Design and Development of SEMS - An IoT-based Smart Environment Monitoring System

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***Abstract*— The twenty-first century is known as the "Age of Science and Technology". By believing in the potential of technology to improve lives, people gain new experiences and come up with innovative innovations in response to how the global environment is changing as technology advances. With each passing day, the environment in our living space undergoes continuous changes. To address the crisis, a budget-friendly and beneficial environment monitoring system for the classroom was devised. This is an Internet of Things (IoT)-based initiative. To create a classroom monitoring system dubbed "IoT-Based Smart Environment Monitoring System," where Multi-purpose sensors, NodeMCU, a display, an alarm, Firebase, and IoT technology were employed. An Android-based user interface was developed for monitoring real-time temperature, humidity, gas, smoke, and other parameters. Thus, LPG gas, smoke, NH4, temperature, and humidity are detected and/or measured simultaneously with a user-friendly interface and a cheap cost.**

Keywords*— *Internet of Things (IoT), Real-time, Environment Monitoring, Microcontroller, Wireless Fidelity (Wi-Fi), Mobile app, Firebase and Smart Environment Monitoring System (SEMS).

I. INTRODUCTION

For humans today, the environment is crucial. On the other hand, environmental pollution is a daily occurrence. However, many are unconcerned about it. People these days worry more about their health than the environment they live in. The most significant element in our daily lives is fire. However, there are times when a fire may bring bad luck into our lives, such as gas leaks, burning elements, careless fire use, etc. According to the World Health Organization (WHO), Bangladesh has a 0.22% fire-related fatality rate [1]. The top three causes of house fires are cooking, heating systems, and electrical malfunctions [2]. There are many different gas compositions in the air, including nitrogen (78%), oxygen (21%), carbon dioxide, etc. These aid in blazing fire [3]. The most necessary elements for a burning fire are oxygen, fuel, and heat [4]. A system that has been constructed, while unable to put out a fire, may lessen the damage it does with the information it provides to prevent similar fire incidents. A fire alarm and smoke detection system were developed using Internet of Things (IoT) technology [5].

Our environment is polluted with noise and pollution from industries, and our usage of motor vehicles is gradually getting worse. To prevent these, a simple system has been created, while it may not be able to provide information, can help decrease the damage caused by toxic gases, gas leakage, smoke, and fire. This system is called the "Smart Environment Monitoring System", SEMS in short, built using IoT technology. This research presents an IoT-based system SEMS capable of measuring leaky gas, and humidity. Leakage gas, ammonium ion (NH4), smoke, temperature, noise, and humidity are detected by various sensitive sensors, which display the findings by displaying information on the system's monitor, mobile app, and firebase. If the system detects smoke, leaking gases, NH4, sounds, or higher temperatures that exceed the threshold for an extended period, it will alert the user through an app on their phone. The proposed system has the following novel features:

- The system can detect LPG gas, smoke, NH4, temperature, and humidity simultaneously.
- The cost of building the system is reasonable.
- The system almost has no false alarm issues.

The paper's content is arranged as follows: In Section II, related works are discussed for context analysis. Section III covers the proposed strategy, requirement analysis, data gathering, and system design. Section IV examines the projected result. Comparative analysis in Section V with relevant research and Section VI at the conclusion discuss the system's conclusion and potential future developments.

II. LITERATURE REVIEW

A significant number of research works have been done on environment control or monitoring systems. These research works concentrated on fire alarm systems, and smoke and gas detection, but frequently produced false alerts due to limitations in identifying real fires. To reduce disruptions and improve home device dependability, this study proposes a more precise fire detection system to solve the problem of false alarms brought on by domestic activities.

Ralevski et al. [6] offer a low-cost IoT system that uses sensors and AI to monitor temperature and gas levels to find house fires and gas leaks. By employing a moving average prediction approach to strengthen communication, home safety is improved. Marman et al. [7] describe a fire detection system that combines smoke and carbon monoxide (CO) gas detectors and uses logic to minimize false alarms and assure quick action. It can identify different types of fire, provide a map for firefighters, and even turn off local air conditioning to help manage fires. Sweeney et al. [8] cover the process of integrating these systems as well as a large- and small-scale dangerous and flammable gas monitoring system in various contexts. Jan et al. [9] present a wireless sensor network-based system for avoiding carbon monoxide poisoning in steel mills by continually sensing CO levels and initiating countermeasures to minimize concentrations, tackling issues of hazardous settings, and ensuring worker safety. Tapashetti et al. [10] explore a low-cost indoor air monitoring prototype for CO and HCHO gases with the intention of raising public awareness of air quality and exploring the possibility of expanding to wider emissions monitoring despite cloud traffic limits. Parmar et al. [11] suggest that to monitor and report on urban climatic conditions, the suggested system uses a NodeMCU WiFi Arduino board with a variety of sensors, including GPS, temperature, humidity, noise, and CO. This system addresses rising pollution problems while providing advantages for geological investigations at a cheap cost. Buck et al. [12] describe an integrated smoke and gas detector that combines a traditional smoke detector with an ionization chamber for smoke detection and a separate gas detector. To distinguish between gas and smoke detection signals, LED modulation and a piezo element are used. Winner et al. [13] describe the system as using digital data transmitted from analog combustible gas sensors that are remotely monitored to perform integrity checks, fault detection, voice fault signaling, concentration computation, and automated sensor calibration constant determination. Foysal et al. [14] utilize an Android app and a NodeMCU microcontroller to control AC equipment voltage and automatically regulate temperature. It offers good temperature control at a reasonable price for a variety of situations, including small-scale businesses, hospitality, and agriculture.

Gottuk et al. [15] combination of smoke detectors and CO sensors were used in the study to improve fire detection, which led to increased sensitivity and fewer false alarms. Compared to photoelectric detectors, ionization detector-based algorithms perform better because they can precisely identify and measure ionized particles, resulting in more accurate measurements for a variety of applications. Hossain et al. [16] describe a fire alarm and smoke detection system that monitors fire, smoke, gases, temperature, and other elements while providing real-time monitoring of CO, smoke, and LPG levels. It uses individual threshold values for each element to turn off alarms, notify homeowners, and contact the fire department as needed. Ishii et al. [17] a precise identification of the presence of a fire is made possible by the fire alarm system's use of analog sensors, which can detect changes in smoke density, temperature, and gas concentration that are associated with fires. The smart alarm system proposed by King et al. [18] recognizes and reacts to the presence of fire and carbon monoxide by activating alarms, alerting emergency services, regulating ventilation, and stopping the spread of risks as necessary.

Najada et al. [19] use big data analysis and machine learning on real-time data from vehicular networks to improve traffic efficiency and road safety by predicting accidents and congestion using a real-time big data system with Lambda architecture to provide a precise estimated time of arrival (ETA) and prevent accidents and congestion. To improve traffic management and safety by tackling numerous road-related concerns, Patel et al. [20] focus on an Internet of Things (IoT)-based traffic monitoring and accident detection system that employs a Raspberry Pi and a camera to process live video for obtaining real-time traffic data.

Marques et al. [21] propose an open-source Wi-Fi-based IoT system for monitoring indoor air quality in real-time, with encouraging findings and the potential to improve ventilation and health treatments in the future. Neagu et al. [22] propose a scenario that combines cloud computing and IoT. It introduces a cloud-based IoT sensor service to monitor the health of the elderly. Bharathi et al. [23] propose a sensor-based Lempel-Ziv-Welch compression and particle swarm optimization-based deep neural network prediction-based, highly accurate, and practical approach for compressing and transmitting IoT-based medical data.

There are several ways to detect fire in each of those systems. Some of them can be used in kitchens [6], factories [9] [18] etc. However, most of these systems cost a lot of money and are designed to make decisions based just on one piece of information, like smoke, LPG, or fire flame. Fire detection systems that analyze CO and fire [18], temperature changes, smoke, and gases [17] are costly to operate and can generate false alarms. There are constantly a variety of activities taking place within every home, both in Bangladesh and throughout the world. Although everyone is aware of the fire, It is frequently used for activities such as cooking, smoking cigarettes, lighting matches, and using mosquito coils. A typical fire alarm will therefore pick up on all of these fire applications and sound an alert. It will not be stopped either. As a result, the systems' main flaw is their inability to reduce false alerts and anticipate actual fires in a house, a tiny classroom, or a small hospital room.

III. METHODOLOGY

The proposed system can be developed in a variety of ways. As part of the system architecture, shown in Section III.B, several types of sensors are used to gather information from the surrounding environment, such as smoke, temperature, humidity, gas, NH4, etc., to analyze it in various ways. But compared to previously created fire alarm systems for homes, the proposed approach uses simple architecture to construct the system with low cost and fewer false alarms. The flow diagram of the proposed system is shown in Fig. 1.

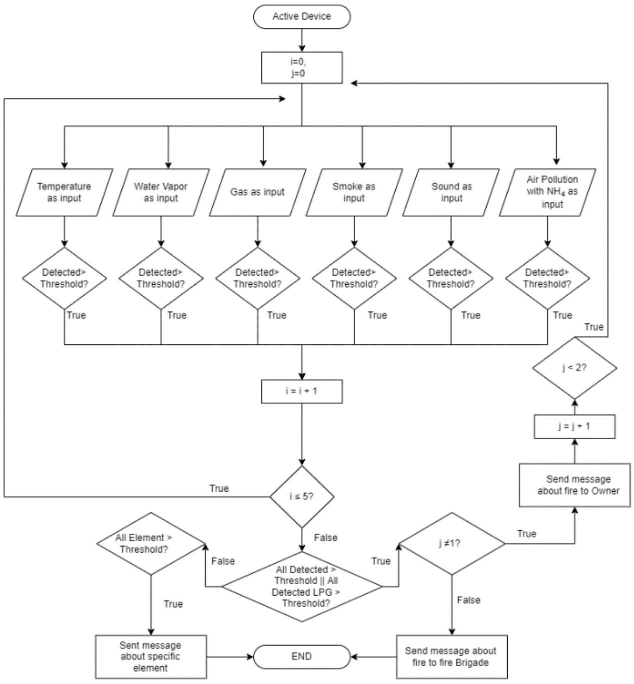

Fig. 1. Flow diagram of the system.

A. Requirement Specification

Every system has software and hardware requirements. The software and hardware requirement specifications define the system's development process and activities. The methodology of research in any subject specifies the approaches and processes used to solve problems in that field. The software and hardware needed for this system are as follows:

1) Hardware requirements:

- NodeMCU (ESP8266 12E)
- Breadboard
- Jumper Wires
- DHT11 Temperature and Humidity Sensor
- 20×4 LCD Display with I2C Driver
- MQ – 135 Gas Detection Sensor
- MQ – 4 Gas Detection Sensor
- MQ – 2 Gas Detection Sensor
- Sound Sensor
- Multiplexer CD4051

2) Software requirements:

- Arduino IDE
- MIT APP Inventor
- Firebase
- Software of required programming languages

B. System Architecture

The sensor collects data from its surroundings before sending it to the system. In our instance, there is only one brain. NodeMCU is one of them. The NodeMCU has become an effective device for increasing industrial productivity. As a result, the data is supplied to the NodeMCU when the sensors send information to the entire system. The data is delivered to the cloud server, Firebase, and the Android app via the NodeMCU. The system's architecture is depicted in Fig. 2.

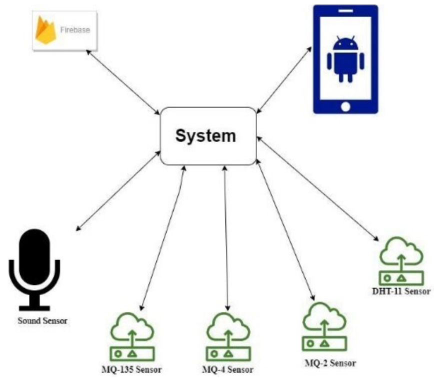

Fig. 2. System architecture of the proposed system.

C. Logical Design

The entire device is housed in a standard cardboard box. A breadboard connects all of the sensors and microcontrollers. Because NodeMCU is connected to the multiplexer with the help of a breadboard, the analog and digital pins of sensors share the other side of the multiplexer. The NodeMCU's VCC and GND have a shared connection point on the breadboard. The sensors are attached to the board's enclosure. The LCD is located on the system's upper side, and the power supply is attached to one side of the system's body. The system's device workflow is shown in Fig. 3.

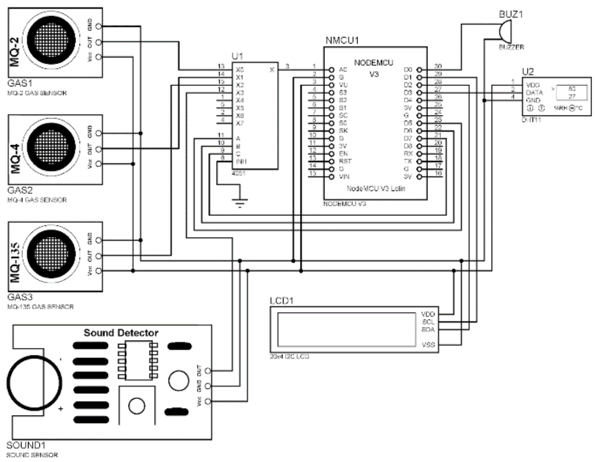

Fig. 3. Logical design of devices used in the proposed system.

D. Setup Analysis

1) Sensors Controlling Procedure: The power bank provides 5V to the whole circuit. The NodeMCU's VCC and GND pins are linked in parallel, resulting in a steady voltage connection between the sensors and the multiplexer, which is critical for reading sensor values. When the sensor receives 5V power, it begins to communicate data through the multiplexer. The NodeMCU's analog and digital input pins are also linked in parallel to the multiplexer to receive the same sensor information. Then, using the developed API, NodeMCU begins to accept data from sensors and send it to

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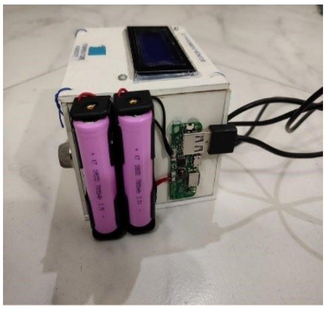
the system LCD as well as Firebase. The value on mobile can also be observed with the help of an Android app.

2) Power Supply Controlling Procedure: A single power source was employed for the entire unit's power supply. The system is powered by a 15,000 mAh power bank. One NodeMCU, sensors (DHT11, MQ-135, MQ-4, MQ-2), and one LCD were powered up with the assistance of this power bank. All of these modules require a large amount of power, which is why this 15,000 mAh power bank was chosen.

3) Complete Implementation of Requirement Design: The device's entire hardware is housed in a simple cardboard box. Multiple sensors, a breadboard, cables, and a variety of additional components are included in the package. A breadboard was used to build the prototype circuit. Here, a NodeMCU and one microcontroller are being used. At the same time, NodeMCU will receive sensor data. First, the VCC and GND of NodeMCU were connected with all the sensors implemented in the. In the other part, a MUX (multiplexer) has been used, where all analog input values from the sensors are utilized with the multiple input ports of the MUX, and an output is generated using one of the input analog points, where it is connected to the one analog pin of NodeMCU. Only DHT11 uses the digital 3 pins of NodeMCU. A 20X4 with an I2C driver LCD on the system was used, where SCL used the D1 pin of NodeMCU and SDA used the D2 pin of NodeMCU. Buzzer used the D0 pin of NodeMCU.

When the system starts using the 5v current from the power bank, the sensors calibrate the data and give the value through the analog NodeMCU and node. MCU collects the data and uploads it to the cloud server Firebase, and at the same time, the data gets a place in the mobile NodeMCU and Node. The MCU collects the data and uploads it to the cloud server Firebase, and at the same time, the data gets a place on the mobile. The value it will give a buzzer the alarm is also getting from the app at the same time After all of this, when the environment takes a suitable place, it will automatically turn off the alarm both on the mobile phone and in the system. Fig. 4 shows the complete implementation as per requirements and design.

(a) (b)



(c)

Fig. 4. Complete implementation as per requirements and design. (a) The device's top side. (b) The device's front side. (c) The device's other side.

IV. EXPERIMENTATION

Two DHT11 sensors were utilized to measure temperature and humidity, as well as MQ-135, MQ-4, and MQ-2 gas sensors to detect smoke and various sorts of gases (NH4 and LPG). This sensor is not intended to detect NH4 and LPG gases, as well as smoke. When it finds any gas, it also finds the presence of several gases and gives each one a value. On the ppm scale, it simply requires NH4, LPG, and smoke in our scenario. As a result, the sensors (MQ-135, MQ-4, and MQ-2) had to be calibrated and mapped such that they could give NH4, LPG, and smoke data on a ppm scale. The use of a certain code is required to retrieve this kind of value. A sound sensor is also being utilized, capable of providing a decibel value.

Fig. 5 shows the system monitor showing the temperature in C, the humidity in percentage (%), and the LPG level in ppm when the lighter is pressed. Flame-capable gas is used to manufacture lighters. The device senses LPG measurements, and it also determines the environment's temperature and humidity values.

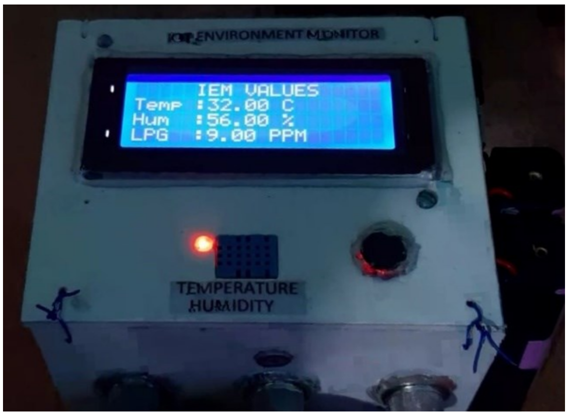


Fig. 5. Experimental results of temperature, humidity, and LPG gas.

This test used actual flames. This method needs the presence of light, flame, smoke, and temperature to create true fire. Therefore, this kind of environment was created by setting fire to tree leaves. Temperature, LDR, MQ2, and flame all of the sensors recorded readings that were higher than the threshold, which suggests that a fire is the cause. Fig. 6 shows the system monitor showing the smoke and NH4 levels in ppm. In the presence of NH4 gas, the system can detect the gas and show the output on the display.

Fig. 6. Experimental results of detecting and/or measuring smoke, NH4, and fire.

Some money in terms of takas (Bangladeshi currency) was expended to complete the project. The total cost of the project is estimated at 5,258 takas. The total cost to complete our project is almost 5,500 takas. Table I shows the total cost estimation decomposed into components. The total cost of building the system is estimated to be about 5,258 or 5,500 takas.

TABLE I. ESTIMATION OF THE TOTAL COST OF BUILDING THE SYSTEM IN DETAIL

Sl No.	Sensor and Component	Price
1	NodeMCU (Esp8266 12E)	500 Takas
2	Breadboard	105 Takas
3	Jumper Wires	90 Takas
4	Power Bank	3000 Takas
5	DHT11	180 Takas
6	20X4 LCD Display with I2C Driver	750 Takas
7	MQ – 135	194 Takas
8	MQ – 4	155 Takas
9	MQ – 2	145 Takas
10	Sound sensor	89 Takas
11	Multiplexer CD4051	50 Takas
	Total	5,258 Takas

V. COMPARATIVE ANALYSIS OF RESULTS

To evaluate the performance quality of our suggested system, which is based on an IoT-based smart environment monitoring system, a comparison of this work with multiple other pertinent and existing IoT system efforts is required. It was attempted to compare this work to that of others utilizing some different criteria. Table II discusses comparative analyses. Table II demonstrates that our system outperforms competing systems in terms of results. It may thus claim that this system is better than other systems.

TABLE II. ANALYSIS OF OUR WORK IN COMPARISON TO RELATED WORKS

Work Done	Smoke	Fire	Gas	Temperature	Humidity	NH4	Cost
This work	✓	✓	✓	✓	✓	✓	Low
Ralevski et al. [6]	×	✓	✓	×	×	×	Low
Marman et al. [7]	✓	✓	×	×	×	×	Medium
Gottuk et al. [15]	×	×	✓	×	×	×	Low
Sweeney et al. [8]	✓	×	✓	×	×	×	Medium
Hossain et al. [24]	✓	✓	✓	✓	×	×	Low

VI. CONCLUSION AND FUTURE WORKS

Maintaining a reasonable range of environmental conditions is one of the most difficult and significant tasks facing the globe today. Certain types of data sets, such as climate change tracking and surrounding air particle density, are critical right now. Our project is primarily focused on and built around the concepts of air pollution, gas leakage security, and sound pollution. A system was created to monitor humidity, temperature, and these elements in addition to the outside environment's NH4 pollution, smoke, and sound pollution. In addition, the problem of gas leaks within dwellings was taken into account. A smart environment monitoring system is created as a result. MIT App Inventor is used to implement a mobile app for data visualization and storage, while Firebase is used as a cloud data storage service. This Internet of Things-based smart environment monitoring system was built with low-cost components. It may be used to collect thousands of pieces of data without delay over a lengthy period. Because the entire hardware system is tiny and portable, it may be installed both indoors and outdoors. There was no issue with the system's Wi-Fi signal dropping or serial data collection failing. As a result, the system is fairly reliable, user-friendly, and adaptable.

Performance can be improved by reducing data access and analytics latency. Performance can also be improved by ensuring that the data is clean and uncorrupted. Optimizing sensor calibration, providing dependable data transmission, and processing for improved data quality can play an important role in increasing the IoT device's accuracy.

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