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DEVELOPMENT OF AN IOT NODE FOR AIR PARTICLES AND METEOROLOGICAL VARIABLES MONITORING

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ABSTRACT

The atmospheric contamination has been wreaking havoc on our society for decades, yet few nations monitor atmospheric contamination in their cities. Taking into account the atmospheric conditions in the city of Monterrey, Nuevo Leon which is a highly industrialized city in northern Mexico, the development of an Internet of Things (IoT) Node began. This node is capable of monitoring the meteorological conditions of the atmosphere such as: Temperature, Humidity, Atmospheric Pressure, Altitude and Fine Particulate Matter. This node was developed using several technologies, some of these are cellular network, serial communication protocol, analog and digital communication. Plus, this node uses sensors, and development platforms which help to monitor the node.

KEYWORDS: Internet of Things, Node, Meteorological, Particulate Matter, Cellular Network.

1 INTRODUCTION

Atmosphere is a word that etymologically means sphere of air. It is a mixture of gases that envelops the earth forming a layer that extends about 1000 km above the earth's surface and has a mass of about 5.6 x 10^{25} tons. The gravitational force determines that the density of the gaseous layer takes a maximum value at sea level and exerts a pressure of 101,325 kPa on the earth's surface. Only 12 of the 1000 km of the atmosphere are breathable.[1] Since industrialization, greenhouse gases have been released into the atmosphere, causing a slow but steady rise in global temperatures. Combustion is the main source of pollutants released into the atmosphere, energy demand, population growth and industrial activity have intensified strongly in recent years, especially in highly industrialized cities such as Monterrey, Mexico. This city has problems related to air pollution, the levels of pollutants, especially fine particulate matter and they have increased due to the companies located in this city. In order to address these problems, it is necessary to know exactly the current state of the atmosphere at key points in the city, to know when to take action and to ensure that the measures are proportional to the level of pollutants present at the time. The Internet of Things will be the way to monitor these key points, developing a node integrated by sensors, antennas, batteries and a microcontroller which will be able to collect, process and send readings of meteorological variables to a cloud data base such as Temperature, Humidity, Atmospheric Pressure, Altitude and Fine Particulate Matter (PM2.5, PM10). Once this information is received and stored, a web page will be available to display the relevant information to the end user, helping him to make the best decision in time.

2 MATERIALS AND METHODS

2.1 MATERIALS

For the development of the IoT Node was necessary to have the following materials: sensor for atmospheric pressure, humidity, and temperature; particulate matter sensor, breakout board for the IoT device, IoT "Particle Boron" device, and antenna for a better cellular signal reception.

2.1.1 BME280 SENSOR

The BME280 sensor is as combined digital relative humidity, atmospheric pressure and temperature sensor based on proven sensing principles. As the atmospheric pressure changes with altitude, it can also measure approximate altitude of a place. The BME280 achieves high performance in all applications requiring humidity and pressure measurement. The humidity sensor provides an extremely fast response time for fast context awareness applications and high overall accuracy over a wide temperature range. The integrated temperature sensor has been optimized for lowest noise and highest resolution.[2] Operating range: atmospheric pressure (300-1100hPa), temperature (-45 to 85C) and relative humidity (0-100%). High accuracy, absolute accuracy of ±1.0 hPa for pressure, ±1 accuracy for temperature and ±3% for humidity.[3] This module can be connected to the IoT device with I2C protocol. The Sensor is shown in Figure 1.

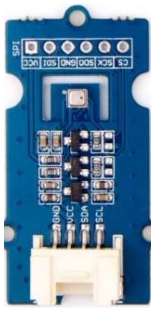

Figure 1: BME280 sensor.

2.1.2 PMS7003 SENSOR

The PLANTOWER PMS7003 universal digital output sensor is capable of measuring suspended particle concentrations. With a measuring range of 0.3 ~ 1.0; 1.0 ~ 2.5; 2.5 ~ 10 Micrometers (µm) with a resolution of 1 µg/m3. The unit of volume of particle number is 0.1 L and the unit of mass concentration is in µg/m3. Its operating voltage is 4.5 ~ 5.0v DC at 100 mA or less.[4] This module can be connected to the IoT device with the UART serial port. The Sensor is shown in Figure 2.

Figure 2: Plantower PMS7003 Sensor.

2.1.3 FEATHER SCREW TERMINAL FOR PARTICLE AND FEATHER MODULES

This NCD brand board offers a convenient screw terminal and power solution for IoT Particle Boron, Argon, Xenon devices. It includes an integrated I2C port for easy expansion. It also provides 3.3v DC and 5v DC I2C communications allowing for easy IoT hardware integration.[5] The Board is shown in Figure 3.

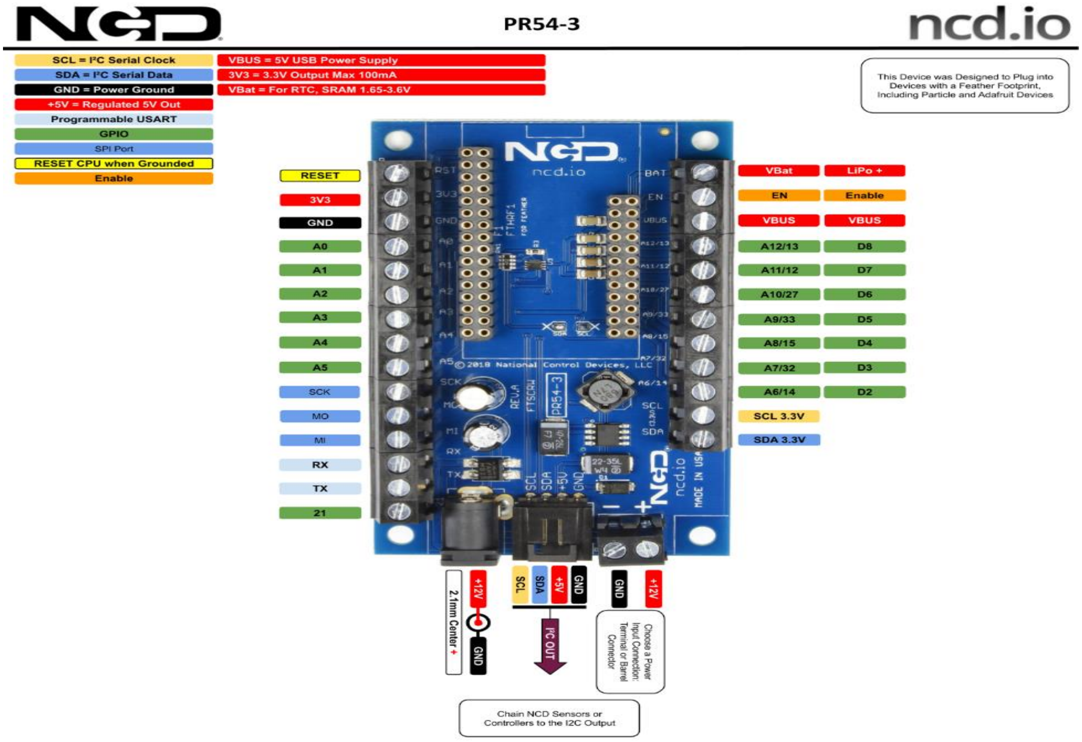

Figure 3: Feather Screw Terminal for Particle and Feather Modules.

2.1.4 PARTICLE BORON

The heart of the IoT Node is the Particle Boron device, where all the sensors will be managed. This powerful development kit with 2G/3G and Bluetooth connectivity. It is based on the NordicnRF52840 and has an integrated battery charging circuit, making it easy to integrate a Li-Po battery and deploy a local network in minutes. This device is perfect for connecting the node to the cloud in locations where WIFI is limited or non-existent.[6] The IoT Particle Boron device is shown in Figure 4.

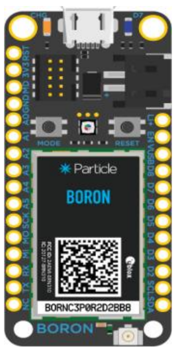

Figure 4: Particle Boron.

2.1.5 TAOGLAS FXUB63 ANTENNA

The FXUB63 is an Extremely Efficient, Wide Band, Flexible LTE Antenna with a small footprint. This easy to install durable, flexible polymer antenna operates on greater than 45% efficiency on LTE bands from 698 – 3000MHz. For use in a wide array of applications which need LTE connectivity, including home automation, emergency services, automotive, healthcare, HD video, vending machines, digital signage, IoT gateways, smart grid, agriculture.[7] The antenna is shown in Figure 5.

Figure 5. Taoglas FXUB63 antenna.

3 RESULTS AND DISCUSSION

3.1 RESULTS

In Figure 6 is shown the integration of the system. The BME280 sensor which is a relative humidity, atmospheric pressure and temperature sensor, is connected to the I2C communication port of the IoT Particle Boron device, through SDA (data line) and SCL (clock line) pins. The PMS7003 sensor which is capable of measuring suspended particle concentrations, is connected to the UART serial port of the IoT Particle Boron device, through RX and TX pins. The IoT Particle Boron device is mounted on the breakout board which is the screw terminal and power solution for IoT Particle.

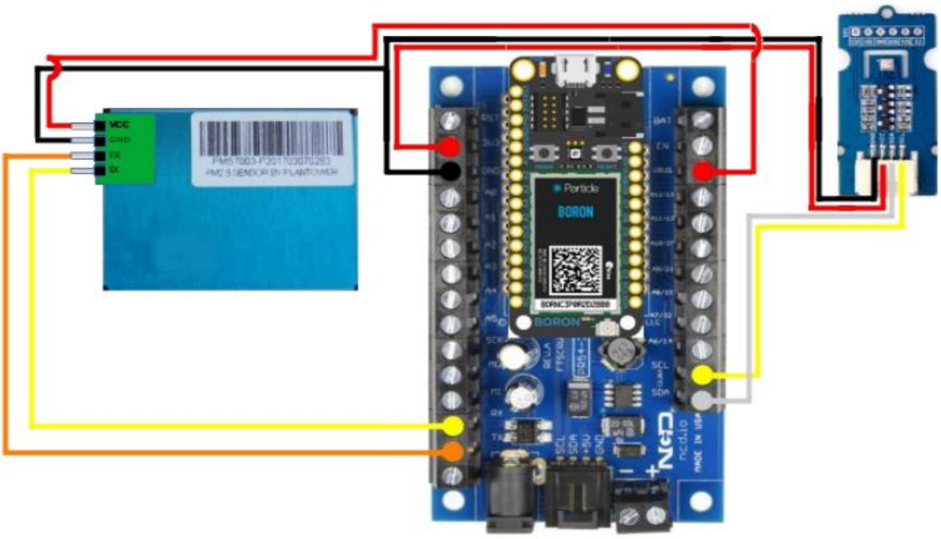

Figure 6: Diagram of components and electrical connections of the node.

After the node was built and installed, sensor readings began to be taken in 60-minute periods, where real-time data on ambient temperature, relative humidity, altitude, atmospheric pressure, PM2.5 and PM10 suspended particles were obtained in a numerical format. Each time a 60-minute cycle was completed, the micro-controller Particle Boron collected and organized the data obtained in a JSON format file and then sent it to a Google Firebase real-time database. Once sufficient data were available, they were processed by a web application and finally displaying them to the end user in the form of graphs. In this way the objective of this project was achieved, to develop and build a node capable of measuring certain meteorological variables in real time to help the relevant authorities to make accurate and quick decisions.

In Figure 7 is shown the real-time temperature monitoring.

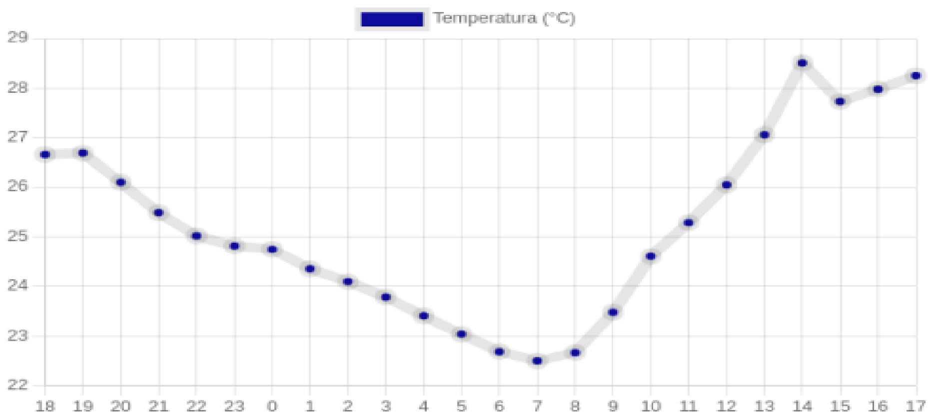

Figure 7: Temperature graph, where the x-axis represents time in hours and the y-axis represents temperature in degrees Celsius(°C).

In Figure 8 is shown the real-time humidity monitoring.

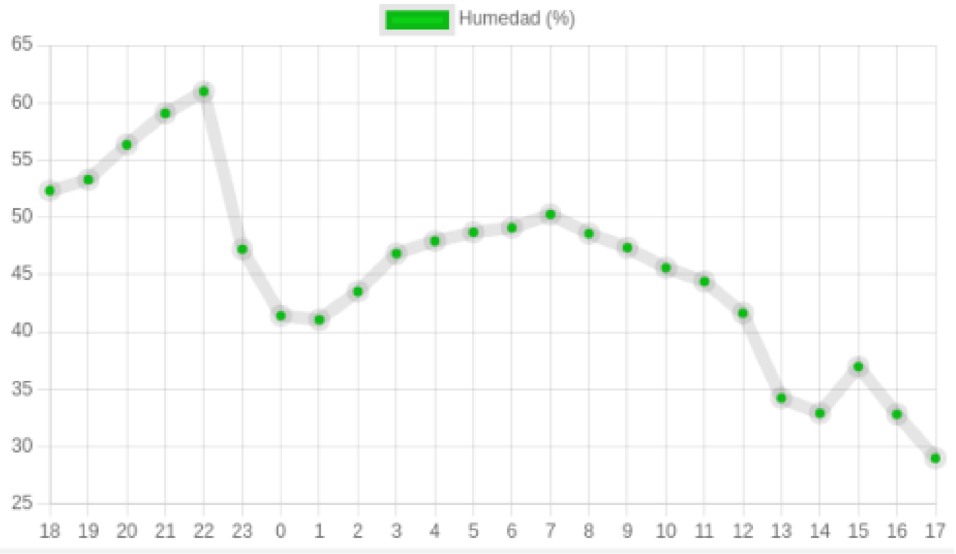

Figure 8: Relative humidity graph, where the x-axis represents the time in hours and the y-axis represents the percentage of relative humidity (%).

In Figure 9 is shown the real-time atmospheric pressure monitoring.

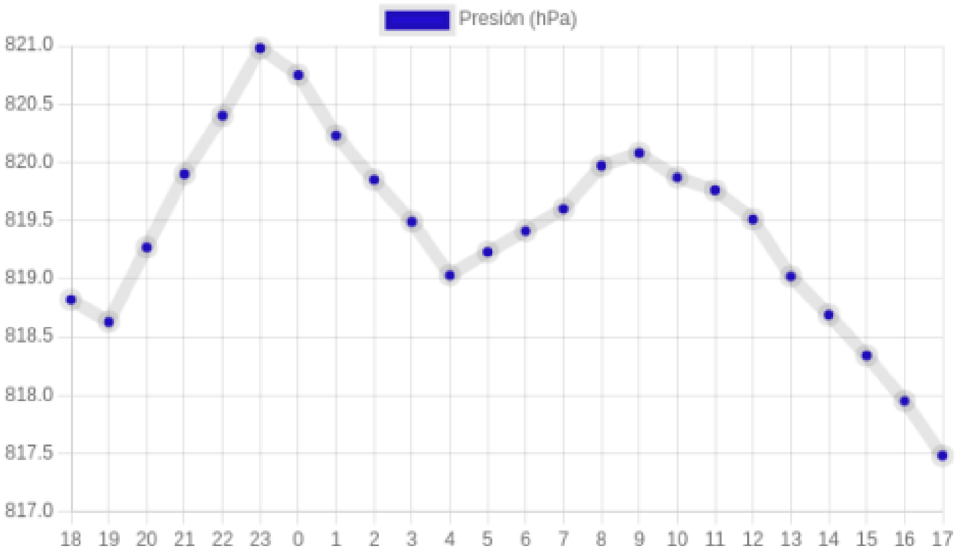

Figure 9: Atmospheric pressure graph, where the x-axis represents time in hours and the y-axis represents atmospheric pressure in hectopascals (hPa).

In Figure 10 is shown the real-time altitude monitoring.

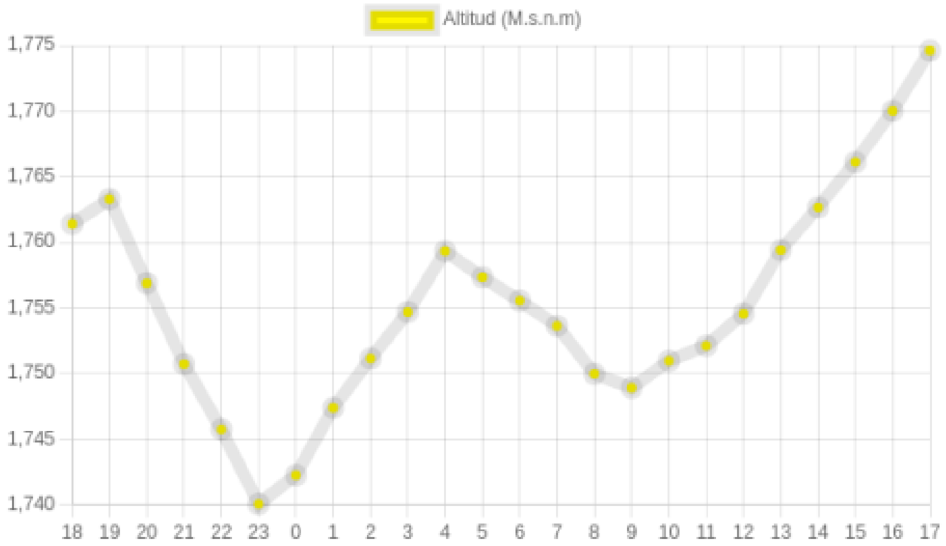

Figure 10: Altitude graph. Where the x-axis represents time in hours and the y-axis represents altitude in meters above sea level (m).

In Figure 11 is shown the real-time particulate matter mass concentrations monitoring at 1, 2.5 and 10 µm particle size.

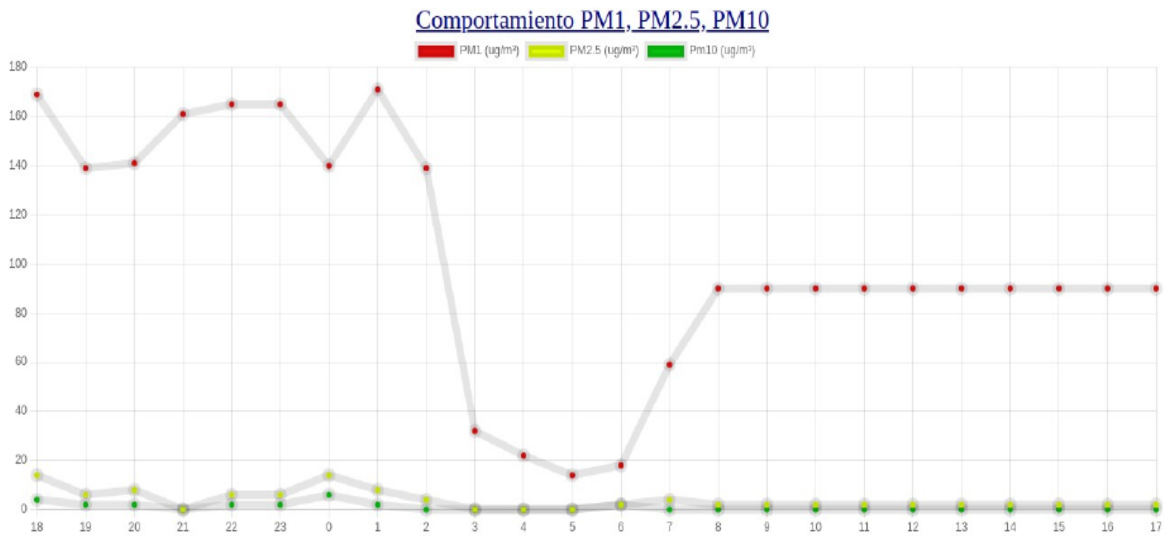

Figure 11: Graph of fine particulate matter concentrations at 1, 2.5 and 10 µm. Where the x-axis represents time in hours, and the y-axis represents concentration in micrograms per cubic meter (µg/m^3).

CONCLUSIONS

An IoT node was developed capable of monitoring in real time temperature, relative humidity, atmospheric pressure, altitude and the concentration of polluting particles in sizes of 1.0, 2.5 and 10 micrometers. The data of the variables are stored in a database in real time and are graphed in a web application which allows to visualize each one of the data so that the end user is alerted to each one of the variables.

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