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LoRa architecture for air quality monitoring

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ABSTRACT

Long Range technology (LoRa) is a technology used in the current Internet of Things (IoT) applications. The frequency supported by this network is around 433Mhz, 868MHz or 915Mhz. This type of network uses the Frequency Shifting Keying and has a small error rate. Moreover, LoRa has the advantage that it is a platform for long-distance communication and another factor is that it has a long-term battery performance. We will present an architecture based on LoRa Gateway which will be connected to PyCom. We will use as well specific gas sensors which will measure the quality of the air. This architecture will be connected to a breadboard with different types of gas sensors to collect data about the air pollutants.

Keywords: LoRa, PyCom, Air pollution, Internet of Things, long-range, low-power

1. INTRODUCTION

LoRa has empowered novel IoT applications in various fields, including health. IoT uses a set of protocols to communicate between devices [1].

Furthermore, Low-Power Wide Area Network (LPWAN) offers radio coverage over very large areas by adapting the transmission rate, power, modulation and duty cycles. In this aspect, end-devices or sensors will have a very low energy intake.

Likewise, LoRa is a LPWAN protocol and is used on end-devices (sensors) with low energy consumption.

LoRa is composed of two distinct layers, one which is referred as a physical layer having a Chirp Spread Spectrum (CSS) and as well as MAC layer protocol (LoRaWAN). The physical layer was produced by Semtech, enabling some advantages to the connection which other types of modules don't have, such as long-range, low-power consumption and low-throughput communications. The module is working on the following frequencies: 433-, 868-, 915MHz bands. Something to note is that the modulation technique is a technology solely used by Semtech and it is confidential.

LoRaWAN allows a medium access control mechanism, whereas all the end-devices can communicate with the specific gateway; a LoRa modulation is used. The best advantage of LoRaWAN is that it is an open standard created by LoRa Alliance [2].

The paper is structured as follows: Section 2 presents related work, while Section 3 describes the LoRa modulation. In Section 4 the hardware components of the testbed are described, namely PyCom LoPy devices. Section 5 describes the experiments and results, while Section 6 concludes the paper and envisions future work.

2. RELATED WORK

With the recent increase in automotive vehicles in large cities the quality air has dramatically decreased, therefore the levels [3] of nitrogen dioxide and ozone rose significantly than the normal values of environmental quality standards.

Daily, a lot of cars are being used in large cities, which result in a high concentration of CO₂ and the effect of a greenhouse is created as well. In order to have a better understanding of the effects of such gases, we have to measure the quantity of gas emission in the air. In Table 1 the standards for gas exposure in Europe are analyzed as following:

<i>Pollutant</i>	<i>Concentration</i>	<i>Averaging period</i>	<i>Permitted exceedances each year</i>
Fine particles (PM2.5)	25 µg/m3***	1 year	n/a
Sulphur dioxide (SO2)	350 µg/m3	1 hour	24
	125 µg/m3	24 hours	3
Nitrogen dioxide (NO2)	200 µg/m3	1 hour	18
	40 µg/m3	1 year	n/a
Carbon monoxide (CO)	10 mg/m3	Max. daily 8 hours mean	n/a
Benzene	5 µg/m3	1 year	n/a
Ozone	120 µg/m3	Max. daily 8 hours mean	25 days averaged over 3 years

Table 1. Air quality Standards in Europe [4]

After analyzing the current the table, we can see that the numbers are exceeding in Figure 1.:

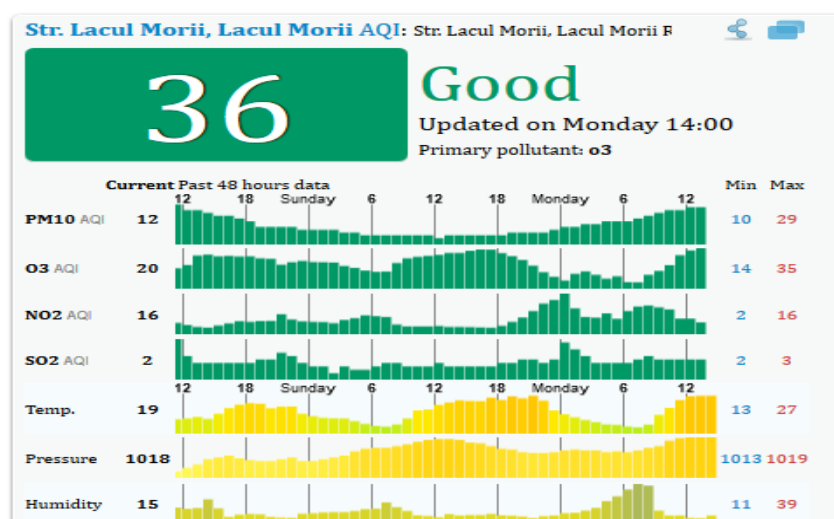


Figure 1. Pollutants parameters in Bucharest [5]

3. LoRa MODULATION

LoRa emerges as a novelty nowadays, and one important factor is that it is a proprietary spread spectrum modulation scheme and it is a derivative of CSS modulation. The sensitivity is exchanged with the data rate in a fixed channel bandwidth. It also induces a variable data rate, whereas we use an orthogonal spreading factor allowing the system designer to trade the data rate for range or power allowing optimization of the network performance in a bandwidth which is constant. This type of modulation has the possibility to function at the same time with another existing network architecture. [6]

3.1 Chirp Spread Spectrum

Chirp Spread Spectrum was invented in 1940's and it was used in military and secure applications, because this type of modulation doesn't require a high transmission power but a low one; it is now widely used in a lot of applications which don't need much power.

The principle of this spectrum enables the increase of the bandwidth of a signal to compensate for the degradation of the signal-to-noise ratio of a radio channel [6]

3.2 LoRa Spread Spectrum and Key Properties

In a LoRa system the modulation is done by making a chirp signal which continuously varies in frequency, therefore the spreading factor being created. The timing and frequency offsets are equal and so the receiver design is simplified. It is generally known that the spectral bandwidth is almost equal to the frequency bandwidth of the chirp. Afterwards the data signal is fragmented at a higher data rate and modulated to the signal that is a spectral bandwidth.

The key properties for LoRa modulation are:

- Bandwidth Scalability;
- Constant Envelope/ Low-Power;
- High Robustness;
- Multipath/ fading Resistance;
- Long-Range Capability;
- Enhanced Network Capacity;
- Ranging/ Localization. [6]

4. HARDWARE DESCRIPTION

PyCom, in our case a LoPy4, is based on MicroPython programming and is a development board which uses LoRa, Sigfox, WiFi and Bluetooth types of protocol. It is one of the easiest way to access an IoT platform because it is made in an easily programmable environment such as Python. Regarding features, it has four networks as above said, has a powerful CPU and can work as well as a Nano LoRa gateway. Moreover, it has an ultra-low power usage (3.3V). It has an Espressif ESP32 chipset, a Dual processor and WiFi radio System chip. The LoRa operating frequencies range between 868MHz in Europe and a 14dBm maximum and the lowest one is 433MHz in Europe and a maximum of 10dBm. The interfaces which can be used are: 2 x UART (Universal Asynchronous Receiver-Transmitter), SPI (Serial Peripheral Interface), 2 I2C (Inter-Integrated Circuit), I2S (Inter-IC Sound), micro SD card, has 8 x 12bit ADC analog channels, 4 x 16 Timers with PWM (Pulse Width Modulation) and as well input

capture and GPIO (General-purpose input/output) up to 24. It has as well a RAM memory of 4MB and external flash of 8MB. The Hash/ encryption is SHA, MD5, DES, AES [7].

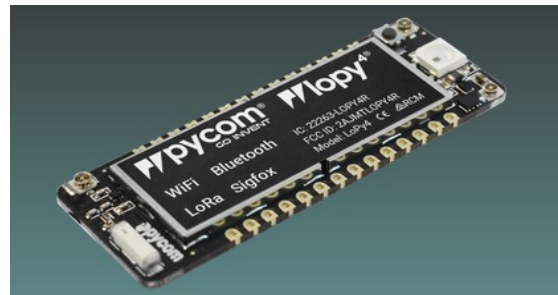


Figure 2. PyCom [8]

5. EXPERIMENTS

We chose the PyCom LoPy4 for our experiments as it has the best coverage, around 22km taken from Table 2 representing a comparison between frequency, range and topology of different interconnectivity technologies. Figure 3 presents the implemented LoRa architecture.

Radio version	Frequency	Range	Types of Topologies
XBee 868LP	863 - 870 MHz	8.4 km	Star, tree, mesh
XBee-PRO 900HP US	902 - 928 MHz	15.5 km	Star, tree, mesh
XBee-PRO 900HP BR	902 - 906.8 MHz 915.6 - 928 MHz	15.5 km	Star, tree, mesh
XBee-PRO 900HP AU	915.6 - 928 MHz	15.5 km	Star, tree, mesh
LoRaWAN 868/433 modules	868 MHz- 433 MHz	>15 km at suburban and >5 km at urban area	Node to node
LoRaWAN 900 module (US)	900-930 MHz	>15 km at suburban and >5 km at urban area	Node to node
Semtech SX1272(LoRa Module)	860-1000 MHz	Line of Sight: 21+ km / 13.4+ miles (LoS and Fresnel zone clearance) • Non Line of Sight: 2+ km / 1.2+ miles (nLoS going through buildings, urban environment)	Star

WiFi PRO module	Europe: 2.412 – 2.472 GHz - USA: 2.412 – 2.462 GHz - Japan: 2.412 – 2.484 GHz	-	-
HAT Dragino Lora / GPS	868 MHz/433 MHz/915 MHz	15-20km	star
PyCom/LoPy4	868MHz/915MHz	Node range: Up to 40km Nano-gateway: Up to 22km (Capacity up to 100 nodes)	-

Table 2. Type of radio connections

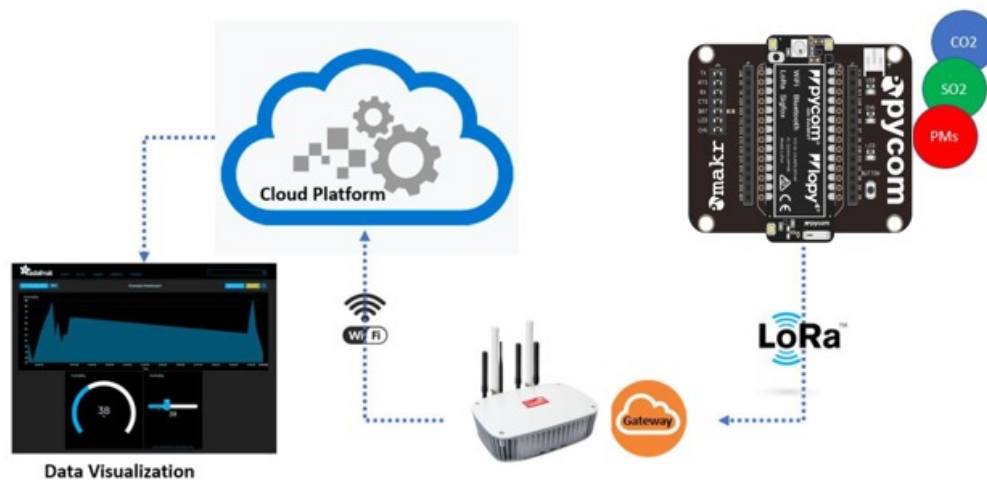


Figure 3. LoRa architecture

Firstly, the gas sensors transmit the data to the PyCom LoPy4 board, afterwards to the Gateway and lastly to the Cloud Platform developed during the SWITCH project [8] for time critical applications. The transmitted data is shown on a web dashboard.

5. CONCLUSIONS AND FUTURE WORK

In this paper we presented how a LoRa architecture using a PyCom as a module will transmit data to a gateway and then to a LoRa gateway. We tried as well the LoRa GPS hat and noticed that by using a PyCom the whole operation is simpler. The PyCom transmits the data received from the gas sensors to the gateway and then to the cloud platform. If we used a LoRa GPS hat, then it would have been more complicated because we would require a Raspberry Pi3 which uses more power than a PyCom and more computation power, whereas what we need is just to transmit the data from the taken measurements to the gateway. In conclusion, a LoRa architecture for air pollution is using low power and has a longer range than other types of network.

As future work we will program the PyCom and connect it to the LoRa gateway to transmit the received data from the gas sensors.

Acknowledgments

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