A LOW-COST LORAWAN WIRELESS IoT SOLUTION FOR REMOTE MANAGEMENT AND ANALYSIS OF CONSUMERS' MEASUREMENT DATA

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ABSTRACT

The aim of this paper is to describe the developed low-cost and low-power LoRaWAN wireless solution for remote management and analysis of consumers' measurement data located in regions with difficult access and low load density. The solution was developed to Sulgipe, a small distribution system operator that supplies energy to around 150,000 consumers in northeastern of Brazil.

This work is part of the Research and Development Program of the electric power sector developed by Brazilian Electricity Regulatory Agency.

INTRODUCTION

The Internet of Things (IoT) aims to create an environment with a large number of connected devices [1], such as smart metering, smart parking, smart metering devices etc. Recently, low-power wide-area radio technologies, such as Long Range (LoRa) and LoRaWAN and SigFox [2], have been developed to support such smart cities and IoT ecosystem. In the Brazilian electric sector, several studies were developed using alternative wireless network technologies, such as ZigBee, SigFox and Bluetooth, but none of them completely meets the existing needs.

The low-power wide-area networking (LPWAN) technologies use robust modulation techniques to cover long distances while supporting relatively low data rate applications. The long-range characteristic of these technologies results in a star network topology making network deployment and maintenance relatively simple [3]. LPWAN offers multi-year battery lifetime and is designed for sensors and applications that need to send small amounts of data over long distances a few times per hour from varying environments [4]. Figure 1 shows where LPWAN fit within a scope of Internet of Things.

LoRa / LoRaWAN is one of the most successful LPWAN technologies due to its openness and open source software support [5]. LoRaWAN defines the communication protocol and system architecture for the network while LoRa is the physical layer or the wireless modulation utilized to create the long-range communication link. Many legacy wireless systems use frequency shifting keying (FSK) modulation as the physical layer because it is a very efficient modulation for achieving low power. LoRa is based on chirp spread spectrum modulation,

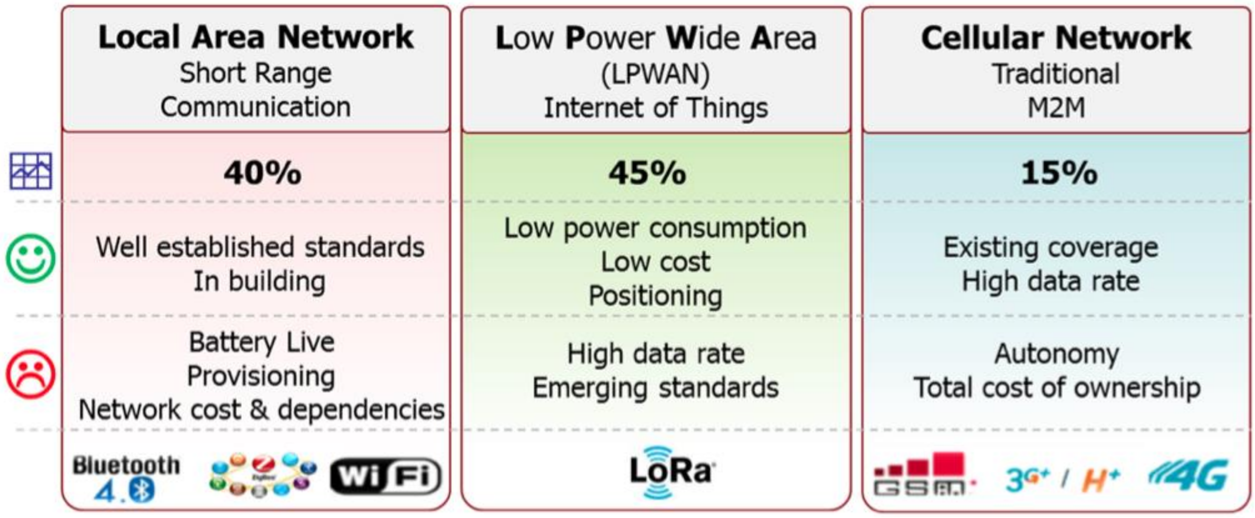

Fig. 1. IoT technologies by projected applications.

which maintains the same low power characteristics as FSK modulation but significantly increases the communication range. Chirp spread spectrum has been used in military and space communication for decades due to the long communication distances that can be achieved and robustness to interference, but LoRa is the first low cost implementation for commercial usage [4].

The advantage of LoRa is in the technology's long-range capability. A single gateway or base station can cover entire cities or hundreds of square kilometers. Range highly depends on the environment or obstructions in a given location, but LoRa and LoRaWAN have a link budget greater than any other standardized communication technology. The link budget, typically given in decibels (dB), is the primary factor in determining the range in a given environment [4].

In this paper it is described a developed low-cost and low-power LoRaWAN Advanced Metering Infrastructure (AMI) solution applied in distribution energy sector for remote management and analysis of consumers' measurement data located in regions with difficult access, far from the load center, with low load density, and, mainly, neither mobile nor radio connections. The work is part of a research and development project (R&D) that has been developed jointly by Sulgipe Power Utility Company and Daimon Engineering and Systems, and supported by Research, Development and Innovation Program of Brazilian Electricity Regulatory Agency (ANEEL).

Sulgipe has the concession of the Brazilian Federal Government to distribute electricity to 14 cities, of which 12 are located in the southern region of Sergipe State, and 2 in the northeast region of the state of Bahia, both states are in northeastern region of Brazil. The total area of concession corresponds to 5,764 km^2, being 77% in the state of Sergipe and 23% in Bahia state, supplying energy to 150,000 consumers units (around 350,000 inhabitants) distributed among residential (89.01%) and commercial (6.55%) classes. The operating voltage corresponds to 13.8 kV.

Due to the socioeconomic characteristics of northeast region of Brazil, the distribution system operators (DSO´s) must supply energy to many consumers located far from the load centre and with low energy consumption. Thus, the cost / benefit ratio for reading electric consumption and management of those consumers when it comes to shut them off or reconnecting them is often high due to the cost of crew dispatch, and the low revenue usually associated to that type of consumer. Traditional solution such as remote communication via GPRS (when connection is available) and smart meters has high operational costs related to data packets per device or kilobytes, and high costs in the process of substitution traditional meters to smart meters. Furthermore, due to the unique geographical characteristics in north-eastern region of Brazil the GPRS connection in rural areas are limited. Using the new low-cost and low-power LoRaWAN AMI solution would bring a more economical way for DSO´s in such situation.

With the innovative LoRaWAN technology of long range and low energy consumption, it is expected to meet up to 10,000 end nodes for each gateway within a radius up to 6 km in urban areas and 10 km in rural areas.

SOLUTION

The solution presented in this paper is a new LoRaWAN AMI solution for remote reading and management of consumers' measurement data with low-energy consumption, located in regions of difficult access. The whole solution is a LoRaWAN communication platform including (1) low-cost end-devices with remote management and analysis of consumers´ measurement data (including cut-off / reconnecting function), (2) LoRa gateways, (3) network server, and (4) a web application server.

The electronic device (end node) developed in the R&D Project can be integrated with the traditional energy meters located at consumer units. It will be scalable and can be applied in several scenarios. Figure 2 shows the overview of LoRaWAN developed solution. As can been seen, the electronic device (end node) is connected to the traditional energy meters in such way that, using a LoRaWAN wireless communication platform, it will send the consumer units' measurement data to LoRa gateways. The gateway will make a connection to the network server for storage of the received information. This process is automatic and is performed on every received uplink. Finally, in the Control Center of the utility is installed a web application software which have access to the data stored in the network server.

End node devices

Figure 3 shows the printed circuit board (PCB) of communication device (end node) developed in the R&D project. Each end node (Fig. 2) contains a LoRaWAN communication module, a RS 232 (or RS 485) communication reader, a Microchip PIC microcontroller, a circuit for recharging a 3.7 V / 6000 mAh Li-Ion battery, a device to control the electromechanical contactor, and a RFID reader. The total cost of each end node (including all components) will be USD $ 40.00.

The end nodes will be able to:

- Reading power consumption: the end node is able to read consumption through serial port (RS 232 or RS 485). In the traditional electric meters without serial output, consumption measurement is made by reading light pulses of LED indicators located in front of the devices;
- Cut-off and reconnection of consumers: the actions of electric power cuts and remote

reconnection of consumer units will be carried out by means of the activation of an auxiliary electromechanical contactor that will be installed inside the electric meter enclosure of the consumer units;

- Prepayment electricity: for this purpose, an RFID sensor is integrated to the circuit enabling the consumer to recharge the amount of energy paid, this being the same technology used by the public transportation system in Brazil. In the prepayment functionality there will also be a visual and audible alarm that will inform the consumer of the proximity of exhaustion of credits and also allow the consumer to use an emergency credit;
- Fraud identification: In order to reduce fraud attempts, sensors will be coupled to metering box cover, allowing the identification of attempts to open the metering box and sending alerts to utility.

LoRaWAN gateway, antenna and network server

The long-range and low-power LoRaWAN gateway receives the measurement data from the end nodes and send it to the network server. Depending on site topology conditions, a single gateway can cover a 6 km radius in urban areas or 10 km in rural areas.

In a LoRaWAN network the end node are not associated with a specific gateway. Instead, data transmitted by a node is typically received by multiple gateways. Each

gateway will forward the received packet from the end-node to the cloud-based network server via some backhaul (either cellular, Ethernet, satellite, or Wi-Fi). The intelligence and complexity are pushed to the network server, which manages the network and will filter

Fig. 3. Printed circuit board of communication device

redundant received packets, perform security checks, schedule acknowledgments through the optimal gateway, and perform adaptive data rate.

In this Project, a Kerlink Wirnet Station IoT outdoor LoRaWAN gateway [6] was installed in the Sulgipe building according to Fig. 4. For data reception and transmission, a combined antennas system ("Array Antenna") composed of four Yagi type orthogonal antennas vertically polarized [7] was used. The antenna was installed in the Sulgipe building, according to Fig. 5, at a height of around 15 m from ground level.

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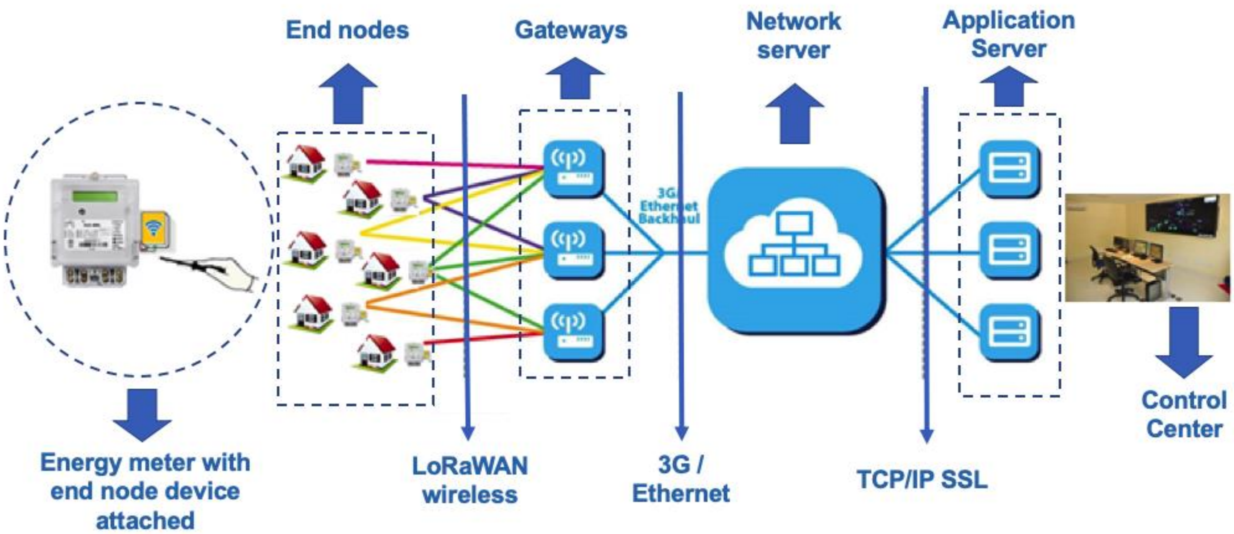


Fig. 2. Overview of the LoRaWAN developed solution.

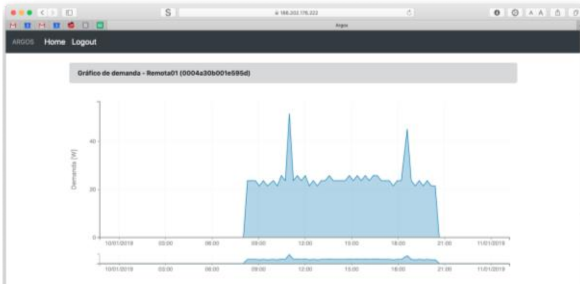
Fig. 4. Kerlink Wirnet Station LoRaWAN gateway installed at Sulgipe building

Fig. 5. Yagi Array antenna adopted in the LoRaWAN solution.

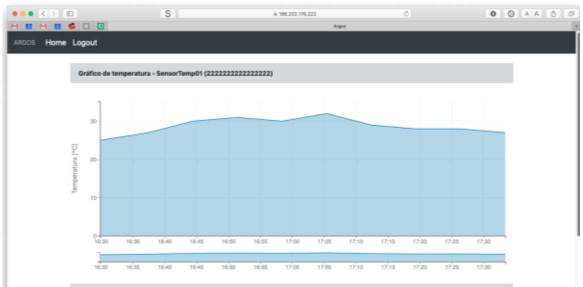
Fig. 5, at a height of around 15 m from ground level.

Web application server

Web application servers are specific software that receive data packets from network servers and perform specific management or analysis of consumption data. By means of the web application server, the Utility is able, for example, to perform power cuts and remote reconnection of consumer units or printing different consumption measurement graphics. Figure 6 illustrates the demand graphs (Wh) and temperature of the control center of Sulgipe.



(a)



(b)

Fig. 6. Graphs generated by web application server. (a) demand (W.h); (b) temperature (ºC) of Sulgipe´s Control Center room.

CONCLUSION

In this paper it was presented a low-cost AMI solution for distribution utilities using traditional meters and LoRaWAN low-power wide-area networking (LPWAN)

solution. This work included the development of end nodes for installing in metering box. These devices are easily integrated with existing meters via serial communication or by reading light pulse LED indicator.

The proposed solution reduces the cost associated with meter reads and associated crew management and administrative support and also allows faster service restoration and flexible payment billing.

An evolution of this work is being developed by Daimon and Sulgipe using the LoRaWAN infrastructure for fault location and Distribution Automation.

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