Development of a SmartAir Quality Monitoring System

Abstract

The aim of this research is to design an air quality monitoring system that can be accessed via the LCD screen, web and smartphone. The process of developing this system involves, the circuit design and operation, PCB fabrication, firmware development, mobile app development, cloud server setup and integration. On completion of the setup, the next step was the testing and calibrating of the system. The results of experiment show that the system is able to detect air quality in parts per million (ppm), with other environmental factors such as temperature and relative humidity.

Keywords: Air quality, Internet of things, MQ 135 sensor, relative humidity, temperature

1.0 Introduction

An atmosphere free of pollution is pivotal to the environment, plants, animals and human health. Any alteration in the natural composition of air has detrimental consequences on humans, animals, plants, economic growth, social wellbeing and the environment around us [1,2].The biggest problem of every nation, developed or developing, is air pollution. It emanates from natural and human activities and grows rapidly due to motorization, construction, mining, agriculture, gas flaring, industrialization, deforestation and population increase [3-6]. The result of these activities is the release of gaseous emissions and particulate matter that contaminates the air and these include ground-level Ozone, Methane, SO_2, CO, CO_2, NO_2, PM, and Pb [7-9].

The rise in health-related issues has necessitated the importance of monitoring air quality and has led to several inventions for real-time monitoring of air quality [10-14]. The authors in [15] proposed a low-cost air sensing model based on IoT, to monitor air quality over a cloud-based platform that will trigger an alarm whenever the air quality goes above the recommended threshold. With the use of MQ135 gas sensor, LPG, SO_2, NO_2, smoke and CO_2 gas were monitored. Data collected were stored in ThinkSpeak API via ESP8266 wireless module. The monitored air quality were displayed in parts per million on the internet-based platform for ease of monitoring.In [16], a novel approach to measure indoor CO_2 using MH-Z19 NDIR infrared gas module was presented. This system was developed using an Arduino Uno microcontroller interfaced with the LCD1602. The microcontroller is connected to MH219 and AM2302 sensors to measure CO_2, temperature and relative humidity respectively. At every five minutes interval, the collected data is displayed on the LCD screen in the form of line chart.

An air quality monitoring system using a Wireless Sensor Network (WSN) to monitor air pollution like NO_X, SO_2, CO and other environmental factors such as relative humidity, temperature and wind speed was put forward by [2]. The WSN was developed by assembling sensor nodes and hosting a web server. The system was made up of 3 sensor nodes, each placed on a pole at a different height level. Each sensor node consists of ADC5669 16 Bit 8 channel, power supply, Mobile Wi-Fi (MiFi) and five sensors, one each for measuring SO2 (MQ-136), NO_X sensor, CO sensor, air temperature and humidity (SHT15) and wind speed (anemometer). The sensors measured data in analog, except for digital data measurement from the SHT15 sensor. Analog data were converted into digital data by 16-bit ADC, then transmitted to Web Server by WiFi. Data from the three sensor nodes were displayed in the form of graphs and tables through a web server and accessed online in real-time through smartphones.Using MQ135 sensor, an IFTTT application, an ESP8266 Wi-Fi enabled chip and a NodeMCU V1.0 microcontroller, [17] constructed a smart air pollution monitoring system. The gas sensor was used in monitoring the concentration of SO_2, NO_2, CO_2 and CO in the air. Data was transmitted via the microcontroller to the internet, through the WiFi enabled chip. Whenever the pollution level of each measured pollutant exceeded the threshold level, an alert message was sent to the user via the IFTTT application. To build-up security in the server, AWS IoT device SDK was used to authenticate messages over the internet network. The advantage of this system was that, whether the system is connected to the internet or not, alerts sent by the system were received by the user on mobile phone from any distance.

For adequate environmental and health protection, an effective air quality monitoring system is a necessary instrument. This creates a need for measurement and analysis of real-time air quality monitoring so that appropriate decisions can be taken by scientist, policy makers and residents in a timely period for the improvement of the living environment [18,19].This research proposes a smart air quality system for real-time monitoring of air quality in Nigeria. The proposed system is necessary as an alternative solution to quashing the hurdles experienced by air quality monitoring stations in Nigeria, either due to the absence or damage of equipment.

1.1 **Statement of the Problem**

The fourth most polluted country in the world is Nigeria. In Bayelsa State, for instance, air pollution causes 4960 respiratory ailments in children, 120 asthma attacks and 49 premature deaths yearly [20]. According to WHO report, millions of people die yearly because of breathing disorders emanating from air pollution and 90% of the world's population are exposed to high level of pollutants which exceed WHO limits [6]. The harmful effects of air pollution have become evident, yet in Nigeria, we do not have access to real-time air quality data. Air quality monitoring systems in Nigeria are all imported and very costly and once there are faulty, it is abandoned. Most air quality systems are launched into space and data collected by such systems are predicted since measurement is not done in situ. Meaningful action against air pollution implies controlling health-related consequences and this begins with sound research and meaningful data. The objective of monitoring air quality is to deliver actionable data and to make the information available to the public, policy makers, scientists, and planners to allow them to take necessary steps to manage and improve the environment. This research proposes an IoT-based system for real-time monitoring of air quality in Nigeria.

2.0 Methodology

To develop this system, the above stages were utilized; the circuit design and operation, PCB fabrication, firmware development, mobile app development, cloud server setup and integration. The above listed steps will lead to the IoT air quality system.

2.1 Circuit Design and Description

The circuit diagram of the air quality monitoring system is shown in figure 1. The heart of the system is based on printed circuit board (PCB) that supports high end microcontroller. The sensors communicate with the system serially, using serial communication protocol based on I^2C communication protocol, so that the serial clock (SCL) sensor modules and serial data (SDA) pins wires to the corresponding I^2C pins on the PCB. The sensors run on 3.3V and 5V DC, so its V_{CC} pin would go to the 5V output on the PCB and the GND pin. The sensor interfaces with the system and communicates with the controller through a serial interface that works at 5V logic level, while the RX logic level works at 3.3V. The touch display uses serial communication while two transistors are used in switching the sensor heaters. A real time clock module keeps track of the time when storing the sensor values using the I^2C communication protocol. The entire device is powered with 5V through a custom-made power supply.

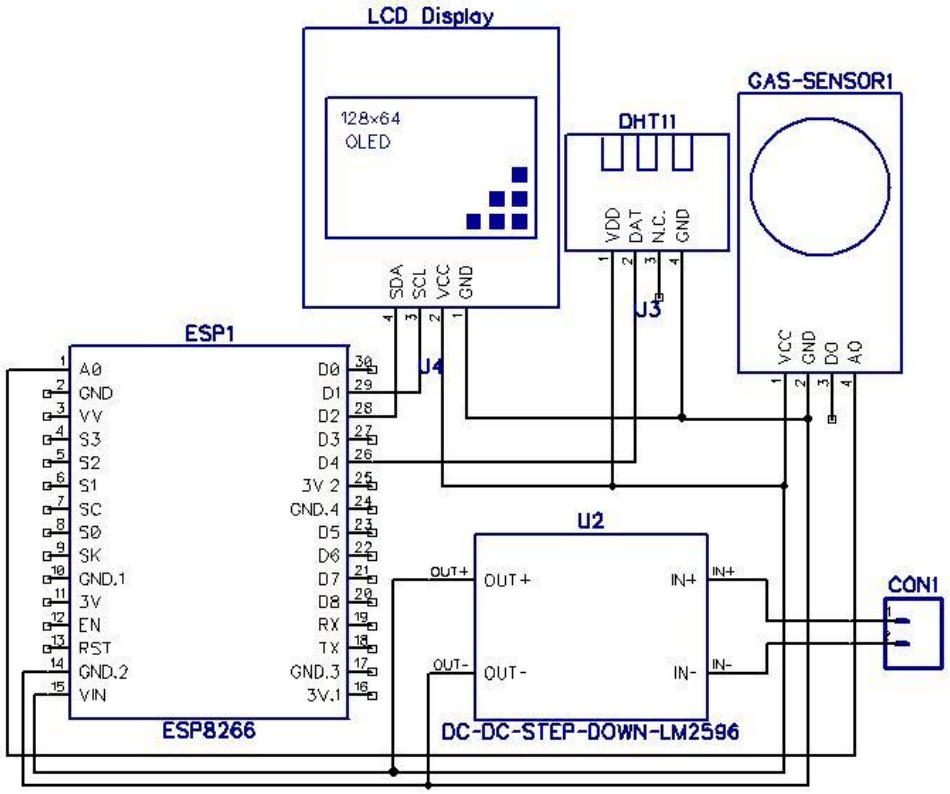


Figure 1: Circuit Diagram of Smart Air Quality monitoring system

The heart of this system isbased on ESP8266 embedded WIFI Module that runs on 5V DC source. Power supply for the system is derived from a fabricated DC-to-DC converter module capable of supplying up to 5V, 2amp DC. A step-down DC-to-DC converter module is used in the system to allow a wide range of DC source.

The sensors are connected to the ESP8266 Wi-Fi module for data exchange in digital and analog form. V_{CC} and the ground pin of the sensors connect to the 5V and ground terminal of the power supply circuit, while the analog pin of the MQ135 gas sensoris connected to the analog-to-digital converter pins of the Wi-Fi module. Connected to digital pin D4 of the ESP Wi-Fi microcontroller module is the DHT11 temperature/relative humidity sensor.In place of a buzzer, a push notification feature has been added to the system to allow notifications to be sent out when air quality is above the WHO recommended threshold level.

The LCD display is connected to the ESP moduleusing serial communication based on I^2C protocol, while power supply pins of the LCD display are connected to the appropriate supply lines to enable the correct supply to be sent to the display. Screen contrast of the LCD would is handled and managed through software.

Power supply of the entire system is derived from custom design standalone power supply withsupport for solar renewable energy. Data pins used in communicating with the ESP8266 WIFI microcontroller development board are; pinD4, connected to data pin of the temperature/relative humidity sensor; pin D1, D2 of the ESP moduleconnects to SDA, SCL of the seral LCD module while pin A0 of ESP8266 module is connectedto theanalogue pin of the MQ 135 gas sensor module.

2.2 Designing of Schematic, Layout Diagram and PCB Production

As a design requirement, the circuit was first developed and simulated using proteus and multism. These programs aided the simulation of the project before it was implemented, making it easier to ascertain, do corrections and take decisions before final implementation.

The program used in creating both the PCB and schematic diagram for the developed air quality system wereDip Trace, Eagle schematic capture program and Altium designer.

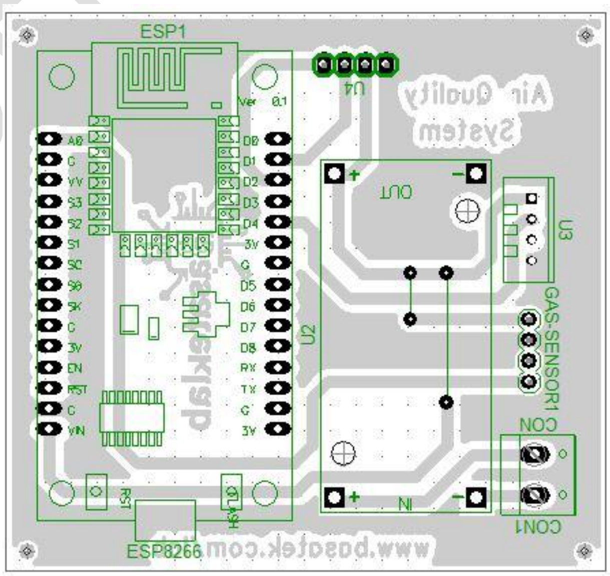


Figure 2: PCB layout Diagram of Air quality monitoring system

After designing the schematic diagram, itwas converted toPCB art work. The converted PCB art-workwasthen printed into a special PCB printing film (Press n Peel sheet), a transfer film used in printed circuit board production.

2.3 System Operation

The device take readings from its sensors and sends the data to an android device via WiFi in every 5 seconds, using a third-party mobile App, Blynk. The device sensor detects and measures the air quality, temperature and relative humidity and communicates with the ESP WIFI module via internet to access the Blynk server so as to display the air quality information. All measured data from the sensors are sent through The Blynk server for easy access. The device supports16x2 character serial LCD display that displays the sensor data sent to the mobile device through the Blynk Mobile App. A gauge gadget in the Blynk mobile app displays a user-friendly result of the air quality data during operation. The LCD display also shows data sent to the mobile device.

In operation, the Blynk mobile app in the android device displays the air quality and timestamps the received data, then sends them to the Blynk server to be stored in a database. When a user opens the Blynk Mobile App, the application reads from the database and visualizes the data graphically on the Mobile App. This option allows for the access of read data to be seen and accessedanywhere in the world. It uses air quality sensors to collect data and a WiFi connection to send them to the cloud server which in turn display the sensor data on the android device.

Sensor readings are taken every 1 or 2 seconds and passed through low-pass filters to reduce data noise. Every 5 seconds, filtered values are sent to the mobile device via WiFi as a JSON string. The Android application takes the received measurements and timestamps to the received data. Then, it sends the JSON string along with the received data to the web server using HTTP protocol. The web server receives and stores the data in a database thus allowing the data to be retrieved when needed. A flowchart and block diagram of the system is given in the figuresbelow.

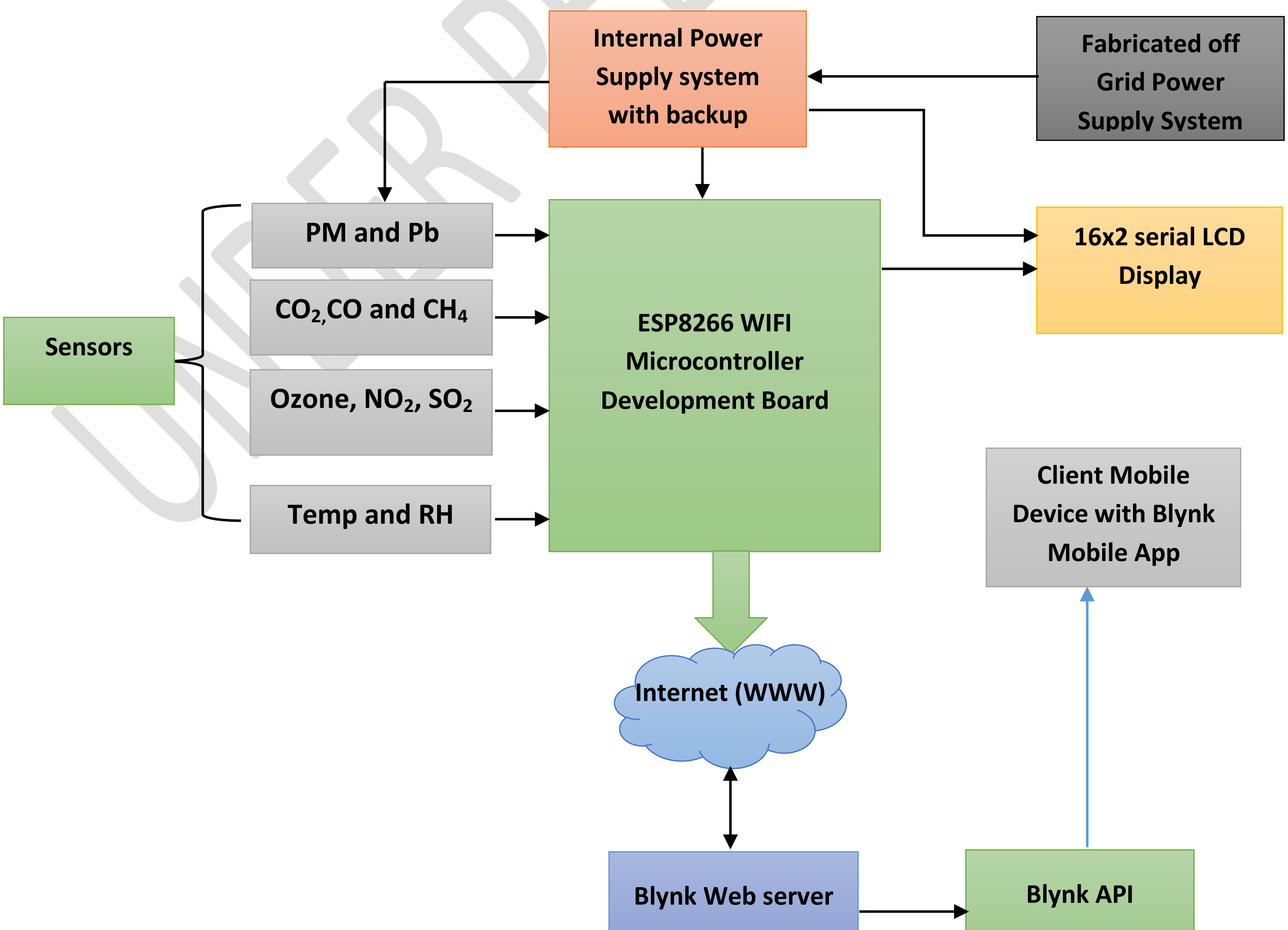
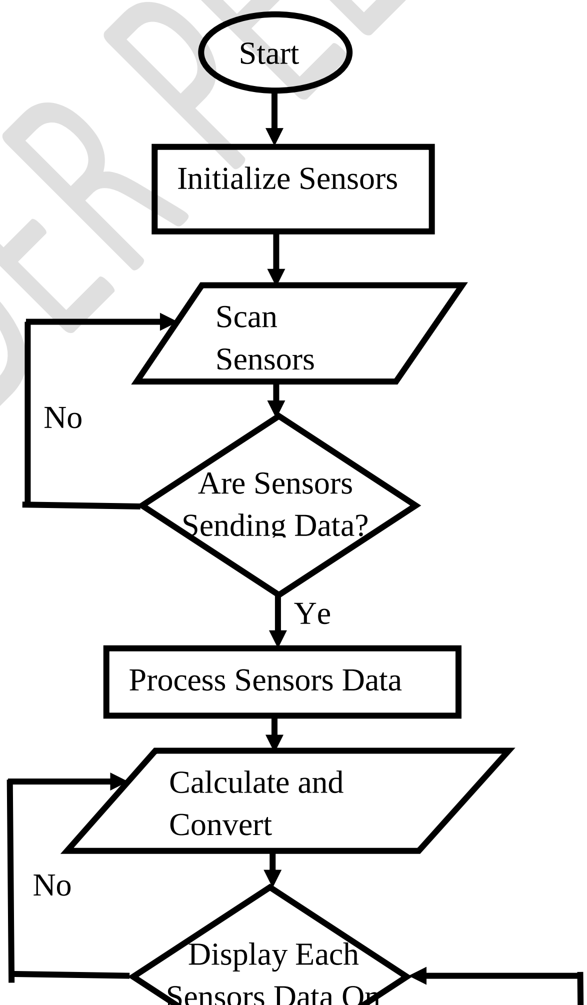


Figure 3: Block Diagram of Air quality monitoring system



2.4 Firmware Development

Developing the required firmware for the system involves the use of an integrated development environment (IDE) based on Arduino IDE. The firmware program allows the system to communicate with the sensor, write to the LCD display and interact with the web server. The Firmware program was written in C. In the firmware development, we usedMpLab for debugging.

2.5 Android App Development

The mobile App (Blynk) was developed using Android Studio, the official integrated development environment (IDE) provided by Google. The IDE is built on JetBrains' IntelliJ IDEA software and is available for download on Windows-, macOS and Linux-based operating systems.

2.6 Cloud Service Setup

In setting up the cloud service, a Blynk account is created to allow access to the servicebackend. The HTML/JavaScript frontend for the web application is made to interface with the android application via HTTP protocol. The database used in storing sensor data from the IoT device and the “Plotly” JavaScript library that makes all graphical visualizations in the webpage has been developed.

2.7 Receiving Data from the IoT Device

In receiving data from the IoT device, the code in charge of retrieving the measured data received from the device was written to handle communication. This code is responsible in retrieving the received JSON string known as Callback from the IoT device. This callback is executed when data available in the IoT device to be read by the android device.

2.8 System Interaction with Web Server

For the system to interact with the web server, Every JSON string received from the IoT device is sent to the web server, along with additional data gathered from the mobile device itself. Moreover, the sensor data is downloaded and visualized on the GUIresult screen.

2.9 Testing and Calibration

Testing and calibration of the system was carried out in two stages; hardware testing and software testing. Hardware testing involvesthe testing of all physical hardware including the sensor, power supply and other circuit components. Software testing involves the writing and debugging of the firmware as well as testing of the system using the Blynk android mobile app codes to ensure that everything corresponds to the technical specification of the system.

3.0 Result and Discussion

Below are component connections inside of air quality system before and after component connection. After connecting all the components according to the schematic diagram, the firmware program was uploaded to the controller. The uploaded firmware allows the system to communicate and interact with the web server in order to read and send the measured data from the sensors.

Fig 5 Inside view of the air quality System

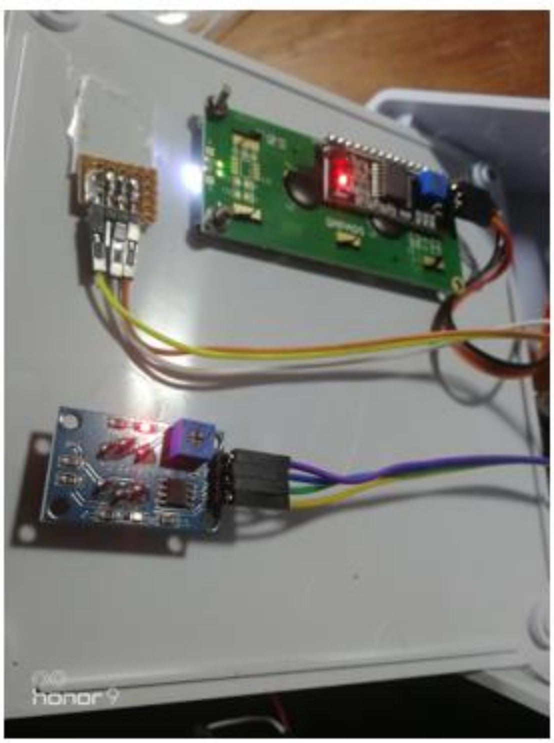


Fig 6 Inside view of air quality system

After the successful upload of the firmware, power was connected to the DC jack using external DC adaptor. The LCD screen turns-on, showingsquare boxes. This means that the system is initializing and trying to establish a connection with the Wi-Fi Network.

Fig 7Initialization Screen of air quality monitoring system

On successful connection to the network, the system displays the temperature, relative humidity and air quality data as seen in the figures below.

Figure 8 Data of Temperature on LCD Screen

Fig 9 Data of relative humidity on LCD Screen

Fig 10Result screen of air quality monitoring system in ppm

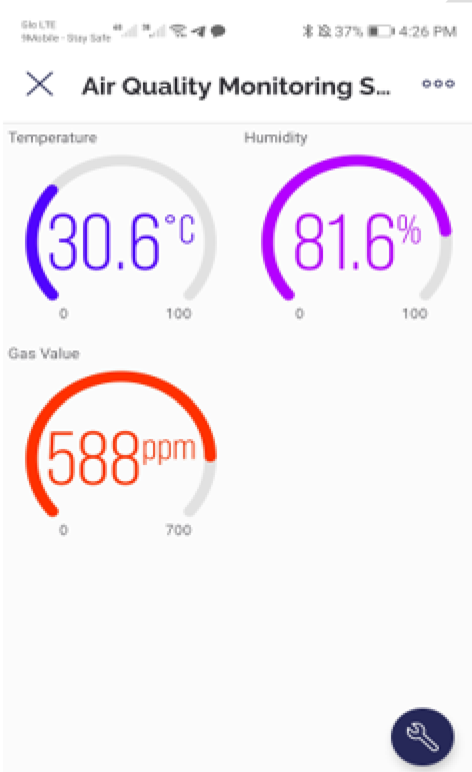


Fig 11 Data of temperature, relative humidity an air quality on mobile app

The displayed data seen on the LCD are also sent to a cloud server (Blynk) for access anywhere in the world.

Conclusion

A smart air quality monitoring system has been developed for the measurement of relative humidity, temperature and air quality. The designed system will be useful in monitoring air quality across Nigeria.

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