriculture has emerged in the past years, this proposes a service based on a wireless sensor network and LoRa [15]. In conjunction with LoRaWAN, LoRa, a long-range wide area network, is the upcoming candidate for low power and long-distance communication [16][17]. In order to mention some applications already implemented in the agriculture field using LoRa and IoT, a precision agriculture has been implemented in a tree farm [18], a monitoring system

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for starfruit plantations [19] and a power saving network for rice fields [20]. All of them require sensors to monitor wellbeing of the plants, trees and crops. The humidity and temperature are directly related to the irrigation of the harvest. There are some applications for implementing LoRa in smart irrigation systems [21][22], but none of these can reach wide areas or can work in any location.

Some solutions in the market can be compared in the website *The IoT Marketplace* [23]. This site offers some nice solutions like the Libelium-Evja Smart Agriculture Solution Kit which includes sensors that measure the relevant data like temperature, humidity, solar radiation and leaf wetness. The Fasal Smart Agriculture Basic Solution kit enables monitoring of environmental parameters in agriculture, vineyards, greenhouses or golf courses. These solutions transfer data using using 4G telecom protocol.

The main contribution of this paper is a monitoring system using LoRa technology for agriculture applications to obtain data from sensors located at a great distance through as a mobile LoRaWAN Gateway device.

The rest of the paper is organized as follows. Section 2 summarizes the prototype development of the IoT system. Section 3 presents experimental results and discussion about the proposal, and Section 4 concludes this work.

II. Development of the IoT System for Agriculture

The development of this smart mobile agriculture system requires the interaction of three key devices:

A. The mobile LoRaWAN Gateway.

B. The LoRaWAN sensor node.

C. The LoRaWAN network server

The key that differentiates this LoRaWAN network from any other is the fact that the gateway supporting the network will be completely autonomous and nondependent of any previous setup. It is possible to use the network while the equipment is in movement either walking or inside a vehicle. In addition, the main proposal of this development is the mobile capabilities of the LoRaWAN Gateway, which are the reason why this paper will be focus in more detail on the development of this device.

A. Mobile LoRaWAN Gateway

The mobile LoRaWAN Gateway block diagram is displayed in Fig. 1. It gives an overall idea on how all the different hardware blocks are assembled to work together as a single embedded system device. In the following paragraphs, each component is detailed.

- Raspberry Pi 3 B+

This is a single-board all-in-one computer powered by a Broadcom BCM2837 SoC with 1.4GHz 64-bit quad-core ARM Cortex-A53 processor. This board also has 4 USB 2.0 ports and the power consumption goes from 350 mA in idle condition up to 980 mA at the maximum operation load.

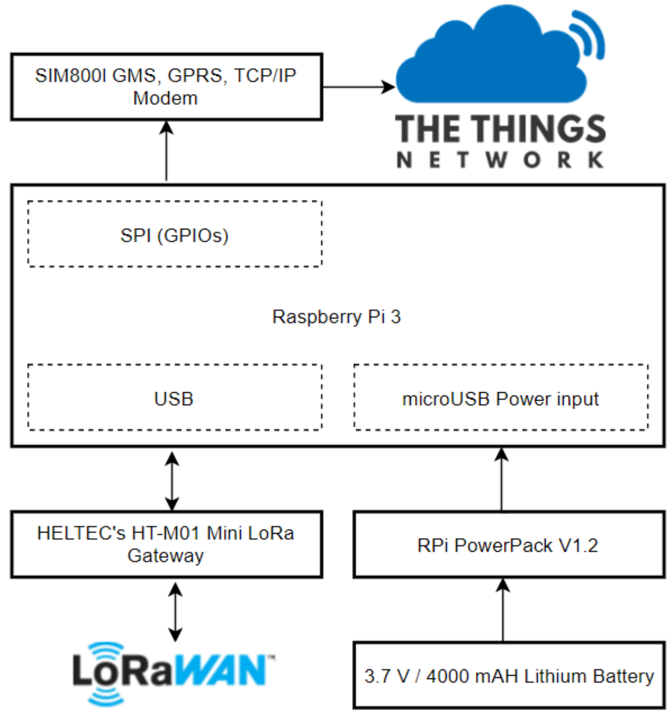


Fig. 1. Mobile Lora Gateway Block Diagram.

- HELTEC's HT-M01 Mini LoRa Gateway.

This will supervise the reception of all the data from the nodes in the LoRaWAN network and transfer the information to the Raspberry Pi 3 B+ for processing. The gateway uses a multichannel high-performance transceiver designed to simultaneously receive several LoRa packets.

The gateway also uses random spreading factors based on the SX1308 low power integrated UHF transceiver chip. This chip is a massive digital signal processor which integrates the LoRa Concentrator IP. It is designed for indoor applications with metal alloy housing and it is recommended to work below 40°C of ambient temperature. This will ensure that the ambient operating temperature of 70 °C is not exceeded inside the housing. The device is shown in Fig. 2.

This gateway has a power consumption of 153 mA when using 8 channels for listening in receive mode, which is the one in our interest.

The LoRaWAN protocol can be run through an external host processor which in this case it will share information with the Raspberry Pi 3 B+ through the USB port. In addition, it can support SPI communication protocol. The internet access will require the USB port of the Raspberry Pi 3 to communicate through the SIM800l module. The Fig. 2 shows the HELTEC's HT-M01 Mini LoRa Gateway.

Fig. 2. HELTEC's HT-M01 Mini LoRa Gateway.

- SIM800l EVB modem module.

This is a GSM/GPRS modem evaluation board which will provide internet connectivity to the Raspberry Pi using GPRS and TCP/IP based on the Quad-band 850/900/1800/1900MHz. The operating voltage range of the chip is from 3.7 to 5 V. In addition, it has a power saving sleep mode with a current consumption of 0.7mA. In order to work it requires a GSM cellular chip from any cellphone service provider. The communication supports a down-link/up-link transfer speed of 85.6 kbps, which is more than enough for the data required bandwidth. That data package is light, containing only some few numbers of bytes per package. The device is shown in Fig. 3.

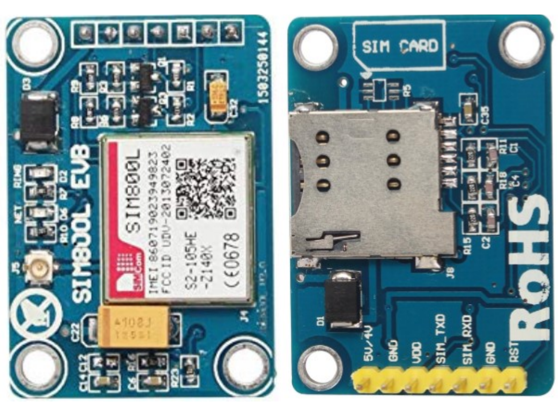


Fig. 3. SIM800l EVB back and forward.

- RPi PowerPack V1.2.

This module board is designed especially for Raspberry Pi 3 B+. Using this module, the Raspberry Pi 3 can be used offline for up to 9 hours with a battery capacity of 4000 mAh. Providing a maximum discharge current of 1.8A enough to power the raspberry Pi 3 B+, the HELTEC's HT-M01 Mini Lora Gateway (Fig 2) and the SIM800l (Fig. 3). The device is shown in Fig. 4.

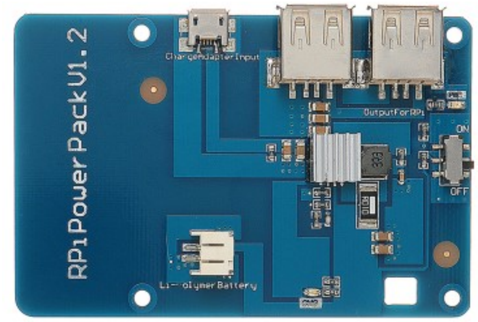


Fig. 4. Power Pack V1.2 Lithium Battery Expansion Board.

TABLE I. LIST OF CONSUMPTION

Component	*Consumption (mA)*
Raspberry Pi 3 B+	~ 500
HT-M01 Mini LoRa Gateway	~ 153
SIM800l modem module	~ 0.7
Total consumption	**~ 653.7**

Table 1 summarizes the total consumption of the whole system. If C is the capacity in amp-hours, x is the current delivered and T is time in hours:

$$C = xT \tag{1}$$

where when using the selected battery capacity (RP$_1$ Power Pack) and calculated total consumption:

$$C = 4000mAh = 653.7mA * T \tag{2}$$

so $$T = \frac{4000mAh}{653.7mA} = 6.119h$$

This means that theoretically, LoRaWAN is able to work for six hours. However, C is the capacity in a certain discharge condition, normally at 20h. If the current increases, the capacity decrease as well. The Peuckert's law, which is an empirical law, reflects this behavior [24]:

$$C = x^{\alpha}.t \tag{3}$$

where α is the Peukert' exponent, ideally is 1, and depending on the technology is higher than one. For Lithium-Ion batteries the range is between 1.02 and 1.12.

Other power sources application can be based on supercapacitors and photovoltaic panels to increase the autonomy of the nodes and the gateway [25][26].

In order to configure the gateway properly, it is needed to install the latest STM32F410CD MCU driver/HAL into the Mini Lora Gateway using the *dfu-util* package command, compile Semtech HAL which contains helper programs and the host driver that communicates through USB with any concentrator board based on Semtech SX1308 multi-channel modem and SX1257/SX1255 RD transceivers. The diagram in Fig. 1 and the prototype in Fig. 5 detail how the LoRaWAN works. Once the device is ready, the Raspberry Pi 3 B+ will work together with the Semtech Mini Lora Gateway.

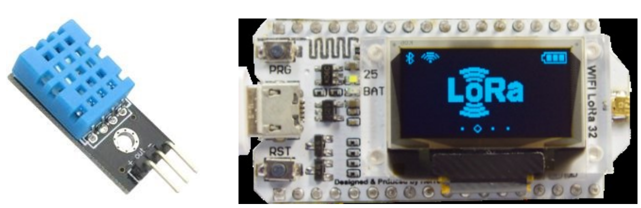
Fig. 5. Mobile LoraWAN Gateway prototype.

The Mini Lora Gateway will be receiving all the packages from all the in-range nodes and will send these to the Raspberry Pi 3 B+. Then the Raspberry Pi 3 B+, using the legacy Semtech's Packet Forwarder, will send the Mini Lora Gateway data to our online service from which it is able to access the sensor's data from Internet.

B. *The LoRaWAN sensor node.*

- DHT11 and Heltec's WiFi LoRa 32 node

A single node is a simple device that uses the DHT11 sensor and delivers the sensors data in a digital format to the network node (Fig. 6.a). In the proposed system, WiFi LoRa 32 (V2) was used which supports WiFi, Bluetooth and LoRa and provides exclusive LoRaWAN protocol source code running on ESP32. It is highly integrated with a very low power consumption design (Fig. 6.b). The node diagram illustration is shown in Fig. 6.c. The Heltec's WiFi LoRa Node prototype is shown as Fig. 7.



(a) (b)

Fig. 6. (a) DHT11 and (b) Heltec WiFi LoRa 32 node

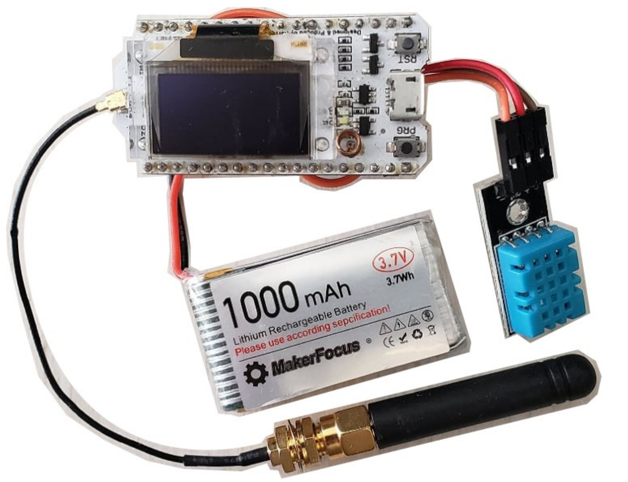


Fig. 7. Heltec's WiFi LoRa Node prototype.

C. *The LoRaWAN network server*

- LoRa 32 node and The Things Network

The Things network is a free, community-owned network for IoT that uses LoRaWAN technology to allow things to talk inside internet without 3G or WiFi. For this reason, this is the selected platform to use. It allows, by the creation of an account, linking and connecting any LoRaWAN gateway or node.

To connect the Mini Lora Gateway, it is necessary to know its *External Unique Identifier*, or *EUI*. This is a unique, human-readable identifier for the gateway. For the purpose of this development and the fact that the Mini Lora Gateway is using the legacy Semtech Packet Forwarder, it is required to use the 16-digit hexadecimal number embedded in the gateway's firmware. It is also necessary to define the frequency of operation of 915 MHz and the router's gateway should be connected to the close router location, for this case: *ttn-router-us-west.* It is also necessary to define an application in which the node device will be registered. After that, the node device must be registered using the identification values defined for the Semtech SX1272 LoRa Mbed Enabled Shield firmware. Once the application is defined, the *LORAWAN_APPLICATION_KEY* value will be assigned and the LoRa module firmware must be modified with this value and re-compiled. This will ensure that The Things Network will identify the node device and communicate properly with it.

After this configuration, the Mini Lora Gateway, the Heltec's WiFi LoRa node and the IoT platform are working together and it is possible to send information to the network and be received by the gateway which will then send this data to internet closing the IoT platform.

III. Experimental Results

The main improvement over another smart agriculture system is the mobility. The idea is to have a wide area network of sensors installed in big area and being capable of reading all the sensors in one kilometer around the mobile LoRa Gateway. Using this technology, it is possible to have the gateway in the car or in a backpack and just being reading all the sensors data around as shown in Fig. 8.

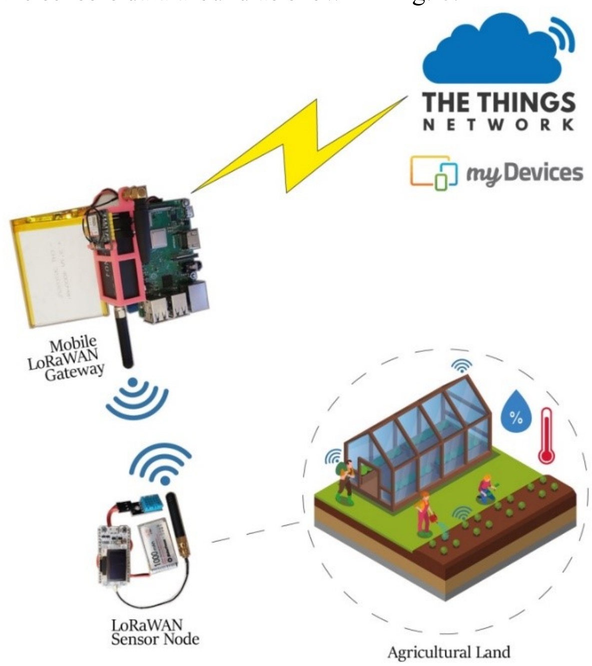
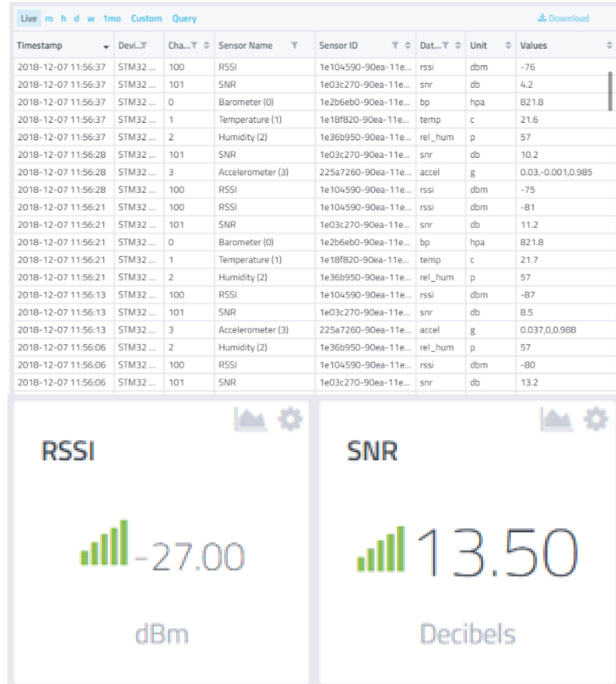


Fig. 8. Smart mobile LoRa Agriculture System.

Fig. 9 shows the results from Cayenne dashboard, these values were taken from The Things Network. The results are consistent, the device is capable to communicate to the mobile LoRa Gateway and the sensor nodes. Still there are a lot of improvements to be shaped, for example the range of the communication can be extended.

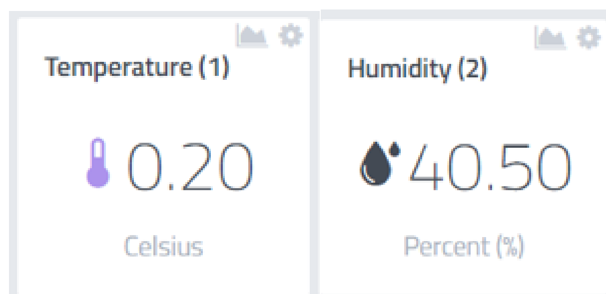
The LoRa communication was successfully tested in an open field within ~300 meters without any problem. This will be extended and tested in future works. The LoRa Gateway uses a 4000 mAh battery and each node uses a 1000 mAh battery. The battery was tested, and it has been working during to nine hours. The node duration was not evaluated but it should last for a week at least when having low consumption mode enabled. Although there were some issues when testing long distances, as a low GPRS signal in sending data to the server and batteries without full charge previously, and it was found that the antenna used for the mobile LoRaWAN Gateway did not meet the expected results, this is a 915MHz 2-3 dBi gain not was designed to perform in outdoor environments. It is expected to obtain better results once the antenna is replaced with a dedicated omnidirectional fiberglass antenna with at least 10 dBi gain.

These issues must be addressed and resolved for future field tests and future developments. The sensor lectures were accurate, and the values have been reflected in the Cayenne dashboard without losing accuracy.



Timestamp	Devi...	Cha...	Sensor Name	Sensor ID	Dat...	Unit	Values
2018-12-07 11:56:37	STM32 ...	100	RSSI	1e104590-90ea-11e...	rssi	dbm	-76
2018-12-07 11:56:37	STM32 ...	101	SNR	1e03c270-90ea-11e...	snr	db	4.2
2018-12-07 11:56:37	STM32 ...	0	Barometer (0)	1e2b6eb0-90ea-11e...	bp	hpa	821.8
2018-12-07 11:56:37	STM32 ...	1	Temperature (1)	1e18f820-90ea-11e...	temp	c	21.6
2018-12-07 11:56:37	STM32 ...	2	Humidity (2)	1e36b950-90ea-11e...	rel_hum	p	57
2018-12-07 11:56:28	STM32 ...	101	SNR	1e03c270-90ea-11e...	snr	db	10.2
2018-12-07 11:56:28	STM32 ...	3	Accelerometer (3)	225a7260-90ea-11e...	accel	g	0.03,-0.001,0.985
2018-12-07 11:56:28	STM32 ...	100	RSSI	1e104590-90ea-11e...	rssi	dbm	-75
2018-12-07 11:56:21	STM32 ...	100	RSSI	1e104590-90ea-11e...	rssi	dbm	-81
2018-12-07 11:56:21	STM32 ...	101	SNR	1e03c270-90ea-11e...	snr	db	11.2
2018-12-07 11:56:21	STM32 ...	0	Barometer (0)	1e2b6eb0-90ea-11e...	bp	hpa	821.8
2018-12-07 11:56:21	STM32 ...	1	Temperature (1)	1e18f820-90ea-11e...	temp	c	21.7
2018-12-07 11:56:21	STM32 ...	2	Humidity (2)	1e36b950-90ea-11e...	rel_hum	p	57
2018-12-07 11:56:13	STM32 ...	100	RSSI	1e104590-90ea-11e...	rssi	dbm	-87
2018-12-07 11:56:13	STM32 ...	101	SNR	1e03c270-90ea-11e...	snr	db	8.5
2018-12-07 11:56:13	STM32 ...	3	Accelerometer (3)	225a7260-90ea-11e...	accel	g	0.037,0,0.988
2018-12-07 11:56:06	STM32 ...	2	Humidity (2)	1e36b950-90ea-11e...	rel_hum	p	57
2018-12-07 11:56:06	STM32 ...	100	RSSI	1e104590-90ea-11e...	rssi	dbm	-80
2018-12-07 11:56:06	STM32 ...	101	SNR	1e03c270-90ea-11e...	snr	db	13.2

(a)



(b)

Fig. 9. The Things Network Cayenne results (a) historical data, (b) front end screen.

IV. Conclusions

This paper proposed a monitoring system using LoRa technology for agriculture applications. It includes capturing data from moving nodes such as vehicles. The experimental results shows that this approach can help current agriculture processes, particularly in small farms and growers, due to the low cost and accuracy of the measurements of humidity and temperature.

This research built successfully a monitoring system with the mobile LoRaWAN Gateway device which can be accessed via any platform (desktop, smartphone) thanks to the IoT integration of the Things network and Cayenne dashboard. This monitoring network reduces the cost keeping accurate monitoring and mobility. As a conclusion, this is great starting point for creating more reliable and mobile solutions for the smart agriculture.

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