Use Case for Air Quality Measuring and Transmission

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Abstract

Fourth and fifth generation (4G-5G) cellular networks provide key enabling technologies for the ubiquitous deployment of Internet of Things(IoT) technology. This has allowed the implementation of different use cases or applications that have allowed their operation to be evaluated. Aligned with several research studies around 5G and 4G that are currently being carried out, this research proposes the implementation of a use case for the measurement and transmission of air quality in Bogotá- Colombia, through the Internet of things and simulations in Software Defined Radio (GNU-Radio). As a result, network performance indicators were obtained that make the application viable both in data acquisition and transmission, in the use case for air quality. In that sense, this research makes it possible to establish the basis for real operations in future implementations of emergent technologies in the city.

Keywords: Monitoring, Air Quality, mobile Networks, emergent technologies, IoT

1 Introduction

At present, mobile networks have become an indispensable tool for the development of society [1]. The current Fifth Generation New Radio (5G-NR) of this technology can offer greater coverage in metropolitan areas. 5G is the digital transformation which refers to everything being connected to the network, that makes industry 4.0 a reality. This technology has the following characteristics: User data speeds of the order of Gbps everywhere, latency in the order of 1 millisecond, 10 times more battery life for devices, improvements to virtual reality, the possibility of experiencing holographic calls, streaming video in high resolution, energy saving and efficiency, smart cities, innovative applications [2, 3, 4, 5], and new use cases involving IoT [6], among others. The technical characteristics of 5G allow us to think of endless new use case scenarios, providing business opportunities. These new services will have a positive impact on the environment, society, and people by making possible the implementation of smart cities.

On the other hand, Air pollution is an issue that worries everyone and systematically disturbs the whole world because the impact is on the population's health. The World Health Organization [7] establishes the "healthy" limit of particulate matter in the air at 20 micrograms per square meter or (mcg/m3). The air that is inhaled daily is full of pollutants known as particulate matter (PM), with a diameter of

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up to 10 microns (PM10), being the most lethal for humans is the one with a diameter of 2.5 microns (PM2.5). Due to their tiny size, these particles go directly to the lungs, affecting children and adults, causing respiratory and cerebrovascular diseases, such as asthma, pneumonia, lung cancer, among others [8, 9].

In a smart city it is important to inform people about the pollution levels in various areas of a city or a specific place. This allows timely and personalized information to be provided to citizens [10, 11] offering them an emerging social awareness about the air quality status as [12]. This paper takes air pollution as a problem, considering that this kind of contamination is the most relevant environmental risk to human health and mix it with emergent technologies to have more information in real time.

Finally, this paper with an IoT-oriented monitoring approach was divided into two parts: (1) description of our air quality acquisition system, here the sensors functionality and feasibility with which it is possible to carry out an implementation is shown and (2) the simulation of our data transmission with 5G-NR technologies, which is carried out under a radio system defined by software. It is meaningfully here as it is not possible to physically carry out the transmission through 5G networks, it is decided to take the characterization of the acquired data and simulate transmission.

This project with an IoT-oriented monitoring approach, has two parts: (1) exposition of our air quality acquisition system (2) the simulation of our data transmission with 5G-NR technologies, which is carried out under a radio system defined by software.

2 Methodology

The development of this paper was carried out through three phases, with a SCRUM [13], [14] approach. Each phase has a product backlog which is reviewed by the team.

Phase 1. Product: Project Planning. The objectives and processes necessary to achieve the results of the project were established in this phase. The following activities were carried out in this phase: Working plan formulation and schedule.

Phase 2. Product: Project Development. Following the objectives set of the previous phase, we propose the following three activities: (I) To Design the system to transmit air quality data acquired in Bogotá, using narrowband IoT oriented to 5G networks and IoT [15]. (II.) To build the designed system using the selected simulation tools. (III.) To perform prototype simulations.

Phase 3. Product: Project Test. In this phase, the results were monitored and measured against objectives and requirements. The following stages were planted: Run the simulation tests, taking into account the KPIs of the system and draft each stage of project development.

3 Results and Discussion

3.1 Signaling acquisition

The air quality data collection was performed with the PMS5003 sensor; its functional block is presented in Figure 1 [15]. This sensor works through the principle of laser dispersion. In this way, when the particles in the air collide with the light beam of a laser diode, it produces a dispersion. Then, a photodiode collects scattered light and finally the curve of change of scattered light regarding time is obtained. The sensor can determine the number of particles with different diameters per unit volume through an algorithm based on Mie theory [16].

The PMS5003 was configured in active mode. This configuration has 2 operation sub-modes: stable mode and fast mode. If the concentration changes are small, the sensor will work in stable mode with an acquisition period of 2.3s. Otherwise, if the concentration is high, the sensor will work in fast mode with

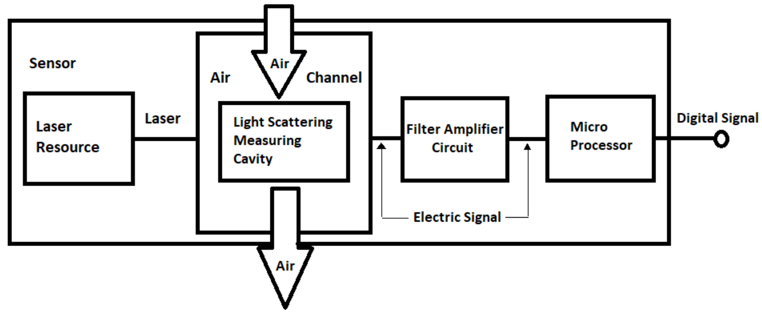

Figure 1: Functional block diagram of sensor PMS5003

a measurement rate between 200-800 ms. In this way, at higher concentrations, the measurement time decreases.

Electrically, this sensor works to 5V, nonetheless, the serial transmission voltage is 3.3 V. For this reason, we use a ESP32 microcontroller [17] due to this device having a physical serial port which gives a 3.3V voltage. Between the sensor and Microcontroller Unit (MCU), the serial data frame has a data rate of 9600 bauds.

We use the PMS library to obtain the dataset that will be used in the simulations. Through the library the PM1.0, PM2.5 and PM10 measurements were obtained as shown in figure 2. The measurement obtained is a 16-bit integer that is stored in a plain text file.

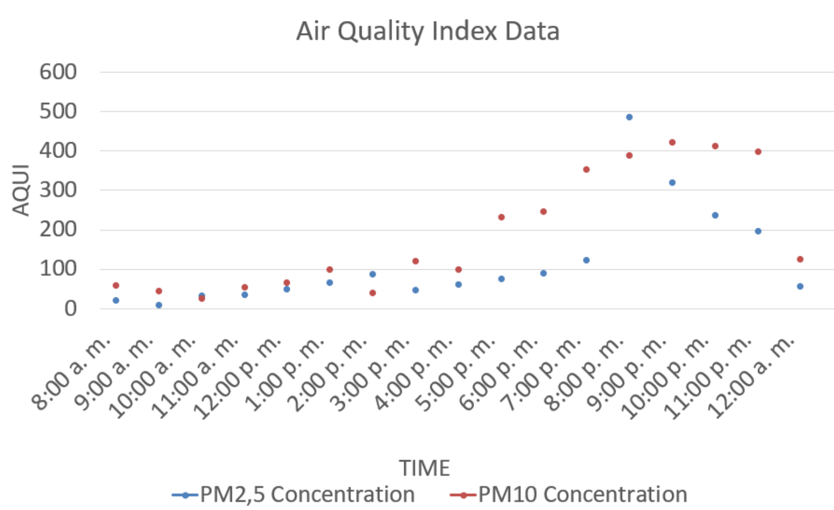

Figure 2: Air quality acquisition

This file is then called in the simulated data through Orthogonal Frequency Division Multiplexing (OFDM) transmission and reception. It must be considered that an IoT network would have many devices in different parts of the city sending the signals. The simulation does not take into account multiple devices; however, it does consider the measurement every 5 minutes and therefore the amount of data is increased, taking into account said interval.

3.2 Simulations of data transmission through GNURadio

In this simulation, the OFDM base algorithm was used for the transmission from the gNodeB (base station) to the UE (User Equipment). The OFDM resource can be found in the official GNU Radio wiki [18]. This type of multiplexing was selected because it is used in Narrow Band-Internet of Things (NB-IoT) and 5G technology [19]. The OFDM encoding was adjusted to simulate the data transmission required for this paper.

It was necessary to adjust the frequency to 3.5Ghz, band c, since it is the immediate implementation band for 5G. The size and origin of the data package was adjusted, taking into account that a measurement of the particulate material sensor will be taken every five minutes to meet the high reliability objective, considering [12]. The fft_len variable was defined with a value of 64, the samp_rate variable with 100khz, the packet_len variable with a value of 96 bytes, the header_mod variable in Binary Phase-shift keying (BPSK) and the payload_mod variable in (Quaternary Phase-shift keying) QPSK.

On the other hand, according to the datasheet of the sensor, HK-A5 Laser [20] or PMS5003 sensor [17], each measurement made has a fixed packet length of 32 bytes. Considering that each measurement is made every 5 minutes as mentioned, the data size to be transmitted is 9,216 bytes as equation (1).

$$\frac{32\,bytes}{1\,measurement} * \frac{24\,hours}{1\,day} * \frac{12\,measurements}{1\,hour} = \frac{9216\,bytes}{1\,day} \tag{1}$$

Figure 3 shows the throughput obtained from the simulations in GNU-Radio. During all the measurement days, the throughput did not present many variations as its standard deviation shown in the equation 2.

$$\sigma = \sqrt{\frac{\sum(X-\overline{X})^2}{n-1}} = 85.43 \tag{2}$$

Where x is the sample mean the average (measurement1, measurement2, etc) and n is the sample size.

All the above means stability in the system data rate. In this case, since it is a simulation, the throughput also depends on the hardware in which it is simulated. It is important to mention that the system has stable variability regarding data transmission speed and the measured throughput as expected for an NB-IoT system [21].

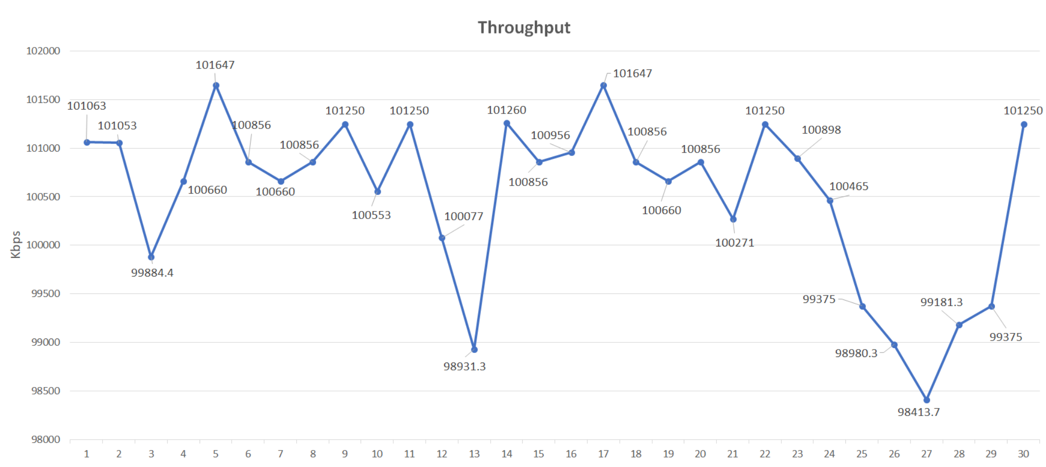

Figure 3: Throughput simulation

Figure 3 shows the Bit Error Rate, there is not much variation in the BER also. The measurements ranged between a maximum of 9.90803E-08 and a minimum of 9,64781E-08.

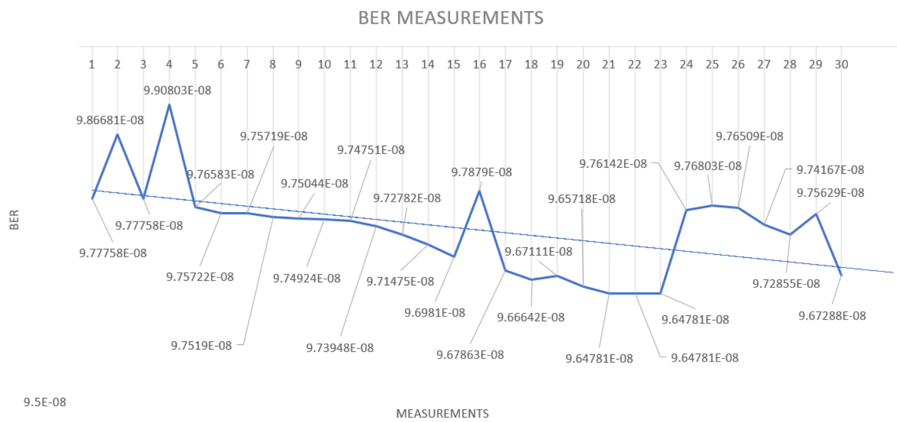

Figure 4: Bit Error rate Measurements

It is important to highlight that most measurements are close to error free, it means that the bit error rate is very low and there is a high data reliability as required for 4G or 5G NB-IoT. The above refers to URLLC (ultra-reliable low latency communications) [22]. This is one of the great pillars of next-generation mobile networks, which consist of offering advanced connection services to enable applications in a wide spectrum, within which is the Internet of things.

In this sense, with the set of measurements made, it is shown that it is feasible to implement a network with emerging technologies that support the amount of data acquired by air quality sensors.

4 Conclusions

This paper implemented an air quality monitoring case of study in Bogota-Colombia. We have developed a particulate matter acquisition system that is linked with a simulated IoT 5G-oriented architecture. Our results possess a qualified throughput and BER, concluding that the simulated system complies with the performance indicators of the 5G emergent networks.

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