Bluetooth Sensor Module for Monitoring Indoor Ambient

Andrei Cristian Haisiuc
Department of Computer and Information Technology
Politehnica University of Timisoara
Timisoara, Romania
andrei.haisiuc@student.upt.ro

Ioan-Alexandru Hedes
Department of Computer and Information Technology
Politehnica University of Timisoara
Timisoara, Romania
ioan.hedes@student.upt.ro

Darius-Ovidiu Firan
Department of Computer and Information Technology
Politehnica University of Timisoara
Timisoara, Romania
darius.firan@student.upt.ro

Cristina Stangaciu
Department of Computer and Information Technology
Politehnica University of Timisoara
Timisoara, Romania
cristina.stangaciu@cs.upt.ro

Sergiu Nimara
Department of Computer and Information Technology
Politehnica University of Timisoara
Timisoara, Romania
sergiu.nimara@cs.upt.ro

Abstract—*The system consists of an energetically and informationally autonomous node, which collects data about atmospheric pressure, temperature, humidity, and gas concentrations for carbon monoxide and methane and sends this data to a dedicated receiver that will store it and make it available for visualization. Communication is realized through the IEEE 802.15.1 standard, via Bluetooth. The node consists of an Arduino Nano which uses an Atmega328P microcontroller, a sensor BMP180 module, two modules for detecting gases - MQ-7 for carbon monoxide and MQ-4 for methane, an HR202 module for humidity and an HC-05 Bluetooth module. On the receiving end, a mobile application for Android phones developed using Android Studio and Java is used. The data can be then visualized as graphs using a Python script. The system can be used to monitor the temperature, humidity, and atmospheric pressure of a room as well as add a layer of safety with alerts when the danger threshold for methane or CO is passed.*

Keywords—monitoring, sensors, IoT, Bluetooth

I. INTRODUCTION

Indoor air quality is a major concern in today's world [1][2][3][4][5], as people spend a significant portion of their time indoors. Poor indoor air quality can cause various health problems, such as respiratory diseases, allergies, and headaches. Therefore, monitoring and controlling the air quality in indoor environments is essential for maintaining a healthy and safe environment. Carbon monoxide (CO) and methane (CH_4) are two of the most common air pollutants that can have significant health impacts on humans. Carbon monoxide is a colorless and odorless gas that is produced by the incomplete combustion of fuels such as gasoline, natural gas, and wood. Exposure to high levels of CO can cause headaches, dizziness, nausea, and even death. Similarly, methane is a potent greenhouse gas that is produced by natural sources, such as wetlands, and human activities, including livestock farming, coal mining, and natural gas production. Methane is also flammable and can pose a risk of explosions in confined spaces.

To address these concerns, we have developed a Bluetooth sensor module that can monitor the levels of CO, CH_4, temperature, atmospheric pressure, and humidity. This sensor module can provide accurate and reliable data on air quality parameters.

The Internet of Things (IoT) has revolutionized the way we interact with the world around us, from the way we communicate to the way we gather and process data.

The importance of IoT in this context lies in its ability to connect devices and enable real-time data collection and analysis. The module we present is just one example of how IoT can be used to improve environmental monitoring and management.

We proposed a cost-efficient solution that aims to provide feedback on the air quality, as well as alerts users in case of hazardous conditions, making it perfect for use in places like kitchens, garages, offices, and other places where there is a risk of a gas leak or where humidity should be kept under a certain level. The system is designed to be easy to install and operate, making it suitable for both residential and commercial applications. The proposed system has the potential to inform the user of hazardous conditions in indoor environments, thereby promoting better health and safety for occupants.

The remainder of the paper is organized as follows: Section II provides an overview of related work in the field of indoor air quality monitoring. Section III describes the proposed indoor monitoring system in detail, including its hardware and software components. Section IV presents the experimental results and discusses the performance of the system. Finally, Section V concludes the paper and outlines future research directions.

II. STATE OF THE ART

Indoor air monitoring systems have become an essential tool for maintaining a healthy and safe environment in indoor spaces. These systems are designed to measure various air quality parameters, such as temperature, pressure, humidity, and pollutants, including methane and carbon monoxide. In this section, we review some of the recent state-of-the-art developments in indoor air monitoring systems.

One relatively recent development in indoor air monitoring systems is the use of wireless sensor networks (WSNs) [6]. WSNs are made up of multiple sensors that can collect data on various air quality parameters and transmit the data wirelessly to a central processing unit. These systems are highly scalable, allowing for the integration of additional sensors or nodes as needed. Furthermore, they are easily deployable, making them suitable for monitoring indoor air quality in a variety of environments, including homes, offices, and industrial settings.

Another development in indoor air monitoring systems is the integration of cloud computing. By utilizing cloud-based storage and processing [7][8], these systems can store large amounts of data, analyze the data in real time, and provide users with real-time feedback on the air quality. These systems also provide remote access to data, allowing for monitoring of indoor air quality from anywhere with an internet connection.

Recently, researchers have also been exploring the use of machine learning techniques in indoor air monitoring systems [9][10]. By training models on large datasets of indoor air quality data, these systems can predict future air quality conditions and provide insights into the underlying causes of air quality issues. Additionally, machine learning can be used to identify and classify specific pollutants, such as carbon monoxide or methane, from other environmental factors.

Finally, the development of low-cost sensors [11] has also contributed to the advancement of indoor air monitoring systems. These sensors are smaller, less expensive, and more energy-efficient than traditional sensors, making them ideal for large-scale deployments. Furthermore, these sensors are highly accurate, providing real-time data on a variety of air quality parameters, including temperature, pressure, humidity, and pollutants such as carbon monoxide and methane.

To make a price comparison with a similar sensor module [12], at the current market value for each individual component, the total price for our module comes to about 16 euros, while the other module comes to about 20 euros. The modules slightly differ in components, but our option is cheaper, offering almost the same data about air quality.

III. Proposed Solution

Our system is designed to be a relatively cheap option for an IoT application that has a wider variety of properties of the room measured than what is currently available, offering data for temperature, atmospheric pressure, humidity, carbon monoxide, and methane. The mobile application allows for data to be visualized and stored locally or remotely.This data can be further used to plot graphs for easier analysis through the Python script. The sensors used: BMP-180 for temperature and atmospheric pressure, MQ-4 for methane, MQ-7 for carbon monoxide, HR202 for humidity, as well as the HC-05 Bluetooth module and Arduino Nano, are all low-cost, the only thing making the system's price go up being the high number of components.

A. System Specification

The node is meant to measure indoor humidity, methane, CO as well as temperature and pressure as well as to work in an Internet of Things network. The android application allows for monitoring multiple nodes and seeing live measurements from each one of them as well as alerting the user in case dangerous thresholds for CO or methane are passed, making our system suitable for monitoring places like kitchens, offices, garages, households and so on.

B. Hardware Design

The hardware diagram for the cost-efficient node of reduced size can be observed in Fig. 1. The node consists of an Arduino Nano which uses an Atmega328P, a BMP180 module for measuring temperature and pressure, an MQ-7 sensor for CO2, an MQ-4 sensor for methane and a HR202 sensor for humidity.

Because the BMP180 module works at 3.3V while the other sensors work at 5V we connected the ground line to a common reference from the Arduino board and the positive power lines are connected to the 5V terminal of the Arduino.

For the BMP180 the first two terminals SDA and SCL are connected to analog terminals A4 and A5 which are used by the Arduino Nano to emulate the I^2C protocol in the software. There is no need for pullup resistances because the module already has those parts included. The next terminals are used for the power supply, the VCC terminal being directly connected to the 3.3V terminal of the Arduino.

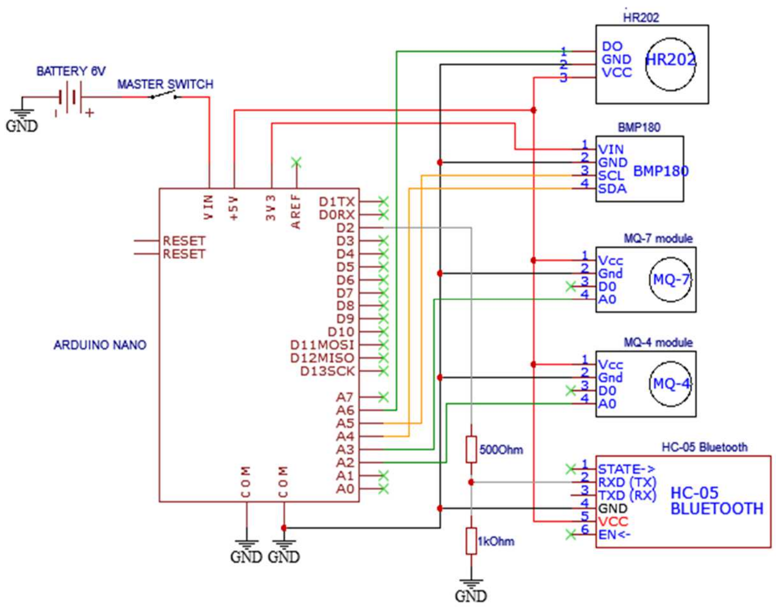

Fig. 1. Hardware Schematic.

The first terminal of interest for the HC-05 Bluetooth module is RXD which will be connected through a voltage divider to the D2 terminal of the microcontroller. The voltage divider is used to convert the 5V signals coming from the Arduino in to 3.3V signals (in conformity with the product page for HC-05, this was tested, and it also works with 5V). For the current project we don't need the TXD terminal of HC-05 because the module will be used exclusively for receiving the serial data from the microcontroller. The terminals for power supply are connected to the designated power lines.

The HR202 humidity sensor is also connected to the power lines with the DO terminal being connected to the analogue A6 terminal.

Finally, the MQ-4 and MQ-7 have their A0 terminal which transmits analogue data connected to terminals A3 and A2 respectively, with the power being connected to the power lines.

C. *Software Design*

The software design is made up of two parts, the design of the Android application and the design of the software in the microcontroller. The application serves to visualize and store the data received from the Bluetooth sensor and the software in the microcontroller is designed to transform the data received from the sensors in to the desired form and send it through the Bluetooth module. The flowcharts for both parts can be seen in Fig. 2 and Fig. 3.

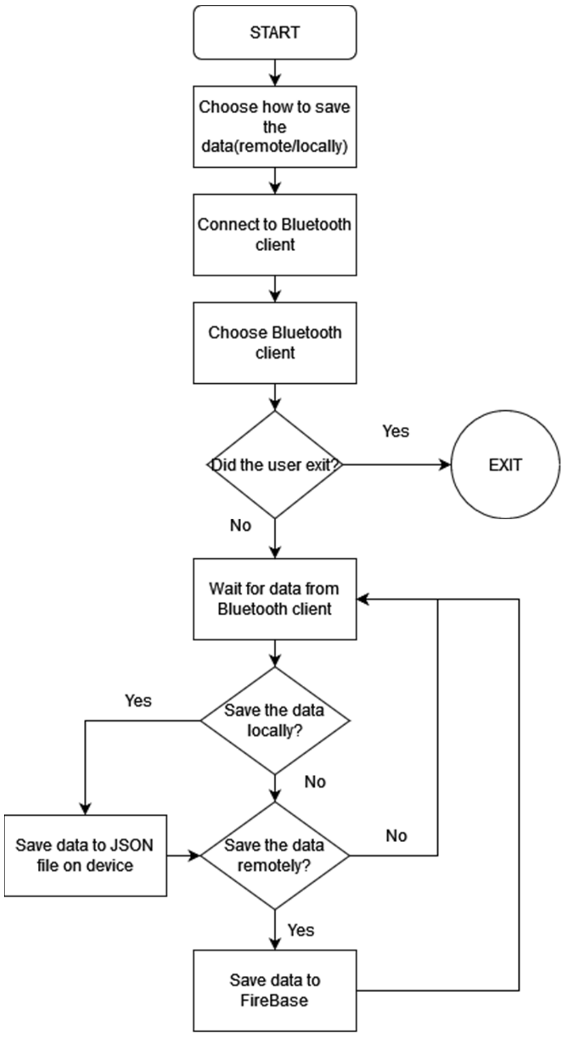

Fig. 2. Software Flowchart.

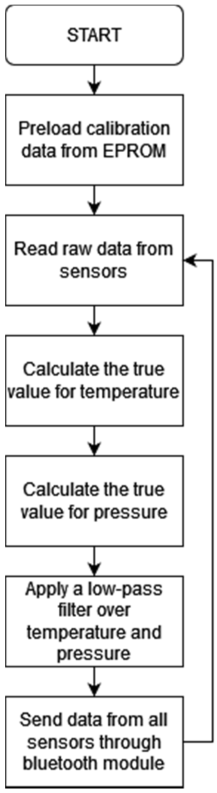

Fig. 3. Node Flowchart.

Here is also a short look at the user interface as depicted in Fig. 4.The button "ADD" will add to the node list inside the application the MAC address provided in the text field (there are checks for the address format using regular expressions), "ENABLE BLUETOOTH" will enable Bluetooth on the device, "CONNECT" will start the data transfer component, "HELP" redirects the user to the GitHub repository of the application. The sliding buttons should be activated before pressing the "CONNECT" button if the user wishes to save the data. Locally, the data is saved as a .json file and for cloud we use Google Firebase.

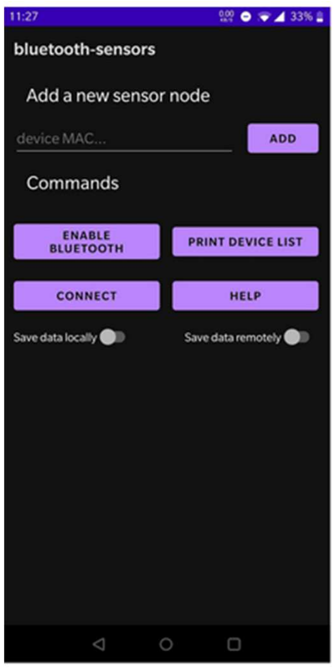

Fig. 4. User Interface.

D. Packet Data Design

For this project we used I^{2}C for interfacing with the BMP180 module. Identifying the subordinate circuits in an I^{2}C communication-based system is achieved through 7- or 10-bit addresses. In our case the address for BMP180 is 0x77 (11). The I^{2}C lines are commanded by the open drain terminals of the circuits. Because of this, the circuits cannot place logic 1 on the two lines – they can place logic 0, or they can leave the line open (high impedance). For logic 1 to be set on the two lines, pullup resistances are used. The Arduino library "Wire.h" is used to simulate the I^{2}C serial interface in the software. In Fig. 5 [13] we can see how a message looks like.

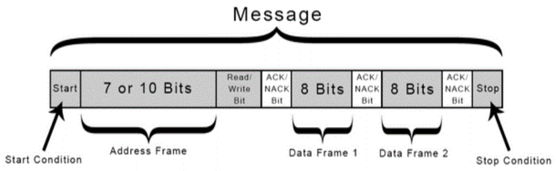

Fig. 5. Message.

This project also uses the USART interface for serial asynchronous communication, using a single stop-bit Fig. 6. The USART serial interface is simulated in the software using the Arduino library "SoftwareSerial.h".

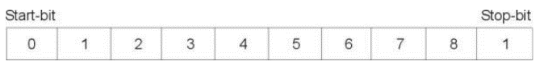

Fig. 6. One Stop Bit.

IV. Experimental Results

In Fig. 7 we can see how the live data from the node looks like in the Android application. We can see the values in real time for temperature measured in Celsius, atmospheric pressure measured in hectopascals, methane and CO both measured in parts per million, all of them represented in floating point numbers, and the value for humidity measured in percents.

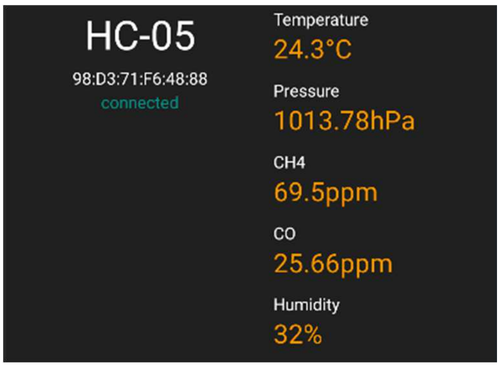

Fig. 7. Live Data from the Application.

If the user chose to save the data remotely, there is also the possibility of using a Python script to visualize the data as graphs Fig. 8. The script receives the following arguments from the command line:

- The MAC address of the node that acquired the data that we want to visualize.
- A word from the following list: cycle (10 minutes), hour, day, week, month; This word refers to the time interval from which we want to see the data.

The data used for making the graphs is stored in firebase so the user should have the firebase-admin dependency and an access key to the database as well as matplotlib dependency.

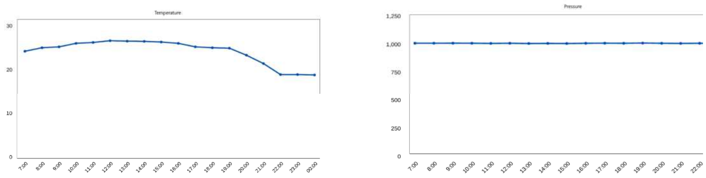

Fig. 8. Graph Data Example for Temperature and Pressure.

V. Conclusion and Future Work

In this research, we designed Bluetooth sensor nodes for measuring temperature, atmospheric pressure, humidity, carbon monoxide and methane concentration levels using an Android application as the user interface. The application is capable of showing the data in real time, alerting the user when a danger threshold for methane and CO has been passed and storing the data locally and remotely. For a better visualization of the data, we developed a python script that uses matplotlib to make graphs out of the data stored in the Google Firebase Database. Our system has all the needed components for measuring data about air quality to then store or display it and is also not too expensive making it suitable for a budget Internet of Things application.

In the future we will add sensors for other gases, support for other mobile devices, not only for Android, we will add more alerts related to the levels of temperature and humidity, making the system suitable for maintaining the health of the user.

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