# Air Quality Analysis in the Surrounding Environments Using a Lora Network

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**Abstract**

This paper presents an analysis and a comparison of the air quality from different areas in different conditions from outdoor and indoor environments, so we could take actions that could improve our well-being or could signal to bigger institutes what exactly should be monitored in what area so we could have the best breathable air. The paper is organized in three parts, the first one describing the air quality analysis and used sensors for indoor and outdoor measurements. The second part is describing the data transmission using the LoRa Wan protocol with an STM32 gateway and end nodes, to transit the analyzed data to a gateway to be able to centralize and process the data. Also, we will check possible ranges for LoRa transmission in a big city.
In the third part of the paper, we will present future development and points that will be checked with different sensors.

Keywords:
LoRa, Gateway, Air Quality, Pollution, RSSI, IOT.

## 1 INTRODUCTION

Our everyday work and living are influenced by the environment, therefore a big impact on our lives has the air quality from that area. To have control of this aspect, we need to do some measurements and have some references to be able to improve our well-being.

Usually when we are working in an indoor space, the last thing that we think about would be the air quality. Due to this fact after working half a day of in the same space, the level of concentration starts to reduce minute by minute, the fatigue starts to settle in the body and the energy is consumed fast. Most of us don't understand this situation, but by just opening a window for a couple of minutes, most of mentioned symptoms will disappear, and this is due to the consumption of Oxygen from that room and the increase of Carbon Dioxide [1].

This kind of issues started to occur especially when the pandemic of Covid 19 started, and everyone was forced to work from home and create mini offices in their own apartments. Due to this also the productivity of the employees started to reduce and for a certain amount of time the phenomenon couldn't be exactly explained.

Usually in each city the Townhall or the government have ore or two air quality sensors to measure the air quality, and usually those sensors cannot cover the entire city to give a precise air quality measurement, that's why this paper will analyze the range of the LoRa devices to be able to mount multiple end nodes in the city to give a more precise measurement.

## 2 AIR QUALITY MEASUREMENTS

### 2.1 Sensor used for the measurement.

The sensors used for the measurements are monitoring the following parameters: Carbon Dioxide ($CO_2$), Dust (PM2.5), Nitrogen Dioxide ($NO_2$), Relative Humidity, Air Pressure, Carbon Monoxide (CO), Temperature, Airborne Chemicals (VOCs) Ozone ($O_3$) [2]

### 2.2 Indoor Measurements

The most relevant elements for Indoor Measurement are Carbon Dioxide and TVOC.

Carbon Dioxide (CO2) is among the numerous molecules that exist in the air. It is a colorless gas that poses no harm in small amounts, but its health impacts become more pronounced as its concentration levels increase.

CO2 is primarily released into the atmosphere through human respiration, but it can also be generated through various combustion processes, including cooking and the use of vehicles. Excessive levels of CO2 in the air can lead to symptoms such as headaches, mental discomfort such as drowsiness or restlessness, and have been associated with reduced productivity and illness.

The measurement of Carbon Dioxide is typically expressed in parts per million (ppm).

Volatile Organic Compounds (VOCs) are organic compounds that readily transform into vapor or gas form. They are emitted by a wide range of everyday products, including solvent-based paints, air fresheners, fragrances, adhesives, and more.

Indoor environments often have VOC concentrations around ten times higher than outdoor environments, which can pose both short-term and long-term health risks. These compounds are commonly introduced into homes through newly purchased furniture, fabrics, office equipment, aerosol sprays, chemical cleaning agents, disinfectants, as well as various paints and solvents.

While some VOCs may have minimal effects on individuals, others are highly toxic and can lead to health problems when exposed to them for extended periods.

*Indoor Measurements – Carbone Dioxide*

The first analysis of the air quality was done in room with a size of 30.5 m3 and the values that are presented in Fig.[1] are during a full day, with different actions and different numbers of people inside the house.

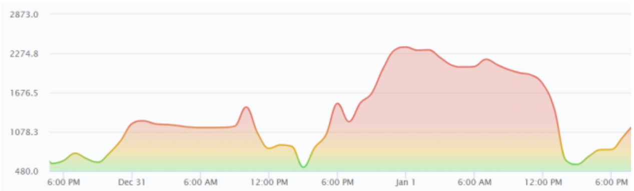


Fig. 1: The fluctuation of the Carbon Dioxide inside a room with a size of 30.5 m3

The graph in Figure 1 displays the interior measurements depicting the fluctuation of Carbon Dioxide levels within a room measuring 30.5 m3 over a 24-hour period. The measurements were conducted between December 30, 2022, and January 1, 2023.

The initial segment of the graph corresponds to the timeframe from 18:00 to 22:00, during which a window was open to allow for fresh and clean air circulation. The minimum concentration recorded during this period was 616 ppm. Subsequently, after the window was closed, the Carbon Dioxide levels began to increase and reached 1248 ppm by 01:30, at which point we vacated the room.

From that moment until 10:00 the following day, the concentration remained relatively stable around 1144 ppm. Upon re-entering the room, the concentration rapidly rose to 1456 ppm. However, after opening the window for fresh air at 11:00, the concentration gradually decreased and reached 539 ppm by 16:00.

From that point onward, the Carbon Dioxide concentration continued to rise until 01:00, reaching a value of 2373 ppm, and remained above 2000 ppm until we opened a window at 12:30. This action caused the concentration to drop to 582 ppm.

*Indoor Measurements – TVOC (total volatile organic compound)*

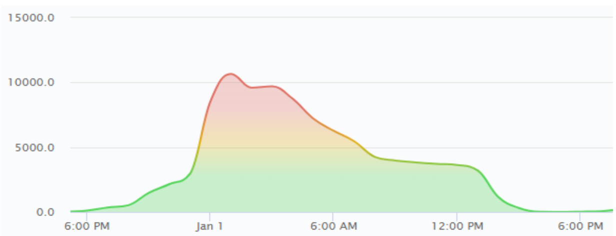


Fig. 2: The fluctuation of the TVOC inside a room with a size of 30.5 m3

The graph from Fig.2 represents the fluctuation of the TVOC inside a room with a size of 30.5m3 due to inside smoking and increased numbers of people.

After fresh air was introduced into the room, the initial TVOC value at 18:00 was 114 µg/m3. Subsequently, it began to increase and reached its peak at 01:00, measuring 10661 µg/m3. Following this peak, the TVOC levels started to decrease, reaching 4243 µg/m3 by 08:00. The rate of decrease then slowed down until 13:00, where the value plateaued at 3199 µg/m3. At this point, fresh air was reintroduced into the room, resulting in a significant drop to 15 µg/m3 within a three-hour timeframe.

## 2.3 Outside Measurements

To encompass a wide range of circumstances, we selected various scenarios for the outdoor measurements. These scenarios included conducting measurements on a heavily trafficked road, on an unoccupied road, during morning and evening periods, on a hill during a high pollution phase when the outside temperature dropped below -5 degrees Celsius, and during a 24-hour scanning period near a parking lot.

Among the *scans*, the most significant one is the measurements taken on the heavily trafficked road.

*Measurement in a heavy transited road*

The measurement took place during the morning rush hour, when the streets are filled with commuters heading to work or taking their children to school. This allowed us to observe the typical pollution levels in a congested area influenced by traffic. Out of all the elements analyzed, only two were significant for this measurement, and their values deviated from the usual levels in this specific scenario, and those are the Nitrogen Dioxide (NoX) and Particle Matter 2.5 (PM2.5).

Particulate matter (PM) is a term used to describe minuscule particles that originate from a complex interaction between liquid droplets and solid particles in the atmosphere. These particles come in various sizes, with some being visible to the naked eye, such as dust and smoke, while others are smaller and require an electron microscope to be observed.

Nitrogen Dioxide (NO2) is a reddish-brown gas that is emitted during the combustion of fuels. It is commonly present in vehicle emissions as well as in the fumes released from burning fossil fuels like propane, kerosene, natural gas, and wood.

When present in high concentrations, it has the potential to irritate the airways within the human respiratory system, potentially leading to expensive hospital visits. Prolonged exposure to NO2 can contribute to the development of chronic illnesses and respiratory infections.

The measurement of Nitrogen Dioxide is typically expressed in parts per billion (ppb).

*Outdoor Measurements – Nitrogen Dioxide (NO2)*

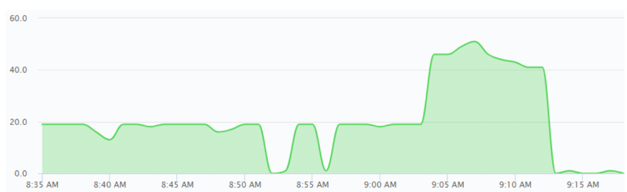


Fig. 3: The fluctuation of the Nitrogen Dioxide on a heavy transited road

Under normal conditions, in an unpolluted environment without traffic in the vicinity, the Nitrogen Dioxide (NO2) level should be approximately 0 ppb. However, our current analysis reveals that the readings indicate levels around 20 ppb, and during a 10-minute period of heightened traffic activity, the values spiked to 45-50 ppb. Subsequently, as the peak traffic subsided (presumably after all the children were dropped off at school), the road traffic rapidly diminished, leading to a decline in $NO2$ levels back to 0 ppb.

To effectively assess the transient nature of this pollution, it is essential to conduct close monitoring at multiple locations throughout the city, particularly in proximity to significant establishments such as schools, hospitals, and offices. This comprehensive monitoring approach ensures accurate evaluation of the pollution levels over time.

*Outdoor Measurements – Particle Matter (PM2.5)*

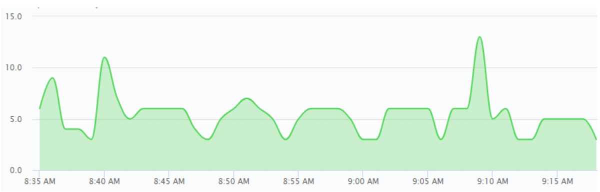


Fig. 4: The fluctuation of the PM 2.5 on a heavy transited road

The measurement of particulate matter in our study exhibits diverse values influenced by the proximity of traffic to the sensor. Additionally, the presence of air currents generated by the traffic flow contributes to variations and fluctuations in the measurements. In the absence of dust or airborne particles, the expected value for PM 2.5 would be approximately 0 ppb.

## 3 LORA PROTOCOL USED FOR DATA TRANSMISSION

### 3.1 Why LoRa?

Why was the LoRa protocol selected and not a different one like ZigBee, wi-fi or Bluetooth?

Because it has low power consumption, and it has a very long range, therefore we just need a big number of end nodes, and just a few gateways to cover an entire city and be able to establish a stable communication. These would be the main two characteristics of choosing this protocol.

### 3.2 LoRa measurements

The following section of this paper presents the establishing connections between a node and the gateway in various locations throughout the city. We measured the received signal strength indicator (RSSI) to assess the signal quality, and subsequently calculated the distance in meters for each measurement on a map. It is worth noting that all measurements were conducted with a clear line of sight between the end node and the gateway, without any obstructions present [3].

First part was to establish the communication between the end node and the gateway, and this part can be observed in Fig. [5]. The communication was set up using to the Network of Things.

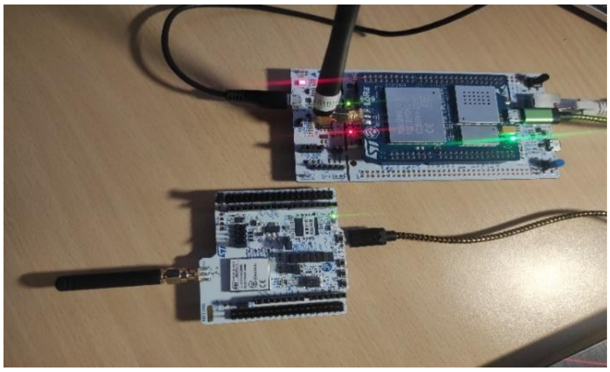

Fig. 5: LoRa Gateway and End Node

Once the connection between the end node and the gateway was established, there were two methods for retrieving the RSSI. The first method involved accessing the RSSI within the "The Things Stack" page. The second method required additional configuration to enable device mapping and forwarding through an API to "Cayenne My Devices." This allowed us to decrypt the payload sent from the end node to the gateway and utilize it to transfer additional information from various sensors.

Based on the measurements we created the following table that presents the values received for the RSSI and for each value the correspondent distance from the gateway to the end node (where the measurement was done).

| Nr. | Value | Unit | Data Type | Distance on map |
|---|---|---|---|---|
| 1 | -52 | dbm | rssi | 2 m |
| 2 | -103.667 | dbm | rssi | 300 m |
| 3 | -116 | dbm | rssi | 6200 m |
| 4 | -114.5 | dbm | rssi | 5500 m |
| 5 | -116 | dbm | rssi | 6300 m |
| 6 | -113 | dbm | rssi | 2160 m |

Table 1: Values of the signal in different locations

It is important to mention that the precise distance measurement from the table was performed on the map. In cases where the exact location of the sensor is not available or if it is in motion, we can calculate the distance between the emitter and receiver using the following formula [4]:

$$\text{Distance} = 10 \wedge ((\text{Measured Power} - \text{RSSI})/(10 * N))$$

Measured Power – should be the RSSI received at 1 Meter distance between the devices.

N – is a constant that depends on the environmental factors. It could take values from 2 – 4.

In the following image we can see also a visual representation of the measurement from the city and from where was the signal sent.

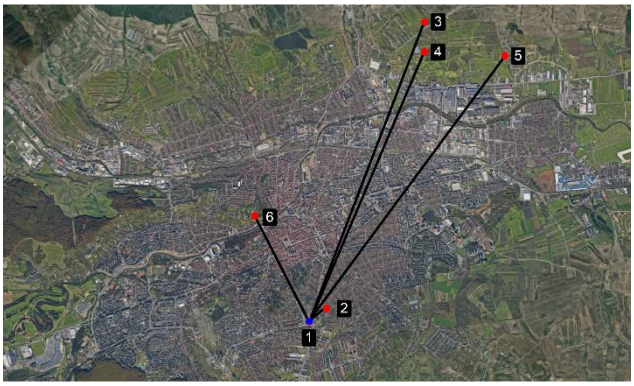


Fig. 6: LoRa Gateway and End Node

Based on the measurements, it is worth noting that in a direct line without any obstructions in the connection path, we were able to receive messages from different locations at distances greater than 6000m. However, it is important to consider that this distance was measured only in one direction from the source. In the best-case scenario, this implies a coverage radius of 6 km, which corresponds to an area of approximately 113 square km.

This suggests that in a densely populated city, if we were able to set up a gateway, such as on a boulevard, to establish a clear path to the sensors, we could potentially cover over half of the city with just a single device.

## 4 FUTURE DEVELOPMENT

The objective of the third section of the paper is to deploy air quality sensors on LoRa end nodes and distribute them throughout the key areas of interest in the city. This approach allows us to collect data from multiple locations simultaneously, enabling a comprehensive analysis of pollution patterns in a large urban environment. To achieve this, sensors such as the BOSCH BME680 [5] gas sensor can be attached and integrated into the end nodes.

Once the end nodes are configured and equipped with the sensors, careful consideration should be given to the placement of the gateways to ensure maximum coverage for all the sensors. Based on the measurements discussed in Chapter 3, the aim is to establish three gateways to cover the entire city of Cluj-Napoca. This strategic positioning of gateways will facilitate efficient data collection and analysis, helping identify areas with high pollution levels that need attention and improvement.

Fig. 7: LoRa Gateway possible coverage for Cluj-Napoca

## 5 CONCLUSIONS

The first part of the paper presents the analysis of the air quality inside a room and outside. From there we can conclude what elements should we analyses in each case to have a clear overview about the air quality.

For the analysis performed inside, the most important elements to be scanned are:

- Carbon Dioxide
- TVOC (Total Volatile Organic Compound)
- PM2.5 (Particle Matter 2.5)
- Carbon Monoxide

For the analysis performed outside, the most important elements to be scanned would be:

- TVOC (Total Volatile Organic Compound)
- PM2.5 (Particle Matter 2.5)
- Nitrogen Dioxide
- Carbon Dioxide
- Temperature
- Humidity
- Air pressure

Most of the time, these elements indirectly impact each other, a factor that can aid us in making more accurate predictions of potential values.

The LoRa measurements revealed an important observation: in a clear line of sight without any obstacles along the communication path, we successfully received messages from various locations at distances exceeding 6000m. Nevertheless, it is crucial to bear in mind that this distance measurement was conducted solely in one direction from the source. Therefore, we could use this technology to cover almost the entire surface of the city with a minimum number of devices.

## 6 ACKNOWLEDGMENTS

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