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Original Article

Smart Outlet: Smart Electrical Outlet with Device Identification Using NFC

João M. S. Alves[1], Johan S. L. Barbosa[1], Rafaela R. Souza[1], Sérgio H. M.S. Andrade[1]*

Avenida Governador José Malcher, 1148, Nazaré, Belém/PA—CEP:66055260

ABSTRACT

The residential electricity consumption tends to expand further and, consequently, stimulates the development of technological tools that allow to establish greater control of energy consumption. Embedded technology systems play an important role in the efficiency of a smart home by providing to users ways to optimize environment management. The implementation of technologies in the residential environment offer to residents a better quality of life and reduce expenses. Therefore, this paper proposes the development of smart electrical outlets able to identify the apparatus connected to them and make available to the user the detailed consumption of each device that was used through a database.

Keywords: *Intelligent Electrical Outlets; Energy Efficiency; Residential Energy Consumption; Smart Outlets; Smart Home; Smart Meter; Smart Grid*

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***CORRESPONDING AUTHOR**
Sérgio H. M.S. Andrade, Faculdade Estácio Nazaré, Brazil;
andrade.sergio@estacio.br;

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1. Introduction

The arrival of the Smart Grid concept has brought about changes in the relation between power distribution company and consumers[1]. The so-called intelligent electric grids involve technologies of control, monitoring, storage and communication, aiming to optimize the use of the available energy resource. Using smart meters and consumption data transmission, the Smart Grid can generate and transmit electric power efficiently, as well, make the process safer[2].

In this scenario of search for energy efficiency another important concept, in the context of intelligent electric grids, is that of *Smart Homes*. Where aims to provide comfort and safety to residents through technologies present in the residential environment that perform functions capable of managing the energy resources present in the environment[3].

The *Smart Homes* are allied with *Smart Grids* in the role of making home electricity consumption efficient, since with the arrival of intelligent power distribution grid the consumer becomes participative in this process, having access to their consumption and being able to take actions to control possible waste of electricity[4]. Therefore, a smart home would complement the process of efficient power distribution and consequently, it would also be able for making energy consumption rational.

Smart measuring elements are important devices that make up *Smart Homes* and *Smart Grids*, through these elements it is possible to measure, calculate and monitor multiple variables and consumable resources present in the environment, believing that through available information it is possible to control costs and prevent unnecessary consumption[5].

Therefore, the purpose of this paper is to develop an intelligent electrical outlet, that will able to identify the device connected to it through Near Field Communication technology (NFC) and will also composed of voltage and current sensors which will allow the measurement of electricity consumption for each equipment that is connected to the smart electrical outlet, making consumption information available to the user through a database, for a correct residential energy management.

2. Related Works

Smart outlets, within the electricity sector, have been developed aiming to optimize energy consumption and allow to consumers a greater control over energy consumption. In [6], was designed a smart socket based on the MSP430 microcontroller, which measures voltage, current, energy consumed, runtime and displays this information through an LCD screen, can be controlled manually by means of buttons on the electrical outlet and via app if there is WiFi or SMS connection. However, despite measuring important variables the form of control (SMS) is obsolete for control nowadays.

While in [7] and [8], the electrical outlets are composed by the ATmega328 microcontroller and are based on the connection protocol called ZigBee, to establish wireless communication between sensors, smart sockets, and the web server. These outlets also perform the function of measuring voltage, current and power consumption and make this information available to the consumer, which through devices with web browser, can monitor real-time power consumption and intervene by interrupting the electrical transmission to the plug, if necessary. In these works the electrical outlets use the ZigBee wireless connection protocol, whose range is short compared to other existing modes of communication and has a low data transfer rate, becoming limited even to simple applications that require a higher rate transfer than its own.

In [6–8], the proposed electrical outlets perform the function of measuring the variables necessary to collect information about electricity consumption. In these works , the smart outlets can be controlled to intervene in the transmission of electrical energy to the connected devices on them, manually via buttons or remotely using tools with wireless connection. However, all these works cited are restricted only to monitoring the electricity consumption and provide forms of control for the user who wants to interrupt the power transmission to the electrical outlet. In these proposals, the idea of identifying different equipment that was connected to the electrical outlet was not been developed, these works also not provide to the user the individual consumption information of the electrical equipment used.

The Near Field Communication technology in the home automation area has been used in [9], for the purpose of composing a profile-based intelligent home lighting system. Were used NFC tags recorded with lighting profiles defined by each user. When the tag is directed to the NFC reader on the system control panel, the ambient lighting adjusts to the desired lighting conditions. In this work, Near Field Communication technology proves to be efficient for this type of application, when it is necessary to securely exchange information at close range.

In [10], was proposed an intelligent street lighting system which automatically adjusts to suit at natural lighting , composed of poles equipped with photovoltaic plates, sensors that collect data for maintenance purposes and make them available to the network server using LoRaWan (Long Range) communication technology, enables longrange secure two-way communication , that is less susceptible to interference with radio transmission.

3. Proposed Work

Is proposed an intelligent electrical outlet (**Figure 1**) that identifies the type of appliance connected to it, through the NFC tag on the device plug. The tag is read by the NFC reader present on the smart outlet, and electrical equipment type information is directed to the ATmega328 microcontroller, which also receives voltage and current data collected by sensors and processes this data on a time basis to calculate energy consumption. The processed data is sent using LoRa wireless communication technology.

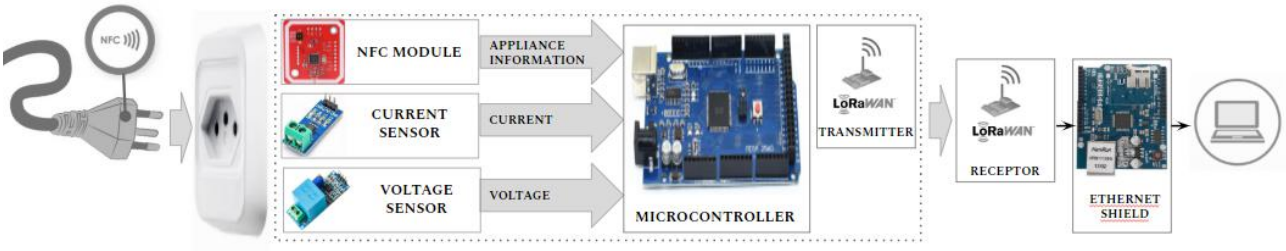


Figure1. Operating scheme of Intelligent Electrical Outlet proposed.

3.1 NFC module

Near Field Communication (NFC) technology is employed using the NFC PN532 Module to read information written on Ntag213 tags. These tags are attached to the plug and contain information about the type of electrical appliance. The Module present in electrical outlet reads tag when electrical appliance is plugged into smart outlet (**Figure 2**) because it is within the communication range of a maximum of 10 centimeters.

An NFC module usually establishes communication within a range of 0 to 10 centimeters, also has different data transfer rates (424 Kbps, 212 Kbps and 106 Kbps), depending on the application[9].

The PN532 is a highly integrated transmission module for contactless communication at 13.56MHz, including 80C51 core-based microcontroller functionality with 40KBytes of ROM and 1KBytes of RAM. The PN532 combines a fully integrated modulation and demodulation concept for different types of methods and contactless communication protocols at 13.56MHz with easy-to-use firmware for different supported modes and the required host for controller interface, the module supports the following protocols: UART, SPI and I2C[11].

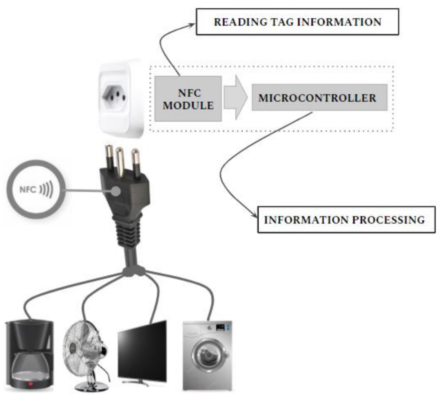


Figure 2. Device identification by NFC Tag.

3.2 Hardware structure

The proposed electrical outlet hardware shown in **Figure 3**, is composed of the ACS712 sensor, which acquires current data in conjunction with the ZMPT101B voltage sensor module. In the outlet structure there is the ATmega328 microcontroller, which is responsible for receiving and processing the data continuously acquired by the sensors and NFC module. To send the processed data, the hardware has a LoRa network module that works as a transmitter directing this information to the database.

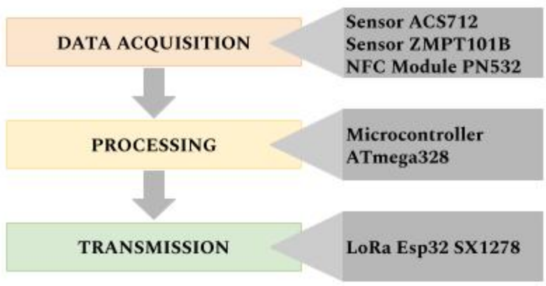


Figure 3. Hardware of the Smart Outlet proposed.

3.3 LoRaWAN network

LoRa (Long Range) is a wireless communication network spread by the LoRa Alliance. In a LoRaWAN Network the nodes are asynchronous and communicate when data is ready to be sent, this type of protocol is called Aloha.

In Mesh or Synchronous network architecture, nodes often need an alert to synchronize with the network and check messages. This synchronization consumes significant amounts of power and consequently reduces battery life, so the LoRa network preserves battery life and can increase network capacity. Another important point is LoRa network security, which uses two layers of security: for the network (node authenticity) and for the application (ensures enduser data access autonomy)[12].

In the smart outlet structure, there is a LoRa communication module responsible for sending the data collected by the sensors and the NFC module that were processed by the microcontroller, this data is sent to another LoRa module which then sends it to the Ethernet Shield W5100, which is responsible for organizing information traffic between the end machine and the local server (**Figure 4**).

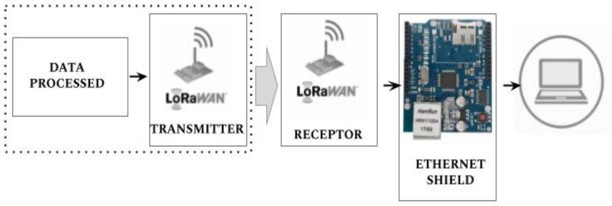


Figure 4. Data transmission by LoRa Network.

3.4 Database

The database aims to facilitate the visualization of consumption information and equipment used in the electrical outlet, as well serve as a tool to analyze the profile of electricity consumption through the history of individual consumption of appliances used.

For the development of the database, we used the software Xampp version 7.1.33-0, which contains the main local web servers. In our application we also use Apache, which will mediate the connection between the server to an HTTP page to transfer files over client-server communication. The user requests access to the HTTP page, which sends the request to the Server, then Apache responds by delivering all converted PHP files to static HTML, showing the content to the user. The database Server then requests the information contained on the HTTP page, storing it in its structure.

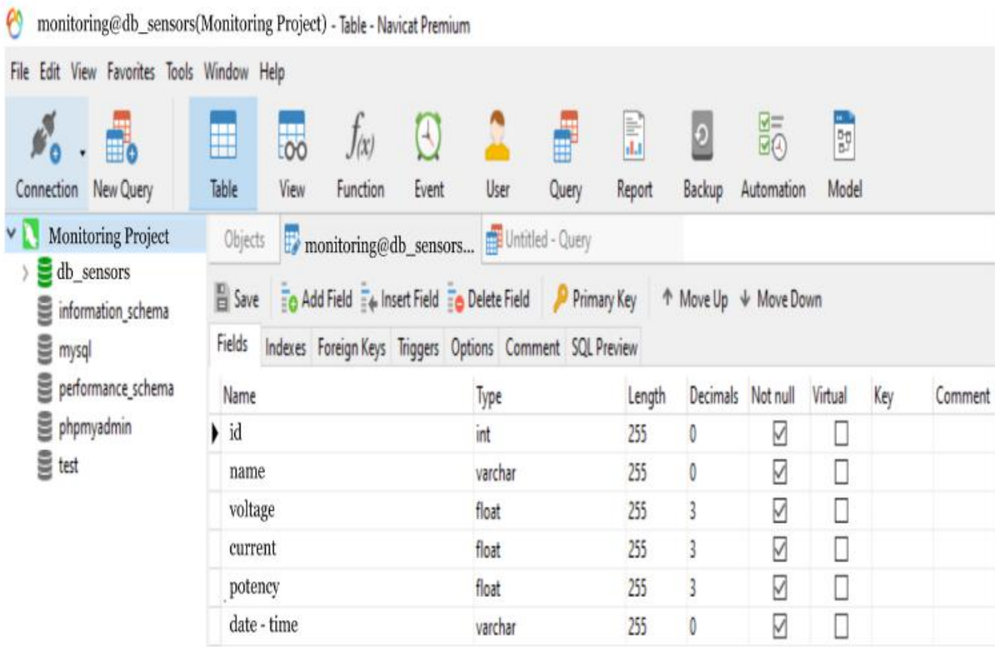


Figure 5. Database view.

4. Results

Through the tests performed we obtained satisfactory results in the operation of the proposed smart outlet, we can notice that there was recognition of different devices that were connected to the electrical outlet, as shown in the tests below.

4.1 Test 1

For the first test, we used a Soldering Iron with the NFC tag inserted in its plug. The image below shows the soldering iron connected to the developed prototype.

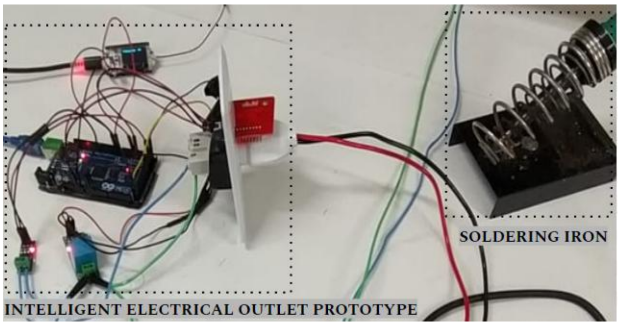


Figure 6. Data acquisition in test with Soldering Iron.

In the data acquisition the equipment connected to the electrical outlet prototype was identified through NFC communication technology, as well, as the measurement of important variables and the monitoring of energy consumption. The collected data was sent through the LoRa module present in the smart outlet hardware, and then this information was received by the other LoRa module as shown in the following image.

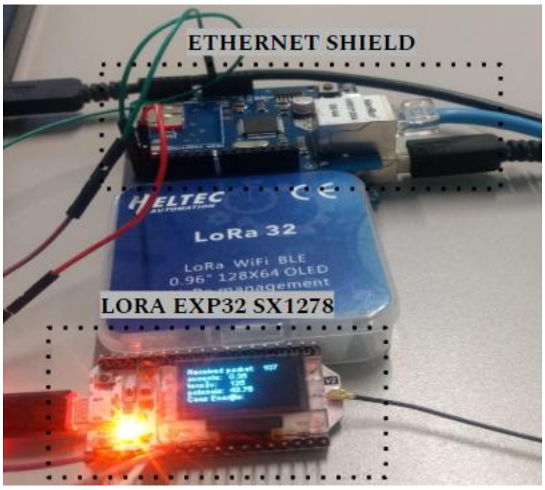
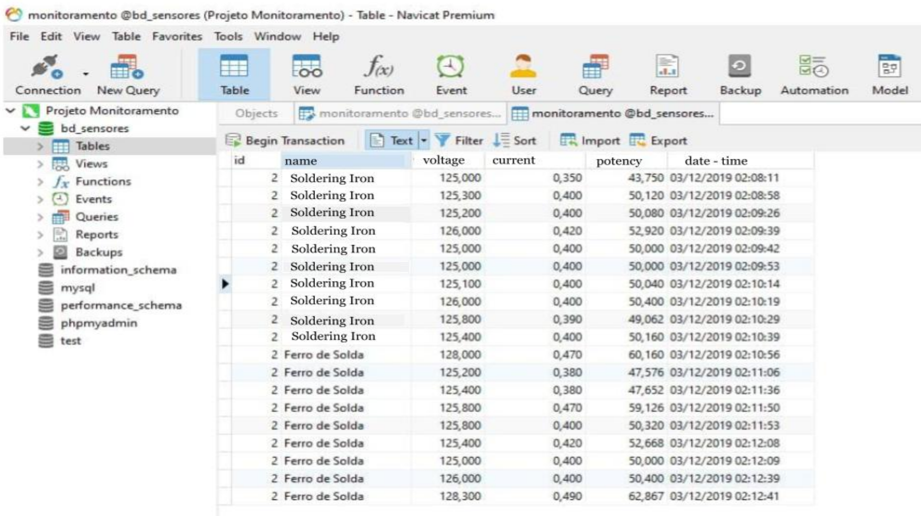


Figure 7. Data reception through the LoRa module in test with Soldering Iron.

Upon receipt of the data, the LoRa module directed them to the Ethernet Shield, which in turn transmitted the information to the HTML page, allowing viewing through the database shown in the image below.



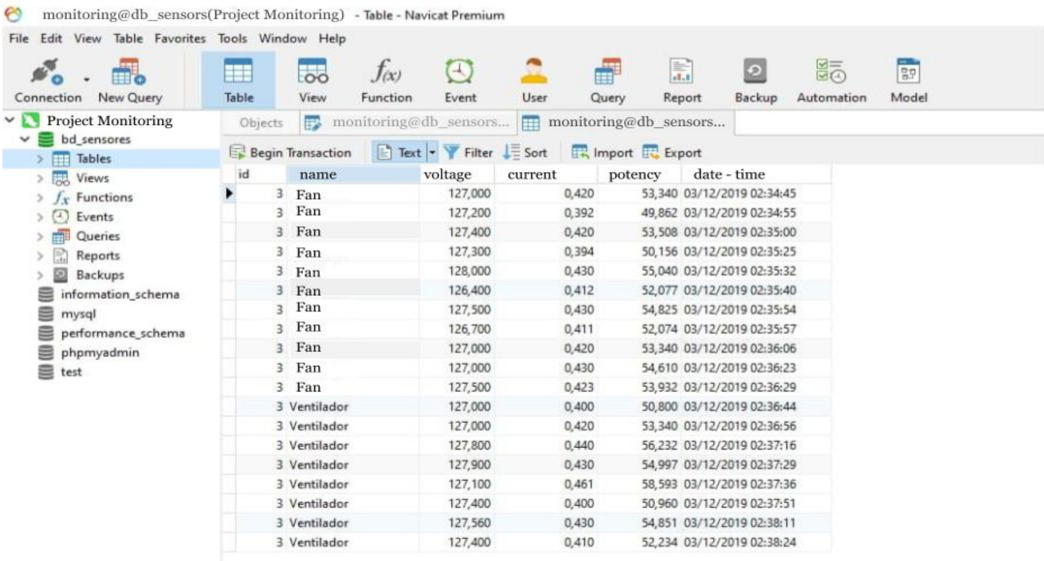
id	name	voltage	current	potency	date - time
2	Soldering Iron	125,000	0,350	43,750	03/12/2019 02:08:11
2	Soldering Iron	125,300	0,400	50,120	03/12/2019 02:08:58
2	Soldering Iron	125,200	0,400	50,080	03/12/2019 02:09:26
2	Soldering Iron	126,000	0,420	52,920	03/12/2019 02:09:39
2	Soldering Iron	125,000	0,400	50,000	03/12/2019 02:09:42
2	Soldering Iron	125,000	0,400	50,000	03/12/2019 02:09:53
2	Soldering Iron	125,100	0,400	50,040	03/12/2019 02:10:14
2	Soldering Iron	126,000	0,400	50,400	03/12/2019 02:10:19
2	Soldering Iron	125,800	0,390	49,062	03/12/2019 02:10:29
2	Soldering Iron	125,400	0,400	50,160	03/12/2019 02:10:39
2	Ferro de Solda	128,000	0,470	60,160	03/12/2019 02:10:56
2	Ferro de Solda	125,200	0,380	47,576	03/12/2019 02:11:06
2	Ferro de Solda	125,400	0,380	47,652	03/12/2019 02:11:36
2	Ferro de Solda	125,800	0,470	59,126	03/12/2019 02:11:50
2	Ferro de Solda	125,800	0,400	50,320	03/12/2019 02:11:53
2	Ferro de Solda	125,400	0,420	52,668	03/12/2019 02:12:08
2	Ferro de Solda	125,000	0,400	50,000	03/12/2019 02:12:09
2	Ferro de Solda	126,000	0,400	50,400	03/12/2019 02:12:39
2	Ferro de Solda	128,300	0,490	62,867	03/12/2019 02:12:41

Figure 8. Database visualization of variables measured in test with Soldering Iron.

Figure 9. Visualization of electricity consumption in test with Soldering Iron.

4.2 Test 2

The second test was performed using a Fan with the Ntag inserted into its plug. We obtained the expected result, the proposed electrical outlet was able to identify another device that was connected to it and made the appropriate measurements viewed in the database.



id	name	voltage	current	potency	date - time
3	Fan	127,000	0,420	53,340	03/12/2019 02:34:45
3	Fan	127,200	0,392	49,862	03/12/2019 02:34:55
3	Fan	127,400	0,420	53,508	03/12/2019 02:35:00
3	Fan	127,300	0,394	50,156	03/12/2019 02:35:25
3	Fan	128,000	0,430	55,040	03/12/2019 02:35:32
3	Fan	126,400	0,412	52,077	03/12/2019 02:35:40
3	Fan	127,500	0,430	54,825	03/12/2019 02:35:54
3	Fan	126,700	0,411	52,074	03/12/2019 02:35:57
3	Fan	127,000	0,420	53,340	03/12/2019 02:36:06
3	Fan	127,000	0,430	54,610	03/12/2019 02:36:23
3	Fan	127,500	0,423	53,932	03/12/2019 02:36:29
3	Ventilador	127,000	0,400	50,800	03/12/2019 02:36:44
3	Ventilador	127,000	0,420	53,340	03/12/2019 02:36:56
3	Ventilador	127,800	0,440	56,232	03/12/2019 02:37:16
3	Ventilador	127,900	0,430	54,997	03/12/2019 02:37:29
3	Ventilador	127,100	0,461	58,593	03/12/2019 02:37:36
3	Ventilador	127,400	0,400	50,960	03/12/2019 02:37:51
3	Ventilador	127,560	0,430	54,851	03/12/2019 02:38:11
3	Ventilador	127,400	0,410	52,234	03/12/2019 02:38:24

Figure 10. Database visualization of variables measured in test with Fan.

With the tests performed, we certify that was possible to develop the tool proposal to assist in the control of electricity consumption, through the measurement of the energy consumption and identification of electrical devices used, the identification of equipment using NFC technology was successful.

The LoRaWan communication technology has proven to be an alternative efficient to be implemented in home automation, with communication tests between LoRa Exp32 modules that were carried on the campus of Estacio Nazaré College, we observed that LoRa Technology offered extensive coverage for data transmission in real time, enabling its use in small and large residences.

With the tests, we also noticed that it is possible to develop the smart electrical outlet without using the ATmega 328 microcontroller on the hardware, because the LoRa Exp32 SX1278 Module is a microcontroller that can perform the processing function of the acquired data.

The total cost for the development of the proposed smart oulet prototype was about US$122,00 (one hundred and twenty two dollars).

5. Conclusion

This work developed a prototype of an intelligent electrical outlet for residential use in view of the importance of implementing intelligent tools that increase efficiency in controlling the use of consumable resources in the residential environment, this work sought to develop a technology to assist in the consumption of electrical energy, providing to the user the access to the energy consumption of each device that was connected to the smart outlet, with the information processed by the electrical outlet,is possible to analyze the user's consumption profile in order to help in a possible change in electricity consumption habits to avoid waste.

Our proposal was developed without developing the possibility of controlling electricity transmission, the proposed intelligent electrical outlet does not allow to the user to intervene in the transmission of energy to the equipment connected to it, neither by manual or remote control. The differential of our proposal was in the identification of the different equipment that were connected to the smart electrical outlet, aiming to increase the performance of the proposed electrical outlet, we pretend to implement the Smart Outlet to a Smart House system, which has a computational intelligence that allows the intervention in the energy transmission in the electrical outlet in an intelligent and optimized way, so that the necessary actions for the control of the expenses with electric energy will be evaluated and executed in an automated way.

The development of this work brought a simple method of identifying devices using the Proximity Field Communication technology, suggesting advances in the development of NFC tags with improvements and reduced size, aiming at a scenario of standardization in the manufacture of electrical equipment, where this equipments are produced with the NFC tag encapsulated in its plugs, containing the important informations about the equipment.

For future work, it is intended to make advances in the study of microelectronic technologies of embedded systems to enable production of the proposed smart outlet in order to preserve and improve its efficiency and reduce the cost of production. It is also expected to implement tools that facilitate access to consumption information provided by the electrical outlet, for example, the development of an interface via app for monitoring using smartphones.

To improve data transfer through LoRa technology, we seek to implement the smart outlet in conjunction with a more robust transmit antenna to minimize interference that the installation site may offer. For future work, it is also expected to implement data processing in the LoRa Exp32 SX1278 module on the smart electrical outlet hardware.

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