LoRaWAN integrated CO2 sensing applied in COVID-19 transmission risk assessment

Caio T. B. Costa, Jean W. Souza, Reinaldo L. Abreu, Danilo H. Spadoti
Instituto de Engenharia de Sistemas e Tecnologia da Informação
Universidade Federal de Itajubá
Itajubá - MG, Brasil
caio.tacito@unifei.edu.br, jeandesouza1211@gmail.com, reinaldolabreu@gmail.com, spadoti@unifei.edu.br

Abstract— **The following work presents the development of a LoRaWAN CO2 sensing aimed to monitoring airborne COVID-19 transmission risk. The team manufactured a 3D printed enclosure prototype device, using low cost, off the shelf components connected to The Things Network cloud. The study shows that the developed IoT sensor takes advantage of LoRaWAN technology's low power consumption and long range, and can be installed in any environment to estimate respiratory disease transmission risk.**

Keywords— **Internet of Things, LoRaWAN, COVID-19**

I. INTRODUCTION

Since COVID-19 was first reported from Wuhan, China, on 31 December 2019, the novel coronavirus has been hugely disruptive to all human activities. Data from the World Health Organization (WHO) portal shows that as of 6:30pm CEST, 28 June 2022, 6,329,275 deaths and 542,188,789 have been confirmed cases globally [1]. Despite the great advances made with mass vaccination carried out in record time [2], the virus person-to-person transmission is still a worrying factor that should be taken seriously by all individuals [3]. Thus, this research aims to develop an IoT tool to assess the COVID-19 risk transmission in a simple and inexpensive way.

The use of a CO2 sensor for COVID-19 transmission risk assessment is documented by [4] and [5] and deriving from the following line of thought: an environment with a high concentration of CO2 indicates that several people are breathing in a place with inadequate ventilation. The circulation of fresh air would imply the stabilization of gas levels in a concentration, commonly found on the Earth's atmosphere. This background level is currently 417.45 ppm (June 27th) according to the NOAA (National Oceanic and Atmospheric Administration) [6] and must be taken into account when interpreting the obtained data .

Commercially available CO2 sensors are generally quite expensive and therefore inaccessible to the general public. With this in mind, the main goal of this work is to find a cheaper, simple and scalable solution, so that the technology can be implemented, e.g. in closed environments with all the monitoring and data processing being carried out externally. Harnessing the power of IoT technology, each sensor communicates directly with the LoRaWAN gateway, eliminating the need of building additional infrastructure, such as routers or Ethernet points at the chosen installed location. Another LoRaWAN network important advantage of the is the low power consumption, allowing easily to built devices powered by a common USB (5V) charger. Figure 1 shows the dispersion of virus aerosols in a closed environment, highlighting the paths taken by the particles in the air and their relation with CO2 gas exhalation.

II. MATERIALS AND METHODS

The core of the developed device was the MQ 135 gas sensor. This sensor has the ability to detect nitrogen oxides particles, ammonia, benzene, alcohol, smoke and CO_2. It is important to note that it is not possible to could be choose which gas should be measured. We assume that the monitored environment is predominantly composed of CO2, the 5th most abundant gas in the Earth's atmosphere [7]. This limitation is due to the fact that the sensor element, an SnO2 alloy strip, reacts chemically in the presence of any of these gases changing its electrical characteristics.

Another point that deserves attention is the relationship between reaction rate and temperature. The sensor has a heater element of 800 mW, which heats the module, operating in an open loop and, therefore, the final temperature will vary according to fluctuations in the ambient temperature. To correct this error source, a DHT11 temperature and humidity sensor were added to the device, correcting the data collected from the MQ135.

The wireless communication was performed by Semtech's SX1276 module, one of the most popular LoRa compliant transceivers [8]. This module was paired to an STM32F103C8T6 microcontroller embedded in a "blue pill" development board, chosen for its excellent cost-benefit ratio and for its 12-bit analog-to-digital converter, which offers 4 times greater resolution when compared to simpler microcontrollers. The microcontroller is responsible for reading the data from the two sensors and storing them in a buffer, sending to the SX1276 module via the SPI protocol. This operation happens once per minute. The embedded software was developed in C++ using the platformIO multiplatform environment. The configuration and communication with the LoRaWAN module were provided by the open source library LoRaWAN MAC IN C (LMIC).

Before transmission, the collected data is treated and each value is represented by a 16-bit integer, that are then transferred to the sending buffer in big endian format. The resulting

6 bytes of information are enqueued and sent to the network in raw binary form and without any padding. This data organization method differs from the ASCII encoding that is commonly used in LoRaWAN communications, and it was chosen to reduce the amount of bytes per value needed, optimizing energy and bandwidth consumption for each transmission.

The device was connected to a LoRaWAN gateway installed at Unifei, integrated into The Things Network (TTN). The 915-928 MHz band was used (AU915_928_FSB _1), OTAA authentication and a frequency of 60 seconds. The data sent to the TTN cloud via LoRaWAN is then transferred to a linux server using the MQTT protocol. This server uses the Node-RED tool to receive and further process the data to human-readable values, which are then saved to an influxDB database and loaded into a Thingsboard dashboard for storage and tracking.

The prototype enclosure was designed using the SolidWorks CAD software and manufacturing was performed by fused deposition modeling in ABS MG-94 material. The 3D printing is strategic due to its unparalleled agility in the manufacturing process and low material cost, resulting in each housing weighing only 57 grams. Analyzing the average price of ABS filament on the market, the production cost is around 3.42 Reais per enclosed prototype. Total cost for the device including the electronics is around 115 Reais.

III. RESULTS AND DISCUSSION

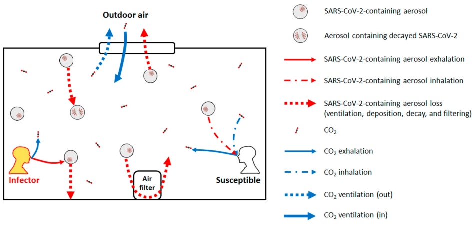

Fig. 1: Aerosol dispersion in air. [4]

The device was installed inside a laboratory room during 3 days. In Fig. 2 it is possible to observe the CO2 levels rising and falling according to the students movements in the inside ambient. The blue line shows the sensing raw reading from the sensor while the red line uses the formula from [9] to compensate the temperature variations and get a more accurate reading. Using the risk calculator available at [5], the H parameter transmission risk [4] was calculated for the test environment and the results are shown in Table I.

CO2 (PPM)	Transmission risk (H)	Classification
505,07	0,01	Low
715,21	0,01	Low
1135,49	0,02	Low
1450,69	0,03	Low
1976,04	0,05	Low
2291,25	0,06	Medium

TABLE I: Indicator of risk in terms of CO2 level. Low risk: H<0.05; Med: H<0.5; High: H>0.5;[4].

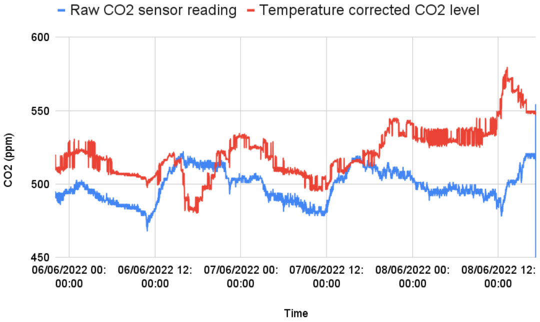

Fig. 2: CO2 levels inside research lab

IV. CONCLUSION

CO2 levels inside the laboratory during the days of the experiment had a peak of approximately 580 PPM, meaning the transmission risk could be classified as low. The authors' objective is to continue working on the development of devices that use CO2 concentration as an indicator of air safety, but with a focus on ultra low power battery operation. This would further increase the device's versatility as it could be virtually installed in any environment, even with no available electrical grid. To achieve this objective, it is planned to develop a CO2 sensing, similar to the ones proposed in [10] and [11]. The CO2 sensing absorbs lines of around 4300nm in an arrangement of infrared light emitters and detectors, eliminating the heater founded in the electrochemical sensor, which is the biggest power drain of the current project.

ACKNOWLEDGMENTS

The authors thank FAPEMIG, CAPES, CNPq and the entire team at LabTel-LaIoT UNIFEI for their support to the research.

REFERENCES

[1] (2022) Who coronavirus (covid-19) dashboard. [Online]. Available: https://covid19.who.int/

[2] A. D. Barrett, R. W. Titball, P. A. MacAry, R. E. Rupp, V. von Messling, D. H. Walker, and N. V. Fanget, "The rapid progress in covid vaccine development and implementation," pp. 1–2, 2022.

[3] K. Yates, "Closing our eyes to covid won't make it go away," 2022.

[4] Z. Peng and J. L. Jimenez, "Exhaled co2 as a covid-19 infection risk proxy for different indoor environments and activities," *Environmental Science & Technology Letters*, vol. 8, no. 5, pp. 392–397, 2021.

[5] Z. Peng, A. P. Rojas, E. Kropff, W. Bahnfleth, G. Buonanno, S. Dancer, J. Kurnitski, Y. Li, M. G. Loomans, L. C. Marr *et al.*, "Practical indicators for risk of airborne transmission in shared indoor environments and their application to covid-19 outbreaks," *Environmental science & technology*, 2022.

[6] (2022) Global mean co2. [Online]. Available: https://bit.ly/3haFtGZ

[7] (2022) Atmosphere. [Online]. Available: https://bit.ly/34XLXXs

[8] (2022) Lora chipsets market - global industry analysis, size, share, growth, trends and forecast 2019 - 2027. [Online]. Available: https://www.transparencymarketresearch.com/lora-chipsets-market.html

[9] V. Kalra, C. Baweja, D. Simmarpreet, and S. Chopra, "Influence of temperature and humidity on the output resistance ratio of the mq-135 sensor," *International Journal of Advanced Research in Computer Science and Software Engineering*, vol. 6, no. 4, pp. 423–429, 2016.

[10] X. Jia, J. Roels, R. Baets, and G. Roelkens, "On-chip non-dispersive infrared co2 sensor based on an integrating cylinder," *Sensors*, vol. 19, no. 19, p. 4260, 2019.

[11] D. Gibson and C. MacGregor, "A novel solid state non-dispersive infrared co2 gas sensor compatible with wireless and portable deployment," *Sensors*, vol. 13, no. 6, pp. 7079–7103, 2013.