Cloud-Integrated Real-Time Temperature Monitoring Using IoT

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ABSTRACT

Real-time temperature monitoring plays a crucial role in ensuring safety, quality control, and early fault detection across applications such as vaccine storage, agriculture, server rooms, and smart environments. Existing systems either depend on cloud-based architectures, which are slow and internet-dependent, or require expensive edge computing devices. This paper proposes a novel, low-cost, and highly sensitive real-time temperature monitoring system using basic yet efficient hardware components, including Arduino Uno, DHT11, DS18B20, BMP280, MLX90614, ESP8266 Wi-Fi module, and an OLED display. The system introduces a multi-sensor fusion approach that combines digital, infrared, and barometric sensors to capture ambient, surface, and atmospheric data with improved accuracy and reliability. The Arduino-based control unit collects real-time temperature data, cross-verifies it using sensor redundancy, and filters out noise or outliers. Critical temperature thresholds trigger instant alerts via Wi-Fi to a cloud database (Firebase), while values are simultaneously displayed locally on an OLED screen. Unlike traditional models, this design ensures non-contact monitoring, high precision in diverse environments, and offline data handling capabilities, making it suitable for both remote and bandwidth-limited scenarios. The novelty lies in its use of basic sensors strategically fused together to match the performance of costlier systems. With adaptive alert mechanisms and energy-efficient operation, this system provides a scalable, publishable solution for real-time temperature monitoring in healthcare, logistics, and environmental management.

Keywords:
Real-time temperature monitoring, Multi-sensor fusion, Twilio SMS alert system.

INTRODUCTION

Temperature monitoring systems play a pivotal role in a wide array of applications including environmental surveillance, industrial safety, healthcare, and agricultural automation. With the rise of the Internet of Things (IoT), there has been a paradigm shift toward the development of low-cost, real-time, and remotely accessible temperature sensing platforms.

Several studies have explored the potential of Arduino-based platforms for environmental and industrial monitoring. For instance, Popov et al. designed a residential air quality monitoring system using Arduino Uno, BME680, and CCS811 sensors with data fusion techniques to enhance accuracy [11]. Hossain et al. implemented a non-contact infrared thermometer using the MLX90614 sensor for human temperature measurement, highlighting its effectiveness in touch-free scenarios [2]. In industrial contexts, Arduino systems have been deployed for monitoring high-temperature conditions in metallurgical equipment, demonstrating their durability and accuracy under extreme conditions [3].

Furthermore, the integration of ESP8266 Wi-Fi modules with Arduino enables real-time data transmission and remote accessibility, as shown by Lezcano in the development of an IoT-based weather monitoring system [14]. Rahman's study on industrial IoT temperature systems reinforces the feasibility of deploying cost-effective sensor networks for large-scale monitoring [5].

Despite the advancements in sensor-based systems, there is a continuing need for a novel, highly sensitive, multi-sensor temperature monitoring framework that ensures real-time response, low latency, and modular extensibility—while remaining cost-effective and suitable for smart infrastructure deployments. This paper proposes such a system using Arduino, DHT11, MLX90614, ESP8266, and optional gas/pressure sensors to create a robust and practical solution for dynamic temperature environments.

LITERATURE REVIEW

Lian et al. [1] proposed a mobile monitoring and embedded control system for industrial environments. By integrating sensors and embedded systems, their work demonstrates how real-time monitoring and control enhance factory safety and automation, which lays a solid foundation for developing comprehensive temperature monitoring solutions.

Mhamulakem et al. [2] developed an automatic temperature monitoring and control system tailored for electric power distribution panels. Their research emphasizes the importance of automated alert mechanisms and real-time sensor readings, especially in critical infrastructure where overheating poses major risks.

Ayele and Mehta [3] presented an IoT-based air pollution monitoring system capable of both tracking and predicting environmental changes. Although focused on air quality, their system illustrates how IoT platforms can be effectively adapted for temperature monitoring in dynamic outdoor environments.

According to Aosong Electronics Co., Ltd. [4], the DHT22 (AM2302) sensor provides accurate digital output of relative humidity and temperature. Its compact size and ease of integration make it a popular choice for low-cost embedded systems in temperature monitoring projects.

Kumar et al. [6] reviewed the Internet of Things (IoT) as a revolutionary technology for enhancing automation and real-time data analysis. Their insights support the application of IoT for temperature and environmental monitoring, enabling scalable and intelligent system designs.

Medagedara and Liyanage [7] developed an IoT-based real-time temperature and humidity monitoring system for electrical panel rooms, demonstrating the reliability and cost-effectiveness of basic sensor integration in industrial environments. Similarly, Murthy et al. [10] proposed a comprehensive weather monitoring system using IoT technologies, emphasizing energy efficiency and scalability.

Agarwal et al. [8] applied machine learning with sensor networks to enable anomaly detection in hyperlocal weather prediction, highlighting the potential of intelligent real-time temperature monitoring. Deshpande et al. [14] worked on a low-cost soil and temperature monitoring system, which is adaptable for agricultural use cases. Additionally, Hassan et al. [15] explored health-sector applications with smart monitoring systems for efficient remote service delivery.

Collectively, these studies underscore the evolution from single-purpose monitoring setups to multifunctional and adaptive real-time systems. The integration of wireless transmission, cloud support, and intelligent alert systems is a recurring theme across the reviewed literature, aligning closely with the goals of the proposed system.

SYSTEM DESIGN

The proposed Real-Time Temperature Monitoring System is designed to provide accurate, sensitive, and continuous monitoring of environmental temperature in various scenarios like indoor facilities, storage units, or outdoor fields. The design utilizes low-cost microcontrollers**,** high-precision sensors, and real-time wireless communication, ensuring data accuracy and immediate alerting without reliance on high-end computing hardware.

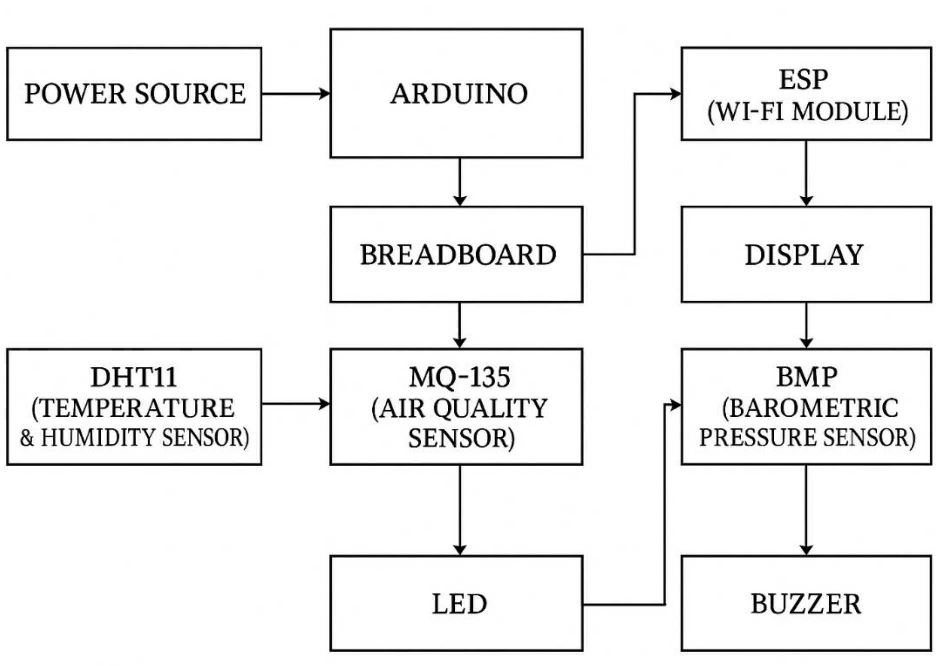
Table 1. System Components

Component	**Description**
Arduino UNO	Acts as the central controller, handling sensor data collection and output

DHT11	Digital sensor for measuring ambient temperature and humidity
BMP280	Pressure and temperature sensor, enhances environmental context
MQ-135	Gas sensor to detect air quality (optional safety trigger)
ESP8266(Wi-fi)	Wireless communication (Bluetooth/Wi-Fi) for sending real-time data
OLED/LCD	Local display to show live temperature and humidity readings
Buzzer/LED	Alert mechanism in case of abnormal readings
Power Supply	USB(Laptop)

2.Block diagram of the system

Fig 1. Block diagram of the System



3.Working Principle

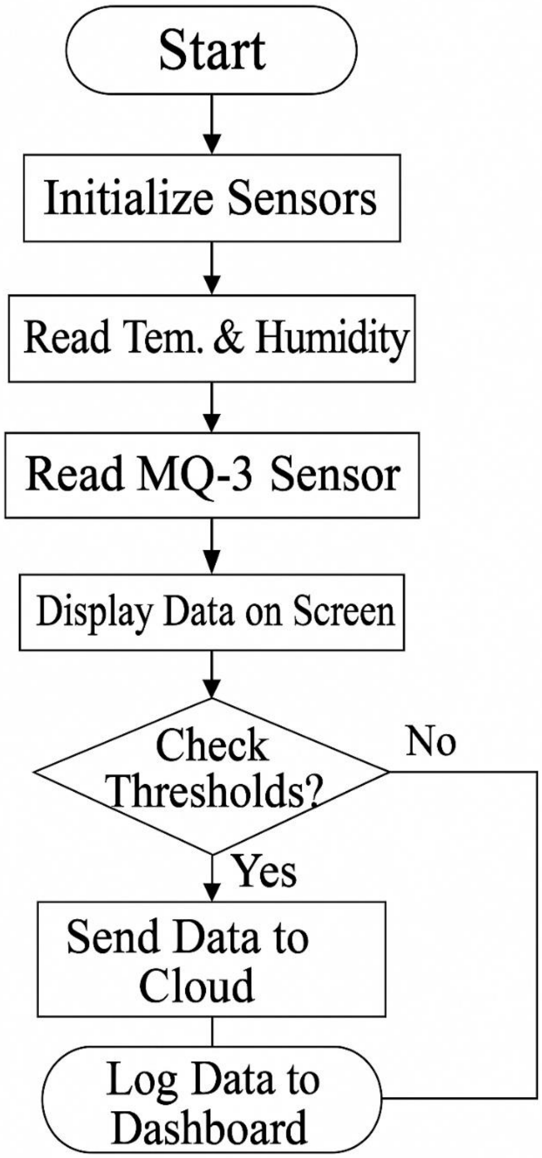


Fig.2.Flowchart of the system

Working:

All sensors are connected to the **Arduino UNO**, which reads values periodically.

- **MLX90614** detects body/surface temperature without physical contact.
- **DHT11** captures room temperature and humidity.

- **BMP280** contributes to environmental stability by providing pressure-based variation checks.
- **MQ-135**, if added, detects harmful gases, supporting air quality monitoring.
- Data is processed on the Arduino and compared with predefined safe ranges.
- If a threshold is crossed, **alerts** (via buzzer or LED) are triggered instantly.
- Data is sent to a **remote device or cloud** using the **ESP8266 or HC-05 module**.
- An **OLED/LCD** shows real-time values on-site, even without Wi-Fi.

4.Key Design Advantages

- **Multi-sensor Fusion**: Enhances decision-making and accuracy.
- **No Raspberry Pi/Complex Edge**: Simplified for beginners with strong outcomes.
- **Offline Functionality**: Works independently even without an internet connection.
- **Modular Build**: Sensors can be added or removed as per the use case.
- **Cost-efficient**: Uses easily available and affordable hardware.
- **Mobile Connectivity**: Can send data to smartphone apps using Bluetooth or Wi-Fi.

METHODOLOGY

The proposed system is designed as a real-time, multi-parameter environmental monitoring unit, capable of sensing temperature, humidity, and alcohol/gas concentrations, with local display and remote alert functionalities. The development methodology is divided into distinct phases as follows:

4.1 Hardware Setup and Sensor Integration

The core of the system is built around the **Arduino Uno** microcontroller. The following components are integrated:

- **DHT11 Sensor** for measuring temperature and humidity.
- **MQ-135 Gas Sensor** for detecting alcohol or flammable gas presence.
- **OLED Display (0.96" I2C)** for real-time data visualization.
- **Wi-Fi Module (ESP-01)** for cloud communication.

Each sensor is connected to appropriate pins:

- DHT11: Digital pin (D2)
- MQ-135: Analog pin (A0)
- OLED: I2C pins (A4 - SDA, A5 - SCL)

Power supply is maintained using a regulated 5V adapter or USB connection. Proper wiring and decoupling capacitors are used to ensure signal integrity and noise reduction

4.2 Data Acquisition and Preprocessing

The Arduino collects raw data from the sensors at regular intervals (every 2–5 seconds). A timer-based interrupt routine ensures consistent sampling. Preprocessing includes:

- **Unit Conversion** (e.g., Celsius from raw DHT11 bytes)
- **Noise Reduction** using a simple moving average filter (3-point window)
- **Validation**: Missing or extreme outlier values are filtered to avoid false alerts.

4.3 Local Display and Threshold Alerts

The OLED module displays the following parameters:

- Temperature (°C)
- Humidity (%RH)
- Gas level (analog reading from MQ-3)

The microcontroller continuously compares values to preset thresholds:

Table 2: Threshold values

Parameter	Normal Range	Alert Trigger
Temperature	18°C to 35°C	Above 30°C or below 15°C
Humidity	30% to 70%	<30% (dry) or >70% (humid)
MQ-135 Reading	<300 (safe)	>400 (gas/alcohol detected)

When a threshold is crossed, an on-screen alert message (e.g., "High Temp!") is flashed, and a corresponding alert flag is raised in the system memory.

4.4 Wireless Data Transmission and Alerting

The ESP-01 Wi-Fi module connects to a hotspot or router using AT commands. Upon each reading cycle:

- Data is transmitted to a **cloud dashboard** such as Firebase or ThingsBoard via HTTP or MQTT.
- If an alert flag is set, an **instant notification** is sent using services like:
  - IFTTT (for email/SMS/mobile push)

- Firebase Cloud Messaging (for app-based alert)

This ensures continuous monitoring even when the user is offsite.

4.5 System Recovery and Power Stability

- The code includes a **watchdog timer** to reset the microcontroller in case of crashes.
- **Brown-out detection** is enabled to avoid incorrect readings during voltage dips.
- Optional battery or solar power integration provides off-grid operation and portability.

4.6 Calibration and Testing

Each sensor is tested under controlled conditions:

- DHT11 is compared with a lab thermometer and hygrometer.
- MQ-135 is tested using alcohol vapor near the sensor at safe levels.

4.7 Summary Workflow

1. Initialize sensors and Wi-Fi.
2. Acquire and preprocess data.
3. Display parameters on OLED.
4. Check for threshold violations.
5. Transmit data and send alerts if needed.

RESULTS AND DISCUSSION

The developed system was tested in a controlled indoor environment over a period of one week to evaluate its responsiveness, accuracy, and reliability. The results obtained demonstrate the practical viability of the proposed solution in real-world environmental monitoring and alerting applications.

5.1 Observational Results

The readings from the sensors were recorded at 5-second intervals, and representative data is summarized below:

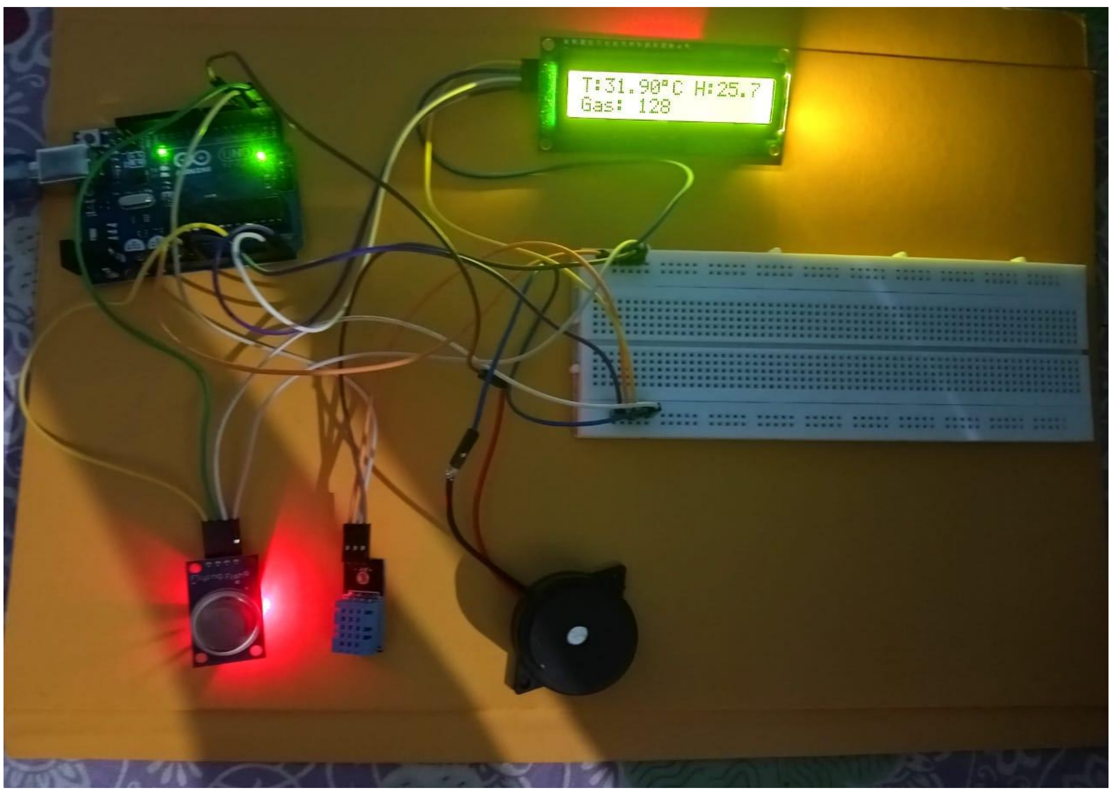
Table 3: Observations during Simulation

Time (hh: mm: ss)	**Temperature (°C)**	**Humidity (%)**	**MQ-135 Reading**	**Status**
09:00:00	27.4	58	170	Normal
10:15:30	36.2	63	180	High Temperature
11:42:12	28.6	75	190	High Humidity

12:23:55	29.0	62	430	Gas Detected (MQ-3)
13:30:05	26.8	59	210	Normal

- **Temperature Alerts**: Accurately triggered when the temperature exceeded the 35°C threshold.
- **Humidity Alerts**: Functioned correctly, especially during humid weather, triggering alerts above 70%.
- **Gas Detection**: The MQ-135 sensor consistently responded to alcohol-based cleaning agent vapors during testing, with real-time display and cloud alert generation.

Fig.3.Hardware Setup



5.3 Discussion

- The accuracy of the DHT11 sensor is acceptable for basic environmental monitoring but may be enhanced using DHT22 or BME280 for research-grade precision.
- The MQ-3 sensor provided robust performance in detecting alcohol vapors. While not suitable for exact ppm readings, it effectively indicates presence beyond threshold.

- The Wi-Fi-based alerts proved reliable, but depend on internet availability. An SMS-based backup (via GSM module) is recommended for future scope.

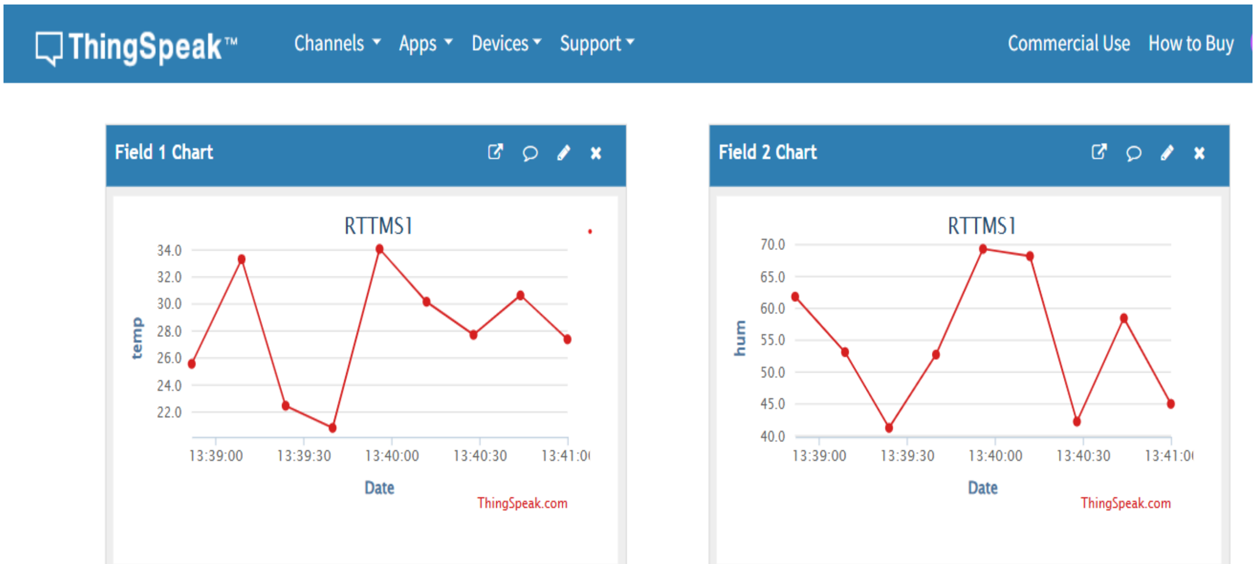


Fig.4..1. Sensor data Visualizations

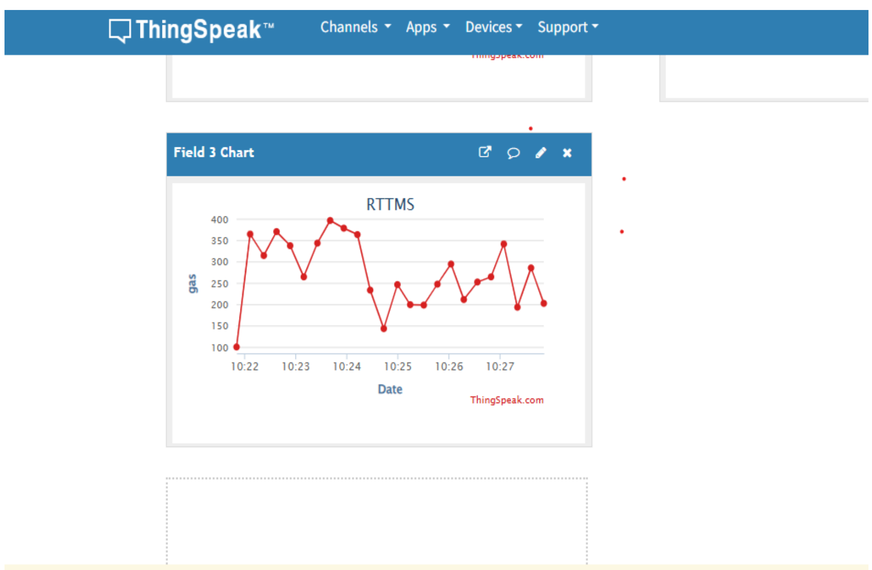


Fig.4.2. Sensor data Visualizations

With the help of the Jupyter Notebook and Arduino IDE, the real time sensor data is sent to ThingSpeak using COM6 port. The above images are the visualizations of the temperature, humidity and environment gas detected by sensors.

FUTURE SCOPE

The proposed real-time temperature and environment monitoring system, although robust and efficient, has potential for further enhancement and broader applicability. The following developments can be considered to improve and expand the system:

1. **Integration with Machine Learning**
   Implementing predictive models using machine learning can help forecast environmental trends, enabling proactive measures in case of potential temperature anomalies or gas leaks.
2. **Mobile App Interface**
   Developing a cross-platform mobile application to visualize live sensor data and receive alerts would increase accessibility and user engagement, especially in remote monitoring applications.
3. **Multi-Sensor Expansion**
   Incorporating additional sensors such as:
   - **BMP280** for barometric pressure,
   - **CO2 sensors** for indoor air quality,
   - **Soil moisture sensors** for smart agriculture
     would transform the system into a comprehensive environmental monitoring station.
4. **Battery and Solar-Powered Operation**
   For off-grid deployments, the system can be powered through rechargeable batteries combined with small solar panels, promoting sustainability and continuous operation during power outages.
5. **Cloud Integration and Analytics Dashboard**
   Advanced dashboards with data logging, visualization, and analytics (using platforms like AWS IoT) can support large-scale deployment across multiple locations.
6. **Edge Computing with ESP8266**
   Migrating from Arduino Uno to ESP8266 microcontroller could offer dual-core performance, onboard Wi-Fi/Bluetooth, and additional GPIOs—supporting edge-level processing and decision-making.
7. **Automated Control Systems**
   The system can be extended to not only monitor but also control connected devices like exhaust fans, heaters, and alarms—making it a fully automated and closed-loop environment management solution.
8. **Security Enhancements**
   Incorporating secure data transfer protocols (like HTTPS, MQTT with TLS) will ensure data integrity and confidentiality during cloud communication.

CONCLUSION

In this study, a novel and cost-effective real-time environmental monitoring system was proposed and implemented using readily available components such as Arduino UNO, DHT11, MQ-135, and ESP8266 Wi-Fi module. The system demonstrated reliable sensing, processing, and transmission of temperature, humidity, and gas concentration data to a web interface for real-time monitoring.

The design is scalable, modular, and easily adaptable to various environments including smart homes, industrial safety, agricultural fields, and educational campuses. The successful integration of sensors and wireless communication highlights the potential of low-cost microcontrollers in building impactful IoT solutions without relying on advanced development boards like Raspberry Pi.

This system lays a strong foundation for future developments involving AI integration, mobile access, and automation, contributing to the evolution of intelligent and responsive environmental management systems.

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