# An IoT-based Air Quality Monitoring Platform

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***Abstract*— Air pollution is a major environmental problem and causes serious damage to human health. Considering the COVID-19 pandemic scenario, the importance of monitoring and controlling pollution emissions becomes more relevant and fundamental for combating the disease. Seeking to contribute with technological tools, this work presents a proposal for a system based on IoT using low sensors to monitor the most novice pollutants to health, according to the recommendations of the World Health Organization. The proposal presents the development in the hardware layer of a device able to measure the concentrations of the following pollutants: Particulate Material ($PM_{2.5}$ and $PM_{10}$), Ozone, Carbon Monoxide, Nitrogen Dioxide and Ammonia by means of three sensors, respectively, PMSA003, MICS-6814 and MQ-131. The device is be equipped with the ESP-WROOM-32 microcontroller that has a Wi-Fi and Bluetooth wireless interface that will allow data to be sent to a server in the cloud. It is important to note that what differentiates from the proposal from others is the implementation of periodic notifications and the sending of alerts for cases in which a given pollutant has reached the maximum acceptable concentration.**

***Keywords*— *IoT, Air Monitoring, COVID-19, Sustainable Cities***

## I. INTRODUCTION

Over the years, air quality is increasingly compromised due to increased emissions of pollutants into the atmosphere that are generally released by automotive, industrial and burnt areas. According to the World Health Organization (WHO) [1], more than four million people die each year due to diseases, mainly respiratory and cardiac, caused by air pollution. These numbers tend to increase considerably due to the pandemic caused by COVID-19. Exposure to air pollution is a risk factor that contributes to the increase in the number of serious cases and deaths caused by COVID-19, as the main aggravating factor of the disease is respiratory complications.

Scientific studies [2, 3] show that there is a relationship between air pollution and the worsening of COVID-19 cases and a possible role of pollution particles as transport vectors for viral transmission. In [2] American scientists investigated the risks that exposure to Particulate Matter (PM) could cause considering the new coronavirus pandemic and found that an increase of only 1 μg/m3 in the concentration of $PM_{2.5}$ in the air was associated with an increase in 8% in the COVID-19 mortality rate. In [3] a preliminary study found RNA samples of the Sars-CoV-2 virus that causes COVID-19 in $PM_{10}$ pollutant particles. If it is proven that COVID-19 is being spread by air pollution, monitoring air quality is essential for controlling the pandemic, since according to the study itself in conditions of high concentration of $PM_{10}$, the pollutant agglomerates and increases the persistence of the virus in the atmosphere.

Considering the data released in the 2019 report by the Health and Sustainability Institute (from Portuguese, *Instituto Saúde e Sustentabilidade*), which presents an analysis of the monitoring of air quality in Brazil [4], the situation regarding the implementation of monitoring instruments is still moving slowly. The industry and academic community has made great efforts to develop solutions and has already achieved significant technological advances, such as, for example, the evolution of passive samplers for equipment with sophisticated embedded electronics that allows real-time analysis of the concentration of a given pollutant. However, the commercial solutions offered by the industry that are generally used by environmental agencies have a very high cost of implementation, maintenance and operation.

In order to contribute to the monitoring of air quality, this article presents a hardware solution based on the Internet of Things (IoT) using low cost sensors, as a way to measure the pollutant indices in the atmosphere. The solution also provides for integration through software with a system for real-time monitoring of air quality and sending of notifications and alerts. The proposed solution is a viable tool for large-scale deployment in a scenario of smart cities, because as it is a low-cost device, it can be installed in homes, schools, hospitals, companies, etc.

The popularization of IoT devices and the emergence of low-cost sensors that make it possible to accurately measure the concentration of gases and pollutants in the atmosphere are attractive tools to fill the scarcity of information about the quality of the air that people breathe. In this context, the work presented here seeks to contribute to the control of the countless environmental and health impacts of people caused by pollution, because without data that prove the problem, it is difficult for the environmental agencies to act, which may even make it impossible to take actions or impose of limits. Regarding the COVID-19 pandemic, the monitoring solution under development could become a tool for the prevention and control of the disease, as it will make it possible to provide real-time information on air quality that can be used to make decisions that must be taken to minimize impacts.

The rest of the paper is organized as follows: Section 2 presents a survey of academic and professional works that address the implementation of pollution monitoring solutions. In the following section, concepts of a monitoring network are introduced, a brief summary of the legal requirements in the Brazilian scope and the correlation of pollution and the COVID-19. Section 4 describes the monitoring system that includes the hardware and software project that is the proposed test article. In the last section, final considerations and future work are presented.

## II. RELATED WORK

The need for air quality monitoring networks stimulates the development of systems, devices, and techniques for measuring and analyzing the concentrations of air pollutants. As part of the work, this section presents a state-of-the-art research on the object of study that will be presented below

The work developed by Thu et al. presented in [5], describes an air quality monitoring solution with IoT sensors and long-range communication. In the hardware layer, a commercial solution from Telaire was used, which includes Arduino Uno microcontroller with long-range module (LoRa) and sensor kit for measuring temperature, humidity, dust, and carbon dioxide ($CO_2$). It is important to note that the work used a sensor capable of measuring the concentration of dust particles, however, it does not specify the concentrations of $PM_{2.5}$ or $PM_{10}$, that is, it only measures in general the concentration of solid particles in the air.

Using a network topology based on Low-Power Wide Area Network (LPWAN) with LoRA technology, a backbone infrastructure for interconnecting devices and the server hosted in the cloud is proposed. At the communication protocol level, Message Queuing Telemetry Transfer (MQTT) was used to transfer the data collected by the devices to the server.

The application that is in the cloud receives the MQTT packages, extracts the data collected by the sensors and stores them in a time series database. A service was also implemented to make information available on a Web interface using the Grafana application. The availability of information in real time is not enough to minimize the possible damage to health, it is necessary to implement informative notifications and alerts when the concentrations of pollutants exceed the acceptable limits.

Also, in [5], the use of Machine Learning to predict the monitored indexes is indicated, however, only prediction graphs are shown for temperature and humidity and it is proposed that the technique can be applied in a similar way to estimate the concentration of dust and $CO_2$ , which would be more relevant in the context of monitoring air quality. The data on the weather forecast is easy to obtain and released daily by meteorological institutions.

Huang et al. published in [6] the development of an air quality monitoring platform capable of measuring the concentration of $PM_{2.5}$ and gases formaldehyde ($CH_2O$), carbon monoxide (CO) and $CO_2$ - it is important to note that CO is more harmful to health than $CO_2$. The article proposes a device in which an electronic circuit board was designed to couple the sensors used, namely: ME2-CO, MG811, ME2-CH2O, HTU21D and PMS3003. The device also monitors temperature and humidity. For the implementation of the wireless connection, the ESP-07 microcontroller, which has a Wi-Fi interface and the nRF51822 chip for communication via Bluetooth 4.0, was shipped on the device board.

The hardware design is compact, and the device has an elegant design, which appears to be a product ready for large-scale production and commercialization. The evidence that the proposed device is accurate in its measurements can be seen in the sensor calibration methodology that has been described and, in the results, presented. The monitoring platform was designed for the device to collect sensor data and send to a mobile application (app) that must be installed on the user's smartphone.

Through the app, the values that are measured in real time are displayed, the article does not inform if the data are stored in time series to enable an analysis of the measurement history. As presented, the data analysis is limited to the smartphone's processing capacity and memory, as the smartphone acts as a solution server. It is also not informed if the app triggers any type of pop-up notification or alert in case of high concentration of a particular pollutant.

The fact that the platform did not implement a cloud storage service for the data that is measured by the sensors, which would be of paramount importance, significantly limits the platform's contribution potential. Because it makes a long-term analysis difficult and if the user wishes to carry out such a study, he must store the measurements manually. The cloud service is also important for data to be shared with government environmental agencies.

In [7] Ladekar et al. present an IoT solution using Raspberry Pi board and Node-MCU ESP8266 for monitoring air quality that measures the concentration of $O_2$ and the pollutants $CO_2$ and $PM_{2.5}$. The proposed prototype is shipped with a Node-MCU ESP 8266 microcontroller that connects GP2Y20100UF ($PM_{2.5}$), MH-Z19 ($CO_2$) and Grove-Gas ($O_2$) by means of an electronic circuit board. The collected data is sent via Wi-Fi to a Raspberry that acts as an MQTT Broker server.

The goal of the paper is to create an air quality monitoring network in indoor environments by allocating kits with the sensors for various locations. The Raspberry must connect to all ESP8266 to receive the data and also send via MQTT to the server that is hosted in the cloud. The data in the cloud is processed using mathematical functions and managed by the Kibana application, which allows visualization in graphics mode. A differential of the solution is the sending of alerts via e-mail and SMS in real time in cases where the upper limits are reached.

The proposal is promising, however, the need to use the Raspberry was not justified, as the data could be sent directly from the ESP8266 to the server through a Wi-Fi gateway for home use at a lower cost. The device could also monitor temperature and humidity, as it would not cause significant impacts and would complement the information base that is used for the analyzes. It should have been implemented to send periodic notifications to inform users about pollution rates, because when the alerts are sent, the concentration of pollution is already high and harmful to health.

A proposal for monitoring air quality using land and air stations using UAV is presented in [8]. Hu et al. describes a monitoring system implemented in a four-layer architecture, namely: sensing layer, transmission layer, processing layer and presentation layer. In the sensing layer, the IoT device is basically composed of the ATmega128A microcontroller that connects the A3-IG sensor that measures the concentration of PM2.5 and PM10 and a chip for wireless connectivity.

The system was designed to reduce energy consumption, both for terrestrial and spatial monitoring. Energy consumption is controlled by the server that manages the devices that can act to request more measurement data when the concentration is high or increases the time to send information when conditions are favorable, allowing the IoT device to operate in idle mode with minimal energy consumption. Perhaps, due to the premise of low energy consumption, sensors were not shipped to monitor other pollutants harmful to health, leaving the solution limited to monitoring only two pollutants.

The sending of data to the processing server hosted in the cloud is carried out by means of an embedded wireless interface using the SIM7000C chip, characterized as an LPWAN technology of the NB-IoT type, which enables connectivity to the Internet via mobile telephony infrastructure. In the processing layer are the services of processing, analysis and preparation for viewing the information. The processing and analysis service implements neural network and marchile learning algorithms to spatially adjust the air quality map and predict short-term future values. In the prediction of future values of air quality, which is based on historical data and meteorological data provided by government agencies, the results present satisfactory accuracy, with an error between 7 and 11%.

In the presentation layer, two services are available, a web interface that makes it possible to consult maps with information about the stations and graphs of the concentrations of monitored pollutants. The second service is a Web chat that allows the user to interact with the system to consult information about the air quality of a given location.

The work described in [8] is a well-designed implementation that used sophisticated techniques in the processing layer to carry out the processing and the prediction of air quality. Spatial monitoring through UAV collections appears to be quite attractive, however, it is limited by several conditions, such as: battery discharge time and environmental conditions (which can even make flight unfeasible). It was not clear in the article whether a human operator is needed to control the UAV, if it is yet another drawback. Data collection at different heights in relation to the ground could be carried out using devices installed in the structure of buildings, telecommunications towers and poles, for example.

The state of the art presented in this article shows that the academic community is joining efforts to develop low-cost monitoring solutions, using IoT, to suppress the scarcity of information on air quality. It is clearly observed that the solutions proposed in articles [5], [6] and [7] monitor little gases and particulate matter. For WHO it is essential to monitor five main pollutants, described in [9], namely: $PM_{10}$, $PM_{2.5}$, Ozone ($O_3$), Nitrogen Dioxide ($NO_2$) and Sulfur Dioxide ($NO_2$). Therefore, it is important that the solutions include a larger amount of pollutants monitored.

## III. Air Quality Monitoring

Air quality monitoring is a tool for environmental control and human health welfare, as air pollution significantly affects the quality of life of the population causing various diseases. It is essential that nations encourage the implementation of air quality monitoring networks to enable their populations to know and monitor the levels of pollution in the region where they live, especially in large urban centers, as they are places that concentrate large industrial centers and commercial vehicles, as well as heavy motor vehicle traffic.

WHO considers the subject treated by this work to be of great relevance. They published in 2005, a guide that establishes criteria and reference values for the monitoring of air pollutants most harmful to health, that is, their monitoring is essential for health of people. Table I taken from [10], which presents a summary of the risk assessment in the complete guide [9], lists the most important and essential air pollutants in a monitoring system with the respective maximum concentration values. The data presented is only a portion of the contribution that WHO offers through [9] for the development of air quality management policies. The complete guide presents scientifically proven health risk assessments and suggests a set of goals to encourage the reduction of air pollution.

TABLE I. Limit Reference Values For The Main Air Pollutants as Indicated by WHO.

| Guideline levels for each pollutant ($\mu g/m^3$) | | |
|---|---|---|
| $PM_{2.5}$ | 1 year | 10 |
| | 24 h (99th percentile) | 25 |
| $PM_{10}$ | 1 year | 20 |
| | 24 h (99th percentile) | 50 |
| Ozone, $O_3$ | 8 h, daily maximum | 100 |
| Nitrogen dioxide, $NO_2$ | 1 year | 40 |
| | 1 h | 200 |
| Sulfur dioxide, $SO_2$ | 24 h | 20 |
| | 10 min | 500 |

The implementation of air quality monitoring networks is a complex and costly task. Governmental entities and environmental agencies recognize the need, but they encounter numerous difficulties ranging from the acquisition of equipment, systems, maintenance, and qualified labor to operate the monitoring networks. The cost to implement a monitoring system using commercial solutions offered by the industry requires millionaire investments and in [5] and [11] costs are estimated at USD 200,000.00 and USD 500,000.00, respectively, for installing a single monitoring station with a number considerable amount of pollutants measured.

Taking the current scenario in Brazil as an example, the results of public assessments in [4] show that the coverage of air quality monitoring does not meet the requirements of current legislation, which began to be established in the late 1980s. More than thirty years have passed and there have been few advances in air quality management in the country, which is much lower than what was foreseen by the laws, because according to [4], monitoring is in fact carried out only in the Federal District and in six states, namely: Espírito Santo, Minas Gerais, Pernambuco, Rio de Janeiro, Rio Grande do Sul and São Paulo. Another important fact is that 56.1% of the stations are located in the metropolitan regions of the capitals.

Figure 1 shows an air quality monitoring station that is part of a network operated by the Environmental Company of the State of São Paulo (CETESB). The station is located in São Paulo/SP, Brazil, on the banks of the Tietê river, and monitors five pollutants, namely: particulate matter of size 2.5 and 10 μm, nitrogen oxides, sulfur dioxide and carbon monoxide, in addition to climatic parameters such as temperature, humidity and solar radiation.

Fig. 1. Air quality monitoring station located in São Paulo/SP, Brazil.

Still in [4], the results show that there are only 375 monitoring stations in Brazil and 319 are in operation (equivalent to 85% of the total number of stations). Of the total stations, 60% are operated automatically, that is, almost half still work with procedures performed manually. The most monitored pollutants are: $PM_{10}$ (in 58.3% of stations); $NO_2$ (in 39.2%); and $O_3$ (in 37.6%). The pollutant $PM_{2.5}$, which according to WHO is one of the main pollutants to be monitored, is measured in only 20.4% of stations. Another aspect that draws a lot of attention is that only the states of São Paulo and Espírito Santo provide information in real time through daily newsletters. However, the situation is even worse because even when high levels of pollutants are detected, leaving the air condition critical and harmful to health, notifications are not sent to alert the population about the risks.

To make it easy for the understanding of the population and the analysis of environmental analysts on air quality, pollution indexes are usually standardized for each pollutant. In Brazil, the current legislation defined a quantity called the air quality index (IQAr) to assist in monitoring and control assessments. In [12] the mathematical formula (1) for the calculation of the IQAr of air pollutants is presented.

$$IQAr = I_{ini} + \frac{I_{fin} - I_{ini}}{C_{fin} - C_{ini}} x \, (C - C_{ini}) \quad (1)$$

In which:

- $I_{ini}$ = index value that corresponds to the initial concentration in the range
- $I_{fin}$ = index value that corresponds to the final concentration in the range
- $C$ = measured pollutant concentration
- $C_{ini}$ = initial concentration in the range where the measured concentration is located.
- $C_{fin}$ = final concentration in the range where the measured concentration is located.

The purpose of IQAr is to standardize and normalize the scale for measuring concentrations. For the calculation based on (1) it is necessary to use a reference table that classifies the concentration ranges based on the measured values and to obtain the quality level. However, Brazilian legislation at the federal level is flawed and has not specified all concentration ranges that define air quality levels, leaving it to the discretion of each state in the federation. Table II shows how the IQAr classifications adopted by the state of Rio Grande do Sul/RS.

TABLE II. AIR QUALITY INDEXES STANDARDIZES BY THE STATE OF RIO GRANDE DO SUL/RS, BRAZIL.

| Air Quality | Index (IQAr) | $PM_{2,5}$ | $PM_{10}$ | $SO_2$ | $NO_2$ | $O_3$ | CO |
|---|---|---|---|---|---|---|---|
| | | (µg/m³) | | | | | PPM |
| Good | 0-40 | 0-25 | 0-50 | 0-20 | 0-200 | 0-100 | 0-9,0 |
| Moderate | 41-100 | 26-60 | 51-120 | 21-125 | 201-260 | 101-140 | **** |
| Inadequate | 101-199 | 61-124 | 121-249 | 126-799 | 261-1129 | 141-199 | 9,1-14,9 |
| Bad | 200-299 | 125-209 | 250-419 | 800-1599 | 1130-2259 | 200-399 | 15,0-29,9 |
| Terrible | 300-399 | 210-249 | 420-499 | 1600-2099 | 2260-2999 | 400-599 | 30,0-39,9 |
| Critical | ≥ 400 | ≥ 250 | ≥ 500 | ≥ 2100 | ≥ 3000 | ≥ 600 | ≥ 40 |

The value of the IQAr is also related to human health security, as shown in Table III. It is more friendly for the lay population to assess air quality and become aware of the possible damage to health that can be caused by exposure to contaminated air.

TABLE III. CORRELATION OF IQAR WITH HUMAN HEALTH RISKS.

| Air Quality | Index (IQAr) | Caution Levels on Health |
|---|---|---|
| Good | 0-40 | Safe |
| Moderate | 41-100 | Tolerable |
| Inadequate | 101-199 | Unhealthy for Sensitive Groups |
| Bad | 200-299 | Very Unhealthy (Attention Level) |
| Terrible | 300-399 | Dangerous (Alert Level) |
| Critical | 400 or higher | Very Dangerous (Emergency Level) |

Greater importance for expanding the coverage areas of air quality monitoring may become a reality if the correlation between particulate matter and mortality from COVID-19 is proven, as investigated by the studies referenced in the introduction [2] and [3]. A COVID-19 control mechanism may then be implemented by collecting more information on the emission of particulate material that can be carried out by means of monitoring devices spread over several locations, such as: buildings, stores, restaurants, schools, banks and etc. The information collected by feeding a database will make it possible to map the regions of greatest risk that people may be exposed to the worsening of COVID-19, as suggested [2] or even contamination by viruses carried by pollution, as analyzed by [3].

## IV. IOT-BASED AIR QUALITY MONITORING

The solution proposed in this article, which is part of a larger project under development, includes the hardware and software layer for real-time monitoring of air quality through a low-cost IoT device. In the hardware layer, an electronic circuit project is being prepared to build a plate with sensors that measure the concentration of $PM_{2.5}$, $PM_{10}$, $O_3$, CO, $NO_2$, Ammonia ($NH_3$). Among the pollutant monitoring functionalities, temperature and humidity monitoring was also inserted, which helped in the analyzes. Communication between the device and the application will be carried out through a Wi-Fi and Bluetooth interface.

The diagram in Figure 2 illustrates a schematic of the solution with the main components that will be shipped on the device board that will perform the measurements. ESP-WROOM-32 (or simply, ESP32) was chosen as the microcontroller, which will be responsible for collecting the data obtained by the following sensors: DHT22, which measures the ambient temperature and air humidity; PMSA0003 which is capable of efficiently measuring and specifying the concentration of $PM_{2.5}$ and $PM_{10}$ particulate matter; MQ-131 will be used to measure the O3 concentration; and MICS-6814 to measure the concentrations of CO, $NO_2$ and $NH_3$, which can also be used to monitor five other polluting gases. Below is a brief description of the components mentioned.

ESP-WROOM-32 is a low-power, high-performance microcontroller, configured with a 32-bit dual core processor, 520 Kbytes RAM, 448Kbytes ROM and 4 MB Flash. The module has Bluetooth connectivity BLE 4.2 and wireless interface, with built-in antenna, standard 802.11 b/g/n with maximum throughput of 150 Mbps. One of the great advantages of ESP32 is the number of GPIO pins and the availability of 18 channels for analog/digital conversion (ADC) with 12-bit quantization. Even if it shows itself as a robust IoT device, the possibility of crashes is not ruled out and to circumvent possible unavailability, the watchdog functionality is implemented - by means of three independent timers of the main system detects crashes and restart the microcontroller.

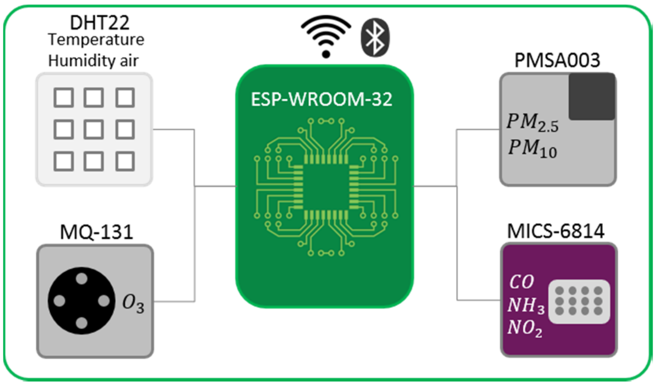


Fig. 2. Schematic diagram of the air quality monitoring device.

Table IV shows the measurement range of the sensors used. The PMSA003 is a compact digital sensor for measuring particulate matter that is suspended in the air. Particulate matter, also called dust, are particles of varying size and the sensor makes use of a microprocessor to implement a measurement technique based on light scattering to identify the size of the particles and the respective concentrations.

The MICS-6814 is a compact sensor with the ability to accurately detect the simultaneous concentration of CO, $NO_2$ and $NH_3$, providing independent channels for each gas. The sensor is very promising, and it is worth noting that it is also possible to measure other five gases, namely: Methane (CH4), Propane ($C_3$H8), Ethanol ($C_2H_5OH$), Hydrogen ($H_2$) and Iso-butane ($C_4H_{10}$). The MQ-131 sensor has high sensitivity for detecting $O_3$ concentration, has a trimpot for calibration and analog output. For monitoring temperature and humidity, the DHT22 digital sensor was chosen because it is accurate in measurements and easy to install.

TABLE IV. RANGE OF MEASUREMENT CONCENTRATION OF THE SENSOR BY POLLUTANT.

| Sensor | Pollutant | Range |
|---|---|---|
| PMSA003 | $PM_{2.5}$ | 0 – 500 µg/m³ |
| | $PM_{10}$ | 0 – 500 µg/m³ |
| MQ-131 | $O_3$ | 10 -1000 ppb |
| MICS-6814 | CO | 1 – 1000 ppm |
| | $NO_2$ | 50 – 10000 ppb |
| | $NH_3$ | 1 – 500 ppm |
| DHT22 | Temperature | -40 a 125 °C |
| | Humidity | 0 – 100 % |

With the monitoring proposed by means of the chosen sensors, it will be possible to obtain relevant and accurate data with low implantation cost, as can be seen in Table V, in which the values of the main components of the device are estimated.

TABLE V. ESTIMATED COST OF HARDWARE COMPONENTS REQUIRED TO ASSEMBLE THE MONITORING DEVICE.

| Item | Type | Cost (USD) |
|---|---|---|
| ESP32 | Controller | $5.00 |
| Power Supply AC/DC | AC/DC Bivolt | $5.00 |
| Wiring and Connections | Components | $6.00 |
| PMSA003 | Sensor | $15.00 |
| MICS-6814 | Sensor | $20.00 |
| MQ-131 | Sensor | $20.00 |
| DHT22 | Sensor | $4.00 |
| TOTAL | | $75.00 |

For the initial configuration and management of the device, the ESP32 Bluetooth interface and mobile application to be developed will be used. The app will be modeled to configure the wireless connectivity parameters (SSID and password) and server information, such as: IP address or domain, port of each TCP/IP transport, token for device identification and general information about the location that will work as a monitoring station.

A macro view of the system is illustrated by Figure 3, in which each green dot in the buildings represents the measurement points through the proposed solution and the topology of how the device will send the data to a server hosted in the cloud. Each device's ESP32, green dot, will connect to the Internet through a home wireless network. In order to send data, the MQTT protocol will be implemented and the server mode will be configured in the application that will process and store the information.

The device will be integrated to enable the use of the Zabbix and Grafana tools as systems for monitoring and visualizing data through graphs, to enable real-time or long-term analysis. The choice of tools is justified by the fact that they are promising in the monitoring of network monitoring, open source, with constant updating and easy management. It is planned to develop a Web service to consume data from Zabbix and/or Grafana via the REST API and allows public access to information.

The Web Service will have an interactive and friendly interface so that users can easily consult information and register their contacts to receive periodic notifications and alerts in case of risks through e-mail, SMS and Telegram. Among the data evaluation options, an analysis dashboard will be implemented through the IQAr based on the classification table in force for a given location, similar to Table II, which allows a more detailed assessment of the health risk of each rating range of the quality of the service. air, as shown in Table III. The possibility of creating accounts on the main social networks will be analyzed, so that automatic posts can be made with the dissemination of information in real time and thereby reach a greater number of people.

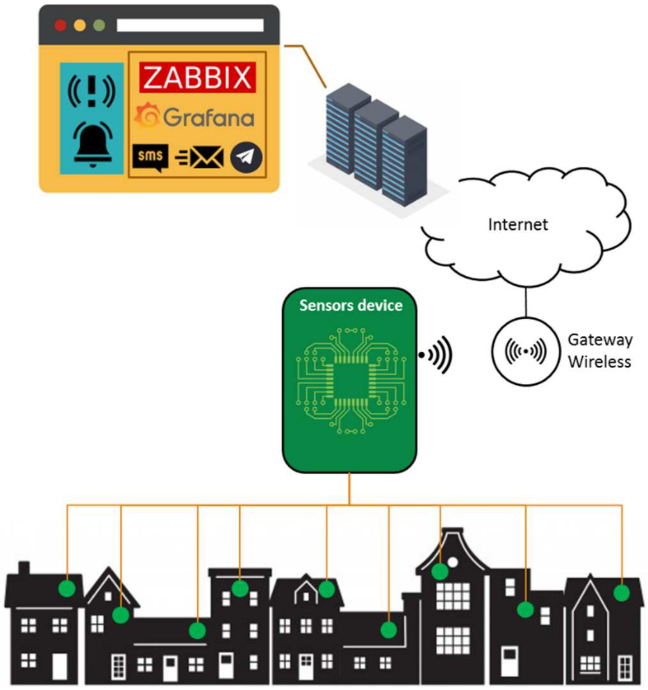


Fig. 3. Illustration on sensor communication with application in the cloud.

For the pilot project, some units of the device will be built that functioned as monitoring stations. The stations will be allocated at the points of presence of the academic fiber optic network located in the metropolitan region of Natal/RN, Brazil and interconnected through the existing infrastructure.

## V. Final Considerations and Future Works

Evidence has been presented that air quality monitoring is a fundamental environmental control and management mechanism in many respects, especially with regards to human health. The proposal described here is a solution that offers a considerable amount of pollutant monitoring, covering four of the five main ones recommended by WHO, using low cost hardware suitable for indoor environments. It is important to note that, in addition to temperature and humidity, initially, it can monitor six different pollutants and may expand to eleven without the need for new sensors.

It is expected that at the end of the proposal's execution, a product will be obtained that meets all the specified objectives and benefits the population, government environmental, health and inspection bodies with real-time information, which may improve the quality of life and avoid illness and death. The academic community will also benefit, as it will have a database to carry out studies and research to identify the impacts of air pollution.

The proposal is promising and it will gain more functionality in future works, such as: a greater number of sensors that can monitor new pollutants, among them Sulfur Dioxide that low cost sensors were not found; Sensing that makes it possible to collect meteorological data such as: rainfall precipitation, solar radiation and atmospheric pressure; and use of artificial intelligence to estimate future behavior of the sampling curves.

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