Smart Home Architecture based on LoRa Wireless Connectivity and LoRaWAN® Networking Protocol

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***Abstract*— In the recent years, the smart home systems have achieved a colossal attention for making people lives easier and more comfortable. In fact, they allow them to control the whole environment of their houses in commodious and effective way. One of the technological progress fruits is the production of a huge number of highly developed and smart systems that assist the technology of smart living.**

In this respect, this paper aims to present a design of a new smart home architecture integrating a wireless communication module to communicate with sensors and smart devices (LoRa). A LoRaWAN gateway was built to manage and establish this communication between the LoRa server (loraserver) and house sensors which are intelligent modules combining both LoRa and Wi-Fi technologies.

***Keywords*— Internet of things (IoT), LoRa, LoRaWAN, Wi-Fi, LoRaWAN gateway, Message Queuing Telemetry Transport (MQTT).**

I. INTRODUCTION (*HEADING 1*)

Over the recent decades, the advent of the internet of things (IoT), in which objects were perfectly connected to each other as well as to the internet, has emerged as one of the most exciting and dynamic developments in communications and information technology [1-2]. Invading many fields such as industry, home automation, transport and so on, the IoT is becoming increasingly attractive to make our life easier and more comfortable. Simply put, due to the IoT, our presence on the spot for control and monitoring is becoming, nowadays, not necessary. According to Machina Research [2], it exists, at present, 16 billion connected objects by IoT with smart homes, smart industries, and smart cities. By 2025, they will be account for more than 20 billion connections. As a matter of fact, most of the huge objects number were connected by Wi-Fi, Zig-Bee, Bluetooth, etc. All these technologies have major issues including battery lifetime and power requirement. However, IoT applications need technologies that can offer, low-cost, low-power operation and low-complexity end devices able to communicate wirelessly over long distances [1-2]. On the other hand, a lot of IoT end devices were battery powered sensor nodes. Hence, the power use profile ought to be carefully designed so as to extend the battery lifespan. LoRa is one of the promising technologies that response to the aforementioned characteristics [1], [3-4]. Regarding to the other technologies, LoRa that operates in an awfully low bandwidth with frequency varies between 430 and 915 MHz [5], was able to provide a long-range connectivity to battery powered devices. In the few recent years, great efforts have been dedicated to the development of different smart home architectures. As presented by S. S. Mohamed et al [6], an architecture based on Arduino microcontroller kit and LabVIEW platform was designed. In their works [7], S. Mahamud et al shed light on Arduino UNO and Wi-Fi in their smart home architecture. In [8], the authors have been interested by the use of GSM, IP, Android and Bluetooth in order to design an architecture of a smart home automation system. Even though this topic has received important attentions and significant efforts by many researchers and engineers, it still represents an interesting research focus and a big challenge. In this context, the key target of this study is to develop a new smart home architecture based on LoRa technology. A local server (loraserver) was also developed and a LoRaWAN gateway was designed to establish the communication between the server and the devices. Moreover, to control smart devices via voice commands, a voice assistant (Mycroft) was integrated in this study. The remainder of this paper was organized as follows: Section II described LoRaWAN and LoRa technology. In section III, the smart home architecture designed in this study was presented. Section IV described the test and the integration of the proposed solution. All obtained test results are also discussed. At the end, the major conclusions are addressed in Section V.

II. LORAWAN AND LORA

LoRaWAN is a new protocol that became the main object of various research throughout the world. Patented by the

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company SMTC Corporation (Semtech Corporation), LoRa is a spread spectrum modulation technique that allows the transfer of data over long distances using less energy.

In fact, it is a SS-Spread Spectrum modulation type focused on using chirp signal which changes constantly according to the frequency. Its main advantage is the similarity in frequency and time offsets to the receiver and the sender which is reduced the receiver complexity [9]. LoRa uses a star topology network, in which the application server is connected to a large number of gateways. These gateways are connected to a large number of end devices.

As depicted in Fig.1, LoRa's architecture consists of two main parts. The first part is the back-end. It contains the network server which is responsible for storing the data received by the sensors. The second one is the front-end which contains the gateways and the terminal equipment. These gateways play the role of a bridge into the network server and end devices. The data transferred between the gateway and the network server is transmitted via an IP connection.

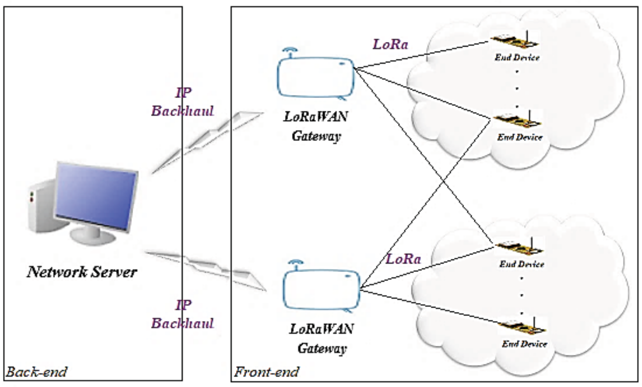

Fig. 1 LoRa architecture

I. ARCHITECTURE

In this study, the smart home design using LoRa technology consists of three different parts. The first part presented the creation of the used gateway and its basic components. The second one introduced the connected devices and described their features as well as their architectures. The third part was reserved to the voice assistant used to provide voice commands to connect equipment.

A. Gateway / Server

Based on a Raspberry Pi3 B+ and a LoRaGO PORT shield, a LoRaWAN gateway was built in this work as shown in Fig.2.

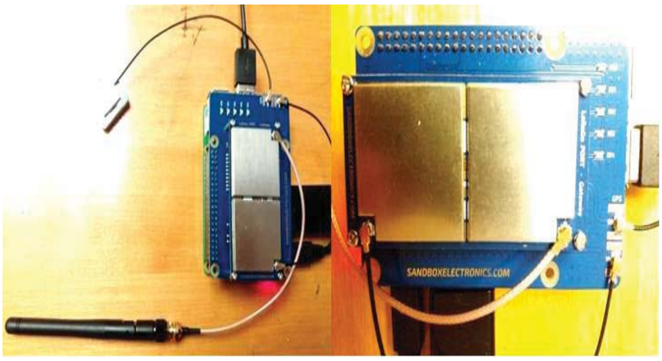

Fig. 2 LoRaWAN gateway

The data protocol used along this research is the MQTT (Message Queuing Telemetry Transport). This protocol, which is developed by IBM, uses the model of publish/subscribe.

As illustrated in Fig. 3, it composes of two types of clients (the publisher and the subscriber) and a broker server that plays the role of a bridge between them when sending messages for topics which seems interesting [10].

MQTT supplies three levels of Quality of Server (QoS) [11-12]:

- QoS0: the message is sent only once and depends on the network quality.
- QoS1: the message is sent at least once.
- QoS2: guarantee the message reception.

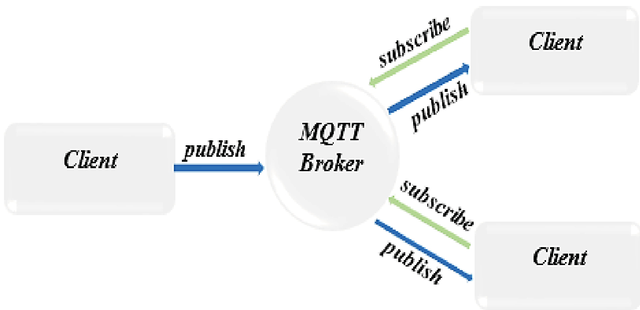

Fig. 3 MQTT protocol

Our approach, that describes the transmission of a message between the network server and the node, is illustrated by the Fig. 4. For sending a message from the node to the gateway, a LoRaWAN uplink is used. Subsequently, for the transmission of the received message to the network server, the gateway avails the internet. And, to publish this message to the application server, the network server employs the MQTT. Then, our network server verifies its downlink message. If a downlink message exists in the node queue, it will be transferred through the gateway to the node after a delay of one second. On the other side, if it is vacuous, any message will not send from the network server to the node in the mode of unconfirmed message.

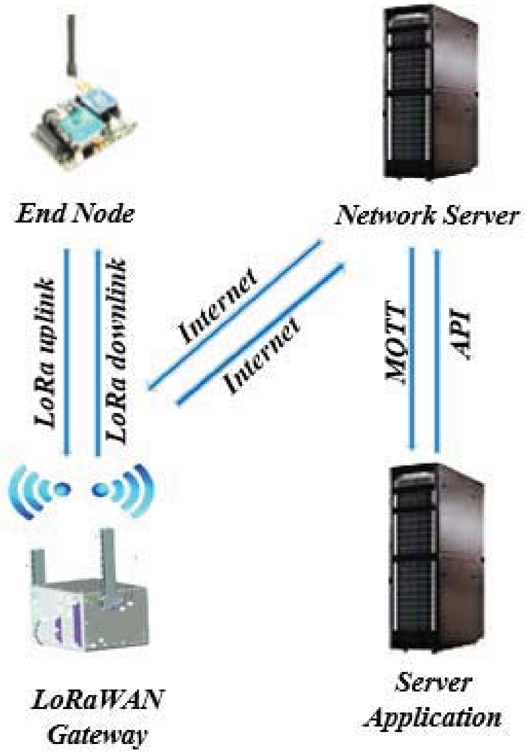

Fig. 4 Our approach architecture

At this instant, the network server will send the message to the application server that decides to response to the node or not. If it is obligatory at this instant to forward to the node a downlink message, the API offered by the server (network server) will be used for adding a message to the network server downlink queue. Once the message has transmitted to the node, it will be asleep and hold on for the following cycle.

B. Connected devices

In this project, two kind of connected devices: the smart thermostat and smart light are used. All these devices are connected to the internet via LoRa and Wi-Fi modules.

As depicted in Fig. 5, the smart thermostat is based on RN 2903 chip and SHT35 sensor. Characterized by its low cost, easy use and high accuracy, this sensor is used to measure ambient temperature and humidity.

In fact, the RN 2903 chip is used, in this study, because it is a fully certified 915 MHz module based on LoRa® wireless technology. Moreover, it uses a single spectrum modulation spread in the sub-GHz band to allow long range, low consumption and high network storage.

It is worthy to mention that the smart thermostat has a Nextion screen for displaying different information such as room temperature and humidity, etc.

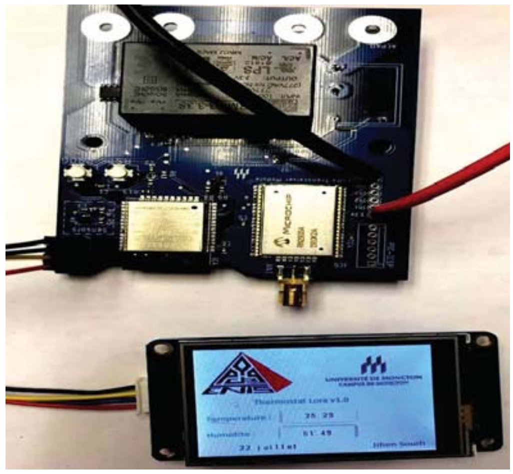

Fig. 5 Smart Thermostat

Concerning the smart light system, it is composed of a lot led connected to an ESP8266 [13] through a Led driver (Link Sprite LED PWM Dimmer Constant Current Driver). Indeed, the principle is simple. When the voice command was made or the website or the mobile application were used to turn on / off the light or to adjust it to a particular intensity via RESTful web services (HTTP request), the settings of the device stored into the SQLite database such as the state, the value, etc. were modified.

The device is always subscribing to the MQTT broker according to the update interval in order to get the recent settings. In this case, the ESP8266 sent a PWM (Pulse Width Modulation) signal to the driver in order to modify the intensity from 0 to 100% or to turn on / off the smart light.

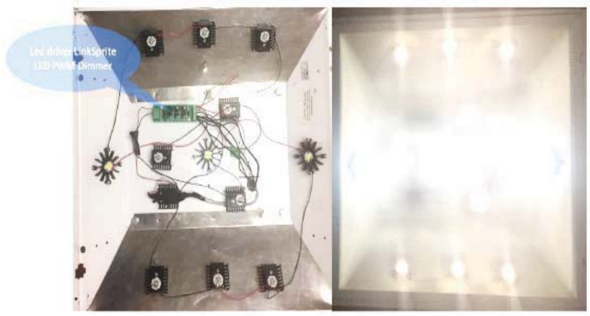

Fig. 6 Smart Light

C. Voice assistant

In order to control our smart devices, a voice assistant (Mycroft) [14] is integrated. We have created customized skills and intents to offer the possibility of making particular actions: turning on / off lights or thermostats, adjusting the light's intensity or the thermostat's temperature. The Fig. 7 represents the Mycroft core architecture.

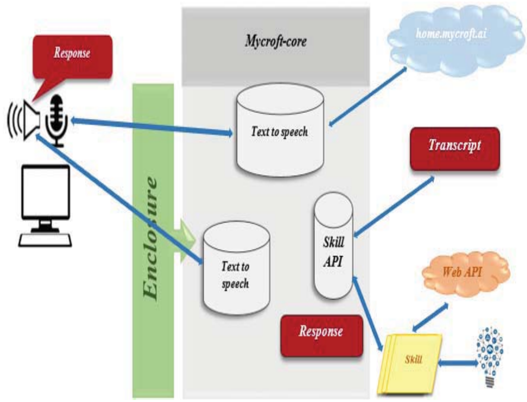

Fig. 7 Mycroft core architecture

II. INTEGRATION

After setting up and configuring the local server, the different parts of our smart home must be integrated. The Node.js [15] website of the local server can be also checked after the add of a new device to our smart home.

In fact, the website deployed in the local server allows to check the power consumption of each device. In addition, it allows us to check the settings of devices and to control them.

The Fig. 8 shows an example of turning off the room light via the website.

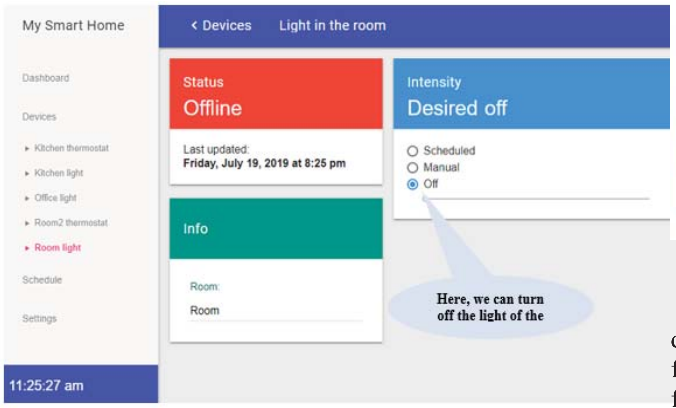

Fig. 8 Controlling the Smart Light

The light intensity in the room can be also adjusted as shown in Fig. 9.

Fig. 9 Adjusting the light intensity

As mentioned above, our smart devices can be controlled via the voice assistant Mycroft. Indeed, custom skills are created to control the connected smart device, such as the ignition, extinguishing and the intensity of the light adjusting. In our case, a wake up word ("MySmartHome") was used to order the smart device. Taking the example of the bedroom light, to activate it, the sentence ("Hey MySmartHome turn on the bedroom one light") must be said. This voice message is processed by the Picroft image to check if there is a skill or not.

It checks whether the request matches to switch on / off the intelligent device we have called (turn on / turn off), or to set specific parameters such as the intensity of the lights we have called (Dim / adjust / regulate, etc.). After acquiring and processing the commands, it sends the data to the local server using the MQTT communication protocol. Then, it checks whether the request is complete or not because the user needs to specify all the parameters, including the device, the part, the setting, according to which we consult the database to get the device, its part and the setting to update it. Finally, when the local server receives data and updates the database, this information is sent to the connected device with the same MQTT communication protocol.

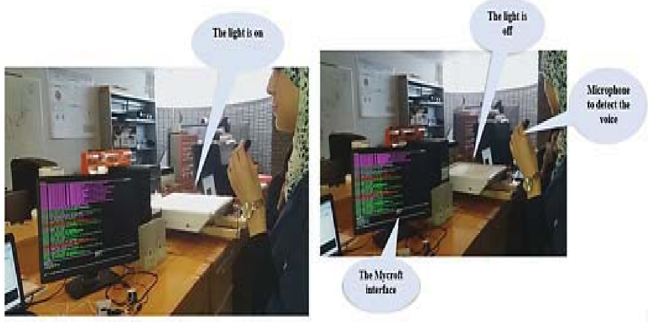

Fig. 10 Turn ON / OFF the smart light using Mycroft

Many studies have investigated LoRa limitations and difference performances between communication protocols for low cost IoT devices [16,17]. The following table shows for example a comparison between LoRa, Wi-Fi and Bluetooth characteristics

Table 1. LoRa, Wi-Fi and Bluetooth characteristics

Characteristics	*Wi-Fi*	*Bluetooth*	*LoRa*
Baud rate [kbps]	10×103	1×103	27
Frequency [GHz]	2.4 or 5	2.4	0.868
Range [m]	1 – 100	10 – 100	20000
Power Consumption [mA]	100 – 350	1 – 10	1 – 10
Security	*WPW/WPA2*	128 *bits*	128 *bits*

A LoRa device has, for a same power consumption as Bluetooth device, a very high coverage range. The designed devices built using LoRa have been tested on the campus at different location and in different rooms over the campus of the Université de Moncton. Using just one LoRa gateway located at the Engineering Building (Faculté d'ingénierie) inside the room 233 G2. The range reached almost the main building (Pavillon Léopold-Taillon) shown in red on the map (Fig. 11)

Fig. 11 Map of the campus of the Université de Moncton

The signal strength at different locations is shown on the following table. A battery powered device was circulated over the campus and the gateway was at one fix location inside the engineering building. The smart home server showed the logs of the LoRa device and the signal power which was detected almost over all the campus.

Table 2. Signal power of LoRa wireless at different locations on the campus.

Building and room	***Signal Power***
Faculté de Génie local 233 G2	Between -121 and -123
Faculté de Génie local 263 G1	Between -98 and -90
Faculté de Génie local 148 G2	-68
Faculté de Génie local 006 G1, Sous-Sol	-94
Faculté des beaux art 2eme étage local 205-C	Between -101 and -106
Faculté d'administration local 163	-112
Faculté de Droit 1er étage	-102
CTSS	-101
Centre étudiant	-106
Pavillon Jaqueline-Bouchard local 163	Between -93 and -111
Pavillon de Taillon	X
Pavillon Jeanne-de-Valois	-100
Pavillon Rémi-Rossignol, Sous-Sol	-107
Résidence Médard-Collette	-100
Résidence Lefebvre	-103

III. Conclusion

Given the wide range of benefits it offers, LoRa has been considered as a promising technology at the edge of technology. It enables secure two-way mobile communication at low cost for IoT applications. It is rapidly gaining popularity and is a preferred technology for IoT systems due to its long range, high network node capacity and long life. It is reputed and accepted in the home automation market. In addition, open source modules exist to implement this protocol. For all these reasons, LoRa was used in this study to implement the smart home solution. An important part of our project was also devoted to the development of a local server (loraserver) for this smart home. In addition, a LoRaWAN gateway has been designed to manage and establish this communication between the loraserver and the sensors. To this end, voice assistant such as Mycroft have been integrated to control our devices via voice commands. The implemented solution will offer the user complete and secure control of connected devices.

Acknowledgment

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