IoT System for Monitoring Sensors' Data using Arduino Mega WIFI, Firebase, Django and Nextion HMI Display

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The monitoring of environmental gases is crucial for protecting human health and the environment. Manual sampling and analysis are a part of traditional methods of gas monitoring, and they take a lot of time, are expensive, and yield little information. In this paper, we developed a real time Internet of Things (IoT) system with monitoring sensor's data using Google Firebase. The main components of the developed IoT system consist of: an IoT gateway, four sensor nodes and a real-time Firebase database with a web application for analytics and display of sensor's data. It addresses the benefits and drawbacks of various sensor types while outlining the fundamentals of gas detection using electronic sensors. Based on Firebase database and using API interface, the website is designed using Django framework of python. Our IoT system also proposes display of the same data on Nextion Basic NX8048T070 7'' HMI TFT LCD Touch Display.

Keywords: Internet of Things, Firebase, Arduino (Mega WIFI), Django, Nextion Display

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1. Introduction

The environment is a chaotic system; air quality is subjected to a wide range of influences and rapid changes. People's everyday life, including their commute to work and their safety at outdoor activities, are directly impacted by the air quality and condition. There is an increasing need for a more effective means of observing, recording, and accumulating data on air quality as awareness about the seriousness of air pollution in many countries is growing[1][11]. The "Internet of Things" era, often known as IoT, is now upon us. The physical and digital worlds simply interact with one another through a variety of sensors and actuators, which is what the Internet of Things is all about. This aim can be accomplished with the aid of the growing idea of Internet of Things, and policy decisions can be made based on facts, and more significantly, their effect can be tracked nearly in real-time [2]. The goal of this project is to develop an IoT (Internet of Things) system that uses an Arduino Mega Wi-Fi, Firebase, Django, and a Nextion HMI display for monitoring sensors. The objective of this system is to manage and track sensors' data in real-time using a smooth and a user-friendly interface. Web Application and cloud platforms are often used to monitor and analyze the collected data for air contaminants [17]. Additionally, the system offers sophisticated data processing and a variety of visualizations. This application is crucial for operating the system and demonstrates all key aspects of this research.

2. Literature Review

This review provides an in-depth evaluation of previous research on monitoring of environmental gases and displaying the data through different methods. Aditya, in [1], demonstrates the need of surveillance system for using Arduino interfacing and inherent need of the IoT. The paper focuses around Arduino Mega Microcontroller and interfacing of PIR sensor with it. The effective motion detection algorithm using Arducam and sending the data to the Firebase API with the help of message body creation and client authentication in JSON. Mohit, in [2] uses a novel approach for monitoring the data of sensors using sensor nodes and nRF24l01+ which relies on RF communication and with the help of ESP8266 IoT board, central hub analyzes relevant calculations and stores the data into Firebase. The proposed system also uses star topology network which connects all the three nodes and performs the calculations for the AQI levels including CO and PM2.5 levels of each node and central hub of WSN. The similar approach was illustrated in [5] by Nuba, where the system proposed a heuristic approach for collecting sensor's data using ESP8266 and Firebase console for the cloud integration of dataand in [13]. The research covers detailed mentioning of the software flow and data collection design circuit using ESP8266 and Firebase. Bento, Antonio Carlos in [6] and [7], proposed and tested the system for displaying the data on Nextion Display interfaced using UART protocol with Arduino. The Real-time data acquisition of sensors using logic of DDS protocol for messaging uses Wireless sensor Network (WSN) and Raspberry Pi for data collection and Django Framework comprising web sockets and HTTP protocol is illustrated [10].

3. Proposed System

The proposed IoT system seeks to establish an integrated practical solution to collect and analyze sensor data. The system's foundational elements are Arduino Mega WIFI, Firebase, Django, and Nextion HMI Display, which all function in tandem to offer real-time data gathering, storage, visualization, and remote control. From the Figure 1, it can be observed that the principal information accumulating device in the system will be an Arduino Mega WIFI [14]. The Arduino Mega WIFI, which is interfaced with gas sensors, acting as sensor nodes, which forms a WSN (Wireless Sensor Network) [18][19], will collect data from its surroundings. Firebase will act as the IoT system's cloud-based database and backend. The sensor data acquired by Arduino Mega WIFI devices will be securely stored. Firebase's real-time nature guarantees that data is quickly available and can be easily processed for analysis or visualization. The primary web application will be built with Django. This application will give users with an easy-to-use interface for monitoring and managing sensor data [15]. The extensive backend features of Django will enable data aggregation, user authentication, and data visualization. The Nextion HMI Display will improve the user experience by displaying sensor data in a tactile manner. The display shows information of gas sensors and monitoring in real time.

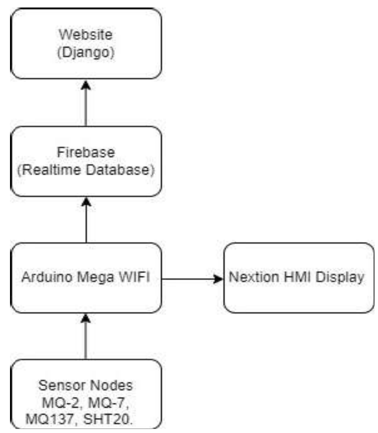

Fig. 1. Block Diagram of Proposed System

4. Components

4.1 Arduino Mega Wi-Fi Board

The ideal low-cost IoT board with an Arduino Mega R3 identical design and an on-board ESP8266 + 8Mb memory, antenna on the Wi-Fi board and an ATmega2560 direct interface, out of which both the Arduino and the ESP8266 can be programmed via a CH340G-based USB to TTL interface, that can also be used as a standard com port, for network-connected embedded computer applications, this is the best suitable option. Fig 2 represents the Arduino Mega WIFI Board.There is implementation of alone ES32 and ESP8266 in many researches[13][16].It is a modified model of the traditional ARDUINO MEGA R3 board. The selection switches are used to change the mode of configurations listed in Table 1. UART1 and UART3 are two serial communications [19], ports for ESP8266 and Arduino Mega (Figure 2). Additionally, there is a USB micro-b port for power supply. On a single board, the CH340G USB-TTL converter, ESP8266 used for Wi-Fi IC, Atmel ATmega2560 microcontroller, and 32 Mb of flash memory are fully integrated. For the Mega-WIFI board's selection and operation in various modes, see the Table 1 below.

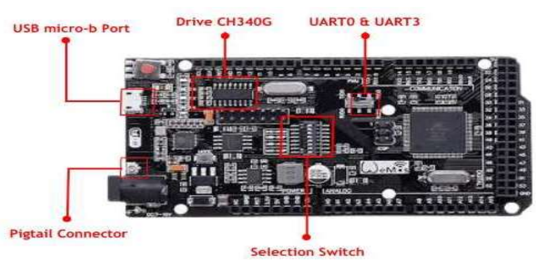

Fig. 2. Arduino Mega WIFI Board

Table. 1. Operating modes of Arduino Mega WIFI Board

Modes	1	2	3	4	5	6	7	8
CH340 connect to ESP8266 (Upload Sketch)	OFF	OFF	OFF	OFF	ON	ON	ON	No USE
CH340 connect to ESP8266 (Connect)	OFF	OFF	OFF	OFF	ON	ON	OFF	No USE
CH340 connect to ATmega2560 (Upload Sketch)	OFF	OFF	ON	ON	OFF	OFF	OFF	No USE
CH340 connect to Mega2560 COM3 connect to ESP8266	ON	ON	ON	ON	OFF	OFF	OFF	No USE
Mega2560+ESP8266	ON	ON	OFF	OFF	OFF	OFF	OFF	No USE
All modules work independent	OFF	OFF	OFF	OFF	OFF	OFF	OFF	No USE

4.2 Sensor System

In an industrial context, a typical sensor keeps track of the desired physical characteristics important for process control and generates an output signal that can be analyzed by the human operators or are sent to a process control system [4]. Chemical sensors, such as gas sensors, are crucial for our system. This sensor consists of a transducer and an active layer which transforms the chemical data intoelectronic signals by changingthe frequency, current, or voltage. A sensor's sensitivity (S) is calculated as $\Delta f/\Delta c$, where Δc is the change in analytic concentration and Δf is the change in sensor response. S is quantified using Hz/ppm or Hz/vol%. Selectivity is the term used to describe the properties which decide whether a sensor can react selectively to a single analyte or a collection of analytes. The smallest amount of an analyte that the sensor can reliably detect under circumstances is known as the detection limit. The amount of time required for a sensor to react to a step change in concentration is known as response time whereas theduration required for a signal to regain its initial value following a step concentration ratio is known as the recovery time. [5]

MQ-2 Gas and Smoke Sensor Module
Hazardous or combustible gases, smoke etc are detected with the MQ-2 sensor. Following figure 2 includes the MQ-2 Gas Sensor's part markings:

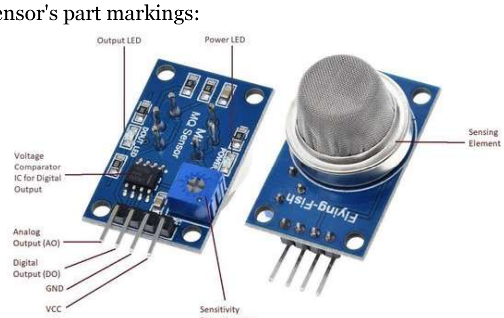

Fig. 3. MQ 2 Gas and Smoke sensor

The MQ-2 Gas Sensor Module contains four pins, a pair of which are used to produce analogue and digital data together with VCC and Gnd. The operational voltage range for this type of module is 5V and a tolerance of 0.1%. The module has two LEDs on board, as shown in the fig 2. When power is provided to the board, the power LED illuminates, and when the potentiometer's trigger value is attained the D-out LED illuminates. The on-board comparator OP-Amp shown in Figure 3 of this sensor transforms the analogue signal, which comes from the input of gas sensor, into a digital signal. Additionally, the Trim-Pot sensitivity adjustment feature allows us to change the device's sensitivity. The sensor element is constructed of platinum wire coated in a tin dioxide covering, whereas the heating element is built from nichrome wire.

MQ-7 Carbon Monoxide Sensor Module

The MQ-7 Carbon Monoxide Sensors are stable, long-lasting, and very sensitive to CO. Below mentioned Fig. 4 represents MQ7 Carbon Monoxide Gas Sensor.

Fig. 4. MQ 7 Carbon Monoxide Sensor Module

Tin Dioxide (SnO2) hypersensitive layer, heating element, measuring electrode, and carbon monoxide sensor are all bonded into a crust formed of plastic along with stainless steel net.A low-temperature state is produced during which the amount of CO is monitored by applying 1. 4 V over the heating coil for 90 seconds. Additionally, to reach the high-temperature condition, in which additional gases absorbed as a result of the low-temperature phase are cleaned, 5 V must be supplied over the heater coil over 60 seconds. For stabilized readings, the sensor needs to burn in (go through a heat cycle) for 48 hours [3].

MQ-137 Ammonia Gas Sensor Module

MQ-137 Ammonia Gas Sensor (Fig. 5)has many benefits, including a long lifespan, low cost, a straightforward drive circuit, and strong reactivity to NH3 gas over a wide range.

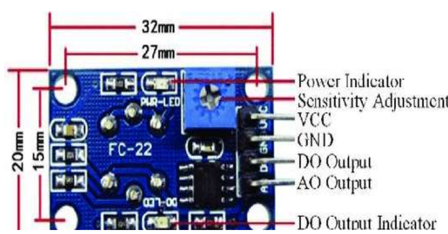

Fig. 5. MQ 137 Ammonia Gas Sensor Module

SnO2, a sensitive substance with less electrical conductivity in clean air, is used in the MQ137 gas sensor. The conductivity of the sensor increases when the presence of NH3 gas increases, and vice versa. High sensitivity, ammonia selectivity, and rapid response are all characteristics of the MQ-137. It outputs a two-way signal on a 5V DC working voltage with an analogue output voltage of 0V to 5V and a digital output voltage of 0V or 5V (TTL Logic) on an LED indicator. Based on the sensor's architecture, the MQ-137 is capable of reading and detecting ammonia gas - vapour at concentrations between 10 and 300 ppm. The sensor's measurement is also influenced by the oxygen concentration (standard condition: 21%)

SHT20 Temperature and Humidity Sensor

In terms of intelligence and form factor, the SHT20 temperature and humidity sensor SHT20 includes a band gap temperature sensor, a reactive type humidity sensor, and a specialised Analogue and digital IC. The chip includes a band gap temperature sensor, a capacitive relative humidity sensor, an amplifier, an A/D converter, an OTP memory, and a digital processing unit. SHT20 requires a supply voltage between 2.1 and 3.6 volts, with 3.3 volts being the optimum value. Microcontroller (MCU) and sensor communication is synchronised using SCL. Alternatives of SHT20 including DHT11 sensor were also used in many researches [14], but SHT20 was found more effective. There is not a minimum SCL frequency because the interface is entirely static logic. Data is entered into and exited from the sensor using the SDA pin. The sensor signals are digital, I2C-formatted, linearized, and calibrated.[3]Figure 6 shows the pin diagram of SHT20 sensor. Also, different sensors that are used in this research are compared with different properties in Table 2.

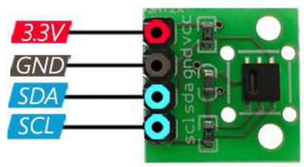

Fig. 6. SHT20 Temperature and Humidity Sensor

Table. 2. Sensor Parameter comparison table

Sr. No.	Sensor	Material Used	Operating Voltage (V)	Operating Temperature Range (°C)	Detection Limit Range (ppm)	Pre-Heat Time (hrs)	Model Name	Manufacture Company Name
1	Smoke Sensor	Tin dioxide coated ceramic with Au-oxide base	5	200 to 300	200-10000	24	MQ2	Flying Fish
2	Carbon Monoxide	SnO2	5	20 to ± 2	20-2000	48	MQ7	Flying Fish
3	Ammonia	SnO2	5	20 to ± 5	10-300	48	MQ137	Flying Fish
4	Temperature & Humidity	Copper Lead-Frame with green epoxy-base	3.3	-40 to +125 (Temp.)	-	-	SHT20	DFROBOT
				0 to 100% (Humidity)				

Nextion Display

Additionally, there is a Human Machine Interface Nextion Touch-Screen Display. The usage of devices for the Internet of Things with the Nextion display device, however, is not covered in much scholarly literature. The TX (blue) and RX (yellow), the power cables 5V (red), and Ground (black), relate to Arduino Mega Wi-Fi board and data is transferred using UART protocol [7]. First, the application used for modifying the ITEAD Nextion Editors displays is installed. This software was set up in the Windows version of a Compaq Presario development notebook, which runs Windows 10 64-bit. A TX/RX communication cable is also included in the set of accessories for the Nextion Display along with a micro-USB adaptor that was utilized for data adaption and transfer [6]. Black and red cables are used for ground wire connections and 5V power hook-ups. The 7 "display on the model utilized for the project is adequate for demonstrating the creation of the proposed solution. The device's documentation states that the link between the devices pin displaying the + (positive) signal denotes the use of a cable carrying power, in this case a red cable, and the connection pin at the - (negative) signal denotes a cable devoid of energy, in this case a ground cable of a black color. [2][3]

4.3 Cloud System

Firebase
The Internet of Things (IoT) is the collective system of hardware, software, sensors, household appliances, and other electronically embedded products that enables data and information sharing. integrating Internet of Things (IoT) into environment allows efficient collection of data that can be used in remote observation of surroundings [4]. IoT projects need an effective way of data transfer between devices, services, and applications to applications, and data must eventually be stored for processing and analysis. And one such platform that offers a reliable backend for handling data management and enabling real-time communication in IoT applications is Google Firebase. Google Firebase, a collection of development tools based on the cloud which has made building, deploying, and scaling mobile apps simpler. It eliminates the need for programming on its platform, simplifying the utilization of its features for enhanced efficiency. In this context, a discussion is presented on a few features of Firebase such as Authentication, and Realtime Database. There are multiple databases used in different approaches [8][9][19], which providesan effective solution, butFirebase Authentication service offers simple-to-use UI frameworks and SDKs, to verify the users. The Firebase Realtime Database is classified as a NoSQL database program for efficient data storing, organizing it in JSON-like documents [1]. It employs synchronization of information, ensuring that any modification to the data is instantly propagated to all connected devices, guaranteeing real-time updates.All acquired data, such as environmental parameters (proportion of carbon monoxide gas) are stored in the Firebase Realtime database.

Django Web Application
Django is an open-sourced web development framework. It is used to mitigate and reuse code, hence reducing total development time. It also offers a default database service, which is solely be useful in the backend process. The web application uses Django to provide the web interface and handle data processing, while Firebase serves as the backend to store and manage the sensor data. The purpose of the project is to establish a scalable architecture utilizing the potent framework of Django and the real-time database capabilities of Firebase [10].The front-end of the web application is created using HTML, CSS, and JavaScript, collectively alongside additional libraries, and frameworks for data visualization such as Chart.js [20]. The required server-side features, such as managing user authentication, data extraction from Firebase, and analytics computations, are provided by Django. In fig 7, the graph of MQ7 sensor is illustrated, where tests were being carried out and sudden spike was observed at the moment of generating the carbon monoxide gas by means of burning paper and leaves, and significant rise was observed which escalated up-to 25%.

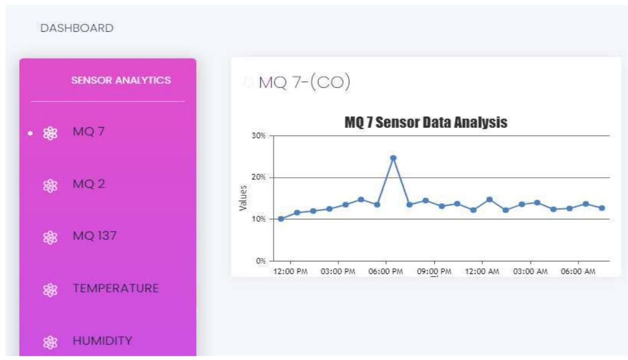

Fig. 7. Sensor data analytics using Firebase and Django of MQ2 Sensor

5. Hardware Implementation

The primary goal of this system is to facilitate data collection from sensors and deliver real-time visualization via a Nextion touchscreen display. Fig 8 illustrates the connections among the controller board, sensors, touchscreen display, and the Firebase cloud platform. The figure illustrates the linkages between these parts and highlights how each one contributes to the system's intended operation. All the four sensors: MQ2, MQ7, MQ137 and temperature and humidity, are connected to the Mega WIFI board. Each of these sensors collect specific information for further transmission. Here the Mega WIFI board acts as the key element for transmitting data and establishing connections within the system, as it serves as a channel in between Firebase platform and the sensors. The Mega WIFI controller has an on-board ESP8266 chip. As a result, the board provides Wi-Fi capabilities to enable internet connectivity and create a wireless connection to communicate with the Google Firebase. The board makes use of Firebase's libraries and APIs to transmit sensor data securely to Firebase's servers, and there it will be saved in a structured manner. Additionally, the board also establishes communication with the Nextion touchscreen display and transmit the appropriate sensor data. The display refreshes on an ongoing basis, offering the user real-time data and giving assistance as a easy to use interface for visualizing and interacting with the information. With the help of this architecture, a variety of IoT applications are made possible, enabling users to observe and communicate with sensor data effectively. Overall, a secure and flexible system for real-time data collecting, storage, and visualization is created by connecting these four sensors to Google Firebase and the Nextion touch screen display through the Arduino Mega WIFI board.

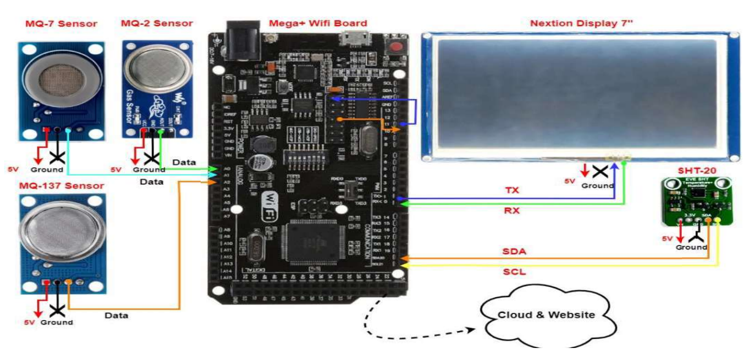

Fig. 8. Connection Diagram

6. Test Results and Discussion

For the retrieval and assimilation of correct data, we carried out functional test of each sensor and actuator used in our project. Testing of MQ2, MQ7 and MQ137 sensors were done precedent of interfacing it with Arduino Mega WIFI board. Each of the sensor's data was individually tested with firebase database for correct retrieval at the time of interfacing with checking the quality of gases [12]. A Web-based monitoring system utilizing Firebase and using local data storage have been contrasted in our project.

MQ2 Sensor

We conducted an array of tests on a MQ2 gas sensor to see how it responded with different strains of smoke. During the tests, we burned paper, an incense stick, to produce different kinds of smoke according to their respective measurement of data. To determine the sensor's efficacy, we meticulously tracked the sensor data for each type of smoke. Fig 9 and Fig 10 represents the experimental setup for testing of MQ2 sensor. In Fig 9, the smoke generated from burning the paper was used to test the value, while in Fig 10, smoke generated by incense stick was used so as no ensure from different reliable sources.

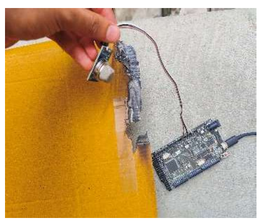

Fig. 9. Testing of MQ2 (Smoke) sensor

Fig. 10. Testing of MQ2 (Smoke) sensor

MQ7 Sensor

Conducted a set of tests on a MQ7 gas sensor to examine how it responds to the carbon monoxide gas that was generated from the smoke. During the scrutiny, we burned paper, an incense stick, and dry leaves to produce different kinds of smoke. In order to gauge the sensor's efficiency, we rigorously tracked the sensor data for each type of smoke.Fig 11 and Fig 12 represents the experimental setup for testing of MQ7 sensor. In Fig 11 and 12, the same procedure was followed as described for the MQ2 smoke sensor, that included burning of incense stick and paper. Additionally, we also added the burning of plastic to detect the carbon monoxide gas and differentiate it from MQ2 sensor. After the detection of CO gas, there was significant escalation in the values that were observed on display.

Fig. 11. Testing of MQ7 (CO) sensor

Fig. 12. Testing of MQ7 (CO) sensor

MQ137 Sensor

The MQ137 Ammonia Gas Sensor was put through a testing method. Sodium hydroxide particles (NaOH) and the crystalline salt ammonium chloride (NH_4Cl) were used to foster a reaction and produce ammonia gas (1). We placed a small quantity of NH_4Cl in a test tube, and then we slowly poured drops of a solution of NaOH on top of the solid NH4Cl. Ammonia gas was produced as a result of the following chemical reaction. Following that, the amount of ammonia gas generated during the reaction was detected and measured using the MQ137 sensor. Fig 13 and Fig 14 represents the experimental setup for testing of MQ137 sensor. The sodium hydroxide pallets are mixed with ammonium chloride particles to produce the CO gas and use it for testing

$$\mathrm{NH4Cl} + \mathrm{NaOH} \rightarrow NH3 + NaCl + H20 \qquad (1)$$

Fig. 13. Experimental Setup for testing

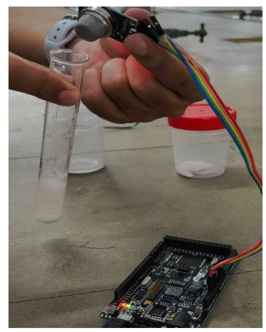

Fig. 14. Testing of MQ137 (Ammonia) sensor

Nextion Display

All the sensors when simultaneously connected to Arduino Mega WIFI Board, Nextion display was tested with observation of accumulated and accurate data on the display. The values were continuously monitored and recorded for observation purposes. The MQ2, MQ137, SHT20 were also verified with firebase results in order to maintain the accuracy and ensuring the matching of data. Fig 15 represents the display of data on Nextion Display, it includes all the sensors, that updates the value continuously on real-time basis. In Fig 15, there are additional features than enhances the user interface of the display

Fig. 15. Sensor's data monitoring on Nextion Display

Firebase

The output of sensor's data was also analyzed on firebase comprising of MQ2, MQ7 and MQ137 among gas sensors and with SHT20 Temperature and Humidity Sensor. Fig 16 represents the display of data on Firebase database. As shown in the figure, two different sections were created to differentiate between gas sensor values and weather station.

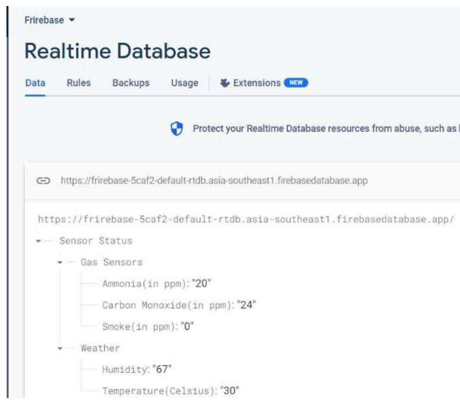

Fig .16. Sensor's data monitoring on Google Firebase Database

7. Conclusion

This research paper results in with a thorough analysis of the synchronization of environment sensors with Google Firebase for Internet of Things applications. The system enables effortless collection of information, storage, and visual representation for efficient environmental monitoring by integrating a website, and a Nextion display, together with the Mega Wi-Fi board. Thorough testing of each sensor assures precise and trustworthy data measurements and offers insightful information about sensor performance. Real-time access to environmental data is made possible by this system, enabling informed decision-making. The system exhibits scalability and adaptability, making it appropriate for many industries. Future research can concentrate on enhancing the system's potential by adding further sensors and investigating cutting-edge data analytics methods. Functionality can be improved, and predictive insights can be provided, by integrating machine learning algorithms and improving the user interface. In general, this study advances environmental management through data collecting, visualization, and taking decision for IoT-enabled environmental monitoring systems. The results show the possibility of energy usage optimization, anomaly detection, and sustainable practices promotion. This research offers a solid solution for real-time data monitoring and analysis in IoT applications. It paves the path for surroundings that are more intelligent and sustainable.

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