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CLOUD-ENABLED IOT ENVIRONMENTAL MONITORING AND ALERT SYSTEM USING RASPBERRY PI PICO

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Abstract

This project proposes a cloud-enabled IoT-based environmental monitoring and alert system built using a Raspberry Pi Pico microcontroller integrated with multiple sensors such as DHT11 for temperature and humidity monitoring, an MQ-series gas sensor for gas leakage detection, and a fire sensor for flame detection. The system continuously monitors environmental conditions and processes sensor data through the Raspberry Pi Pico controller. When abnormal conditions such as high temperature, gas leakage, fire presence, or unusual humidity levels are detected, the system immediately triggers alerts through a NodeMCU Wi-Fi module connected to a cloud-based SMS API. These alerts are sent directly to the user's mobile phone via internet-based messaging services without the need for a GSM module or SIM card. Additionally, real-time status information is displayed on a 16×2 LCD and a buzzer provides local audible warnings. By integrating low-cost hardware with cloud communication technologies, the proposed system provides a reliable, scalable, and cost-effective solution for remote monitoring and emergency notification. This system is suitable for applications such as smart homes, industrial safety monitoring, laboratories, and server rooms where continuous environmental monitoring and quick response to hazardous situations are essential.

I. INTRODUCTION

The rapid growth of the Internet of Things (IoT) has significantly transformed the way environmental conditions are monitored and controlled. IoT technologies enable the integration of sensors, embedded systems, and cloud communication platforms to collect and transmit real-time data from physical environments to remote users. Such systems have become essential in areas such as industrial safety, smart homes, agriculture, healthcare, and environmental protection where continuous monitoring of parameters like temperature, humidity, gas concentration, and fire hazards is critical for preventing accidents and improving operational efficiency [1], [2].

Traditional monitoring systems rely heavily on manual supervision or standalone devices that provide limited accessibility and delayed response during emergencies. With the development of low-cost microcontrollers and wireless communication technologies, IoT-based monitoring systems have emerged as efficient solutions for real-time environmental data collection and remote notification. Embedded systems integrated with wireless modules enable continuous monitoring and allow users to access system status from anywhere via the internet [3]. These systems help organizations quickly respond to abnormal conditions such as overheating, gas leakage, or fire outbreaks.

Temperature and humidity monitoring are among the most important aspects of environmental sensing. Sensors such as DHT11 are widely used in IoT applications due to their low cost, simple interfacing, and ability to measure both temperature and relative humidity simultaneously. The DHT11 sensor integrates a thermistor and a capacitive humidity sensing element to provide digital output signals that can be easily processed by microcontrollers [4], [5]. Such sensors have been extensively used in smart agriculture, weather monitoring, and industrial control systems to ensure optimal environmental conditions.

Similarly, gas sensors such as MQ-series sensors play a vital role in detecting hazardous gases and preventing industrial accidents. Gas leakage remains a major safety concern in laboratories, manufacturing plants, and storage facilities. IoT-based gas detection systems provide continuous monitoring and generate alerts when gas concentration exceeds predefined thresholds, thereby improving safety and reducing potential risks [6]. Integrating gas sensors with wireless communication technologies allows real-time alerts to be transmitted to remote users through internet-based platforms.

Recent advancements in IoT have also introduced cloud-based monitoring systems where sensor data is transmitted to cloud servers for analysis, visualization, and notification services. These systems provide scalable infrastructure for real-time monitoring and enable users to access environmental data from anywhere using

smartphones or web interfaces [7]. Cloud platforms combined with wireless microcontrollers such as NodeMCU and ESP-based devices allow seamless communication between sensors and remote monitoring applications.
The introduction of compact microcontrollers such as the Raspberry Pi Pico has further enhanced the development of low-power and cost-effective IoT solutions. The Raspberry Pi Pico, based on the RP2040 microcontroller, provides sufficient processing capability, flexible GPIO interfaces, and compatibility with multiple sensors, making it suitable for embedded monitoring systems [8]. Recent studies have demonstrated the effectiveness of Raspberry Pi Pico-based monitoring platforms for environmental sensing, greenhouse monitoring, and industrial safety applications [9].
Modern IoT monitoring systems increasingly incorporate multiple sensors to detect different environmental hazards simultaneously. Multi-sensor integration improves the reliability and accuracy of monitoring systems by collecting data from various environmental parameters such as temperature, humidity, air quality, and gas concentration [10]. These systems are particularly useful in critical environments such as server rooms, laboratories, and industrial facilities where abnormal environmental conditions can lead to equipment failure or safety hazards.
Another important feature of modern IoT systems is the integration of real-time alert mechanisms. Traditional alert systems rely on GSM modules and SIM cards for sending SMS notifications, which increases hardware cost and operational complexity. Cloud-based APIs and internet messaging services now provide a more flexible and scalable alternative for sending notifications directly through internet connectivity without the need for GSM hardware [11]. Such solutions reduce system cost while maintaining reliable real-time communication.
In addition to remote notifications, IoT monitoring systems often include local alert mechanisms such as buzzers, displays, or indicator LEDs to provide immediate warnings at the monitored location. Local alerts combined with remote notifications ensure that both on-site personnel and remote users are informed about hazardous conditions promptly [12].
Recent research has focused on designing low-cost IoT-based environmental monitoring systems using embedded platforms, wireless communication modules, and cloud services. These systems aim to provide real-time monitoring, automated alerts, and improved safety in various application domains including smart agriculture, pollution monitoring, industrial automation, and smart buildings [13], [14].
Despite significant progress in IoT monitoring technologies, there is still a need for simple, scalable, and cost-effective systems capable of integrating multiple sensors and delivering instant alerts through internet-based communication services. Therefore, this work proposes a cloud-enabled IoT environmental monitoring and alert system using Raspberry Pi Pico, multiple sensors, and a cloud-based SMS API. The system monitors temperature, humidity, gas leakage, and fire conditions and sends real-time notifications to users through internet connectivity. The proposed solution demonstrates the potential of combining low-cost hardware, cloud platforms, and IoT technologies to create reliable and efficient environmental monitoring systems for safety-critical applications.

II.Literature Review

Several researchers have proposed IoT-based monitoring systems to improve environmental safety, automation, and real-time data communication. These studies highlight the importance of integrating sensors, embedded systems, and cloud technologies to monitor environmental parameters such as temperature, humidity, gas leakage, and fire hazards.
R. K. Kodali et al. developed an IoT-based environmental monitoring system using a microcontroller and multiple sensors to monitor temperature and humidity conditions in real time. The system transmitted data to a cloud platform where users could analyze environmental parameters remotely. Their study demonstrated that IoT technology could significantly improve remote monitoring efficiency and reduce the need for manual inspection in industrial environments [16].
A. S. Al-Fuqaha et al. presented a comprehensive overview of IoT architectures and communication protocols used in smart monitoring systems. The study highlighted the importance of integrating low-power sensors, embedded controllers, and cloud services to enable scalable IoT solutions. Their research emphasized the role of cloud computing and wireless communication technologies in enhancing real-time monitoring capabilities [17].
M. S. Hossain et al. proposed a smart environmental monitoring system using wireless sensor networks and IoT platforms. The system collected environmental data such as temperature, humidity, and gas concentration and transmitted the information to a remote monitoring server. The

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authors concluded that wireless sensor networks combined with IoT frameworks could significantly improve environmental monitoring accuracy and reliability [18].

S. Ferdoush and X. Li designed a cloud-based IoT monitoring platform that enabled real-time data collection and remote alert generation. Their work focused on integrating sensors with cloud storage and mobile communication systems to provide real-time alerts to users. The research demonstrated that cloud-based architectures can improve the scalability and accessibility of IoT monitoring systems [19].

K. Ashton discussed the concept and evolution of the Internet of Things and emphasized how interconnected devices can improve automation and data exchange across different application domains. The study highlighted the importance of sensor-based monitoring systems in industrial automation, environmental monitoring, and smart city development [20].

P. Sethi and S. R. Sarangi proposed an IoT-based air quality monitoring system that utilized MQ-series gas sensors to detect harmful gases. The system transmitted sensor data through wireless communication modules to a cloud platform for analysis. The authors demonstrated that IoT-based gas monitoring systems can provide early warnings and improve safety in urban and industrial environments [21].

A. Salam and S. A. Siddiqui presented a multi-sensor IoT monitoring system designed for smart agriculture. The system integrated temperature, humidity, and soil moisture sensors with wireless communication modules to provide continuous environmental monitoring. Their results showed that IoT technology can improve resource management and environmental control in agricultural applications [22].

S. K. Datta et al. proposed an IoT framework that integrates embedded systems with cloud services to enable real-time monitoring and data analytics. The study highlighted the advantages of cloud-based IoT platforms in providing scalable infrastructure for monitoring systems across multiple application domains [23].

A. Rahman et al. designed a fire detection and alert system using embedded sensors and wireless communication modules. The system could detect fire hazards and send alerts to remote users through internet-based communication networks. Their research emphasized the importance of early warning systems for improving safety in residential and industrial environments [24].

Y. Liu et al. proposed a smart monitoring system that integrates multiple sensors and cloud communication technologies to provide real-time environmental monitoring. The system utilized IoT gateways and wireless networks to transmit sensor data to cloud servers for analysis and alert generation. Their research demonstrated that multi-sensor IoT systems can significantly improve environmental monitoring accuracy and response time [25].

Overall, previous studies demonstrate the growing importance of IoT-based environmental monitoring systems that integrate multiple sensors, embedded controllers, and cloud communication technologies. However, many existing systems rely on GSM-based communication modules or require complex infrastructure. The proposed system addresses these limitations by utilizing a Raspberry Pi Pico controller, multiple environmental sensors, and a cloud-based SMS API to provide a low-cost, scalable, and efficient environmental monitoring and alert system.

III.Proposed Methodology

The proposed system is designed to develop an IoT-based environmental monitoring and alert system using a Raspberry Pi Pico microcontroller integrated with multiple sensors and cloud-based communication services. The system continuously monitors environmental parameters such as temperature, humidity, gas leakage, and fire presence. When abnormal conditions are detected, the system immediately sends real-time alerts to the user through a cloud-based SMS API using internet connectivity.

1. System Overview

The proposed methodology consists of several components including sensors, a microcontroller, a wireless communication module, and an alert system. The Raspberry Pi Pico acts as the central controller that receives input signals from various sensors and processes the collected data. Based on the predefined threshold values, the system determines whether the environmental conditions are normal or hazardous.

The system uses a DHT11 sensor to measure temperature and humidity levels. A gas sensor (MQ-series) is used to detect harmful gases or gas leakage, while a fire sensor detects the presence of flames. These sensors continuously send data to the Raspberry Pi Pico, which analyzes the readings and identifies abnormal environmental conditions.

2. Sensor Data Acquisition

The sensors connected to the Raspberry Pi Pico continuously collect environmental data. The DHT11 sensor measures temperature and humidity

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values and transmits the digital output to the microcontroller. Similarly, the gas sensor detects gas concentration levels in the surrounding environment, and the fire sensor identifies flame presence. The collected data is processed by the controller to determine whether the values exceed predefined safety thresholds.

3. Data Processing and Decision Making

Once the sensor data is received, the Raspberry Pi Pico processes the information using embedded programming logic. The system compares sensor readings with predefined threshold values. For example, if the temperature exceeds a specified limit such as 33°C, or if gas or fire is detected, the controller identifies the condition as abnormal. Based on this decision-making process, the system activates the alert mechanism.

4. Cloud Communication Using NodeMCU

To enable internet connectivity, a NodeMCU Wi-Fi module is integrated with the Raspberry Pi Pico. The NodeMCU sends the processed sensor data to a cloud platform using internet communication protocols. The system utilizes a cloud-based SMS API to generate instant notifications. This eliminates the need for traditional GSM modules and SIM cards, making the system more cost-effective and scalable.

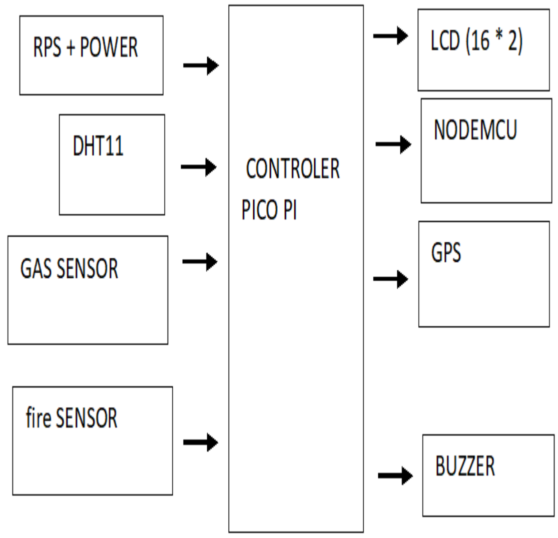
5. Alert and Notification Mechanism

When the system detects abnormal environmental conditions, two types of alerts are generated:Local Alert: A buzzer is activated to provide an audible warning at the monitored location, allowing nearby personnel to take immediate action. Remote Alert: The NodeMCU sends a request to the cloud SMS API, which instantly sends a text message notification to the user's mobile phone via internet connectivity.This dual alert mechanism ensures that both on-site and remote users are informed about potential hazards in real time.

6. Data Display and Monitoring

The system also includes a 16×2 LCD display to provide real-time information about environmental parameters. The LCD continuously displays temperature, humidity, and system status messages. This feature allows users at the monitoring location to quickly observe environmental conditions without accessing external devices.

IV.SYSTEM ARCHITECTURE



The system architecture of the proposed IoT-based Environmental Monitoring and Alert System is designed to monitor environmental conditions and provide real-time alerts using cloud communication. The architecture consists of multiple sensors, a central controller (Raspberry Pi Pico), communication modules, and alert mechanisms. The block diagram illustrates how different components interact to collect environmental data, process it, and send notifications to the user.

1. Power Supply (RPS + Power)

The regulated power supply (RPS) provides the required operating voltage to all components of the system including the Raspberry Pi Pico controller, sensors, NodeMCU module, LCD display, and buzzer. Stable power is essential to ensure reliable operation of the sensors and communication modules. The power supply converts AC input into regulated DC voltage suitable for the microcontroller and other electronic components.

2. Raspberry Pi Pico Controller

The **Raspberry Pi Pico** acts as the main processing unit of the system. It receives data from all connected sensors, processes the information, and determines whether the environmental conditions are normal or abnormal. The controller continuously reads sensor values and compares them with predefined threshold levels. If any sensor detects a hazardous condition, the controller activates the alert mechanisms and sends the data to the communication module for remote notification.

3. DHT11 Temperature and Humidity Sensor

The **DHT11 sensor** is used to measure environmental temperature and humidity. It provides digital output that can be easily interfaced

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with the Raspberry Pi Pico. The sensor continuously monitors the surrounding environment and sends temperature and humidity readings to the controller. If the temperature or humidity level exceeds the predefined limit, the controller triggers an alert.

4. Gas Sensor

The **gas sensor (MQ-series)** is used to detect the presence of harmful gases or gas leakage in the environment. The sensor outputs analog signals based on the concentration of gas detected. The Raspberry Pi Pico reads these signals and determines whether the gas level exceeds safe limits. When gas leakage is detected, the system immediately activates the buzzer and sends an alert message through the cloud service.

5. Fire Sensor

The **fire sensor** detects the presence of flames or high infrared radiation caused by fire. When the sensor identifies fire in the monitored area, it sends a signal to the Raspberry Pi Pico controller. The controller processes the signal and activates the emergency alert system to notify users about the potential fire hazard.

6. NodeMCU Wi-Fi Module

The NodeMCU module provides wireless internet connectivity to the system. It communicates with the Raspberry Pi Pico and transmits sensor data to a cloud-based platform. When abnormal environmental conditions are detected, the NodeMCU sends a request to the cloud SMS API, which generates an instant SMS notification to the user's mobile phone. This eliminates the need for GSM modules and SIM cards.

7. LCD Display (16 × 2)

The 16 × 2 LCD display is used to show real-time environmental parameters such as temperature, humidity, gas status, and system alerts. The Raspberry Pi Pico continuously updates the LCD display with the latest sensor readings. This feature allows users at the monitoring location to observe system status and environmental conditions easily.

8. GPS Module

The GPS module provides location information of the monitoring system. In case of an emergency such as gas leakage or fire detection, the system can include location details in the alert message. This feature is particularly useful for large industrial environments or remote monitoring applications where the exact location of the hazard needs to be identified quickly.

9. Buzzer Alert System

The **buzzer** acts as a local alert device. When the system detects abnormal environmental conditions such as fire, gas leakage, or high temperature, the Raspberry Pi Pico activates the buzzer to provide an audible warning. This allows nearby personnel to respond immediately to potential hazards.

10. Overall System Operation

The sensors continuously monitor environmental conditions and send data to the Raspberry Pi Pico controller. The controller processes the data and compares it with predefined safety thresholds. If any abnormal condition is detected, the system activates the buzzer, displays warning messages on the LCD, and sends sensor data to the NodeMCU module. The NodeMCU communicates with the cloud-based SMS API to send real-time alert notifications to the user's mobile phone. This integrated architecture ensures continuous monitoring, quick detection of hazards, and immediate notification to users.

The proposed system architecture provides a reliable, low-cost, and scalable solution for real-time environmental monitoring and alert systems suitable for industrial safety applications, smart homes, laboratories, server rooms, and agricultural environments.

V. Experimental Results and Performance Analysis

1. Experimental Setup

The proposed IoT-based environmental monitoring and alert system was implemented using a Raspberry Pi Pico microcontroller, DHT11 temperature and humidity sensor, MQ-series gas sensor, fire sensor, NodeMCU Wi-Fi module, 16×2 LCD display, and a buzzer alert system. The system was tested in a controlled indoor environment to evaluate its ability to detect abnormal environmental conditions and send real-time alerts through the cloud-based SMS API.

The sensors continuously collected environmental data, which was processed by the Raspberry Pi Pico. When the sensor readings exceeded predefined threshold values, the system generated both local alerts (buzzer) and remote alerts (SMS notification) through the cloud communication platform. The performance evaluation focused on parameters such as sensor accuracy, response time, alert delivery time, and system reliability.

2. Temperature and Humidity Monitoring Results

The DHT11 sensor was used to monitor temperature and humidity values in real time. During the experiment, different environmental conditions were simulated to observe system response.

Table 1: Temperature and Humidity Monitoring Results

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Time (min)	Temperature (°C)	Humidity (%)	System Status
0	26	58	Normal
5	28	60	Normal
10	30	62	Normal
15	33	65	Alert Triggered
20	35	67	Alert Triggered

When the temperature exceeded the predefined threshold of **33°C**, the system successfully triggered the alert mechanism. The LCD displayed warning messages and an SMS notification was sent to the registered mobile number.

Performance Observation:
The system demonstrated stable temperature and humidity monitoring with minimal delay. The average response time for temperature alerts was approximately **2–3 seconds** after threshold detection.

3. Gas Leakage Detection Results

The MQ-series gas sensor was tested by exposing it to different gas concentrations to evaluate detection capability. The sensor output was monitored and analyzed to determine system performance.

Table 2: Gas Detection Test Results

Test No	Gas Concentration Level	Sensor Output	Alert Status
1	Low	180	Normal
2	Moderate	320	Warning
3	High	450	Alert Triggered
4	Very High	520	Emergency Alert

When the gas concentration level exceeded the predefined safety threshold, the Raspberry Pi Pico activated the buzzer and transmitted the alert to the cloud platform.

Performance Observation:
The gas sensor successfully detected gas presence with high sensitivity. The alert system responded within **2 seconds** of detecting unsafe gas levels.

4. Fire Detection Performance

The fire sensor was evaluated by exposing it to small flame sources at varying distances. The sensor detected infrared radiation emitted by the flame and triggered the alert mechanism when the threshold was exceeded.

Table 3: Fire Sensor Detection Results

Distance from Flame (cm)	Sensor Detection	Alert Status
50	Not Detected	Normal
30	Weak Detection	Monitoring
20	Strong Detection	Alert Triggered
10	Immediate Detection	Emergency Alert

The results showed that the fire sensor could reliably detect flames within **20 cm** range and activate alerts immediately.

5. SMS Alert Response Time

The response time of the cloud-based SMS alert system was measured to determine communication efficiency.

Table 4: Alert Transmission Time

Event Type	Detection Time (sec)	SMS Delivery Time (sec)
High Temperature	2	6
Gas Leakage	2	5
Fire Detection	1	5

Performance Observation:
The average SMS notification delivery time ranged between **5–6 seconds**, demonstrating efficient communication between the NodeMCU module and the cloud SMS API.

VI. Conclusion and Future Scope

The proposed cloud-enabled IoT environmental monitoring and alert system using the Raspberry Pi Pico demonstrates an efficient and cost-effective solution for real-time monitoring of critical environmental parameters such as temperature, humidity, gas leakage, and fire detection. By integrating multiple sensors with a microcontroller and a NodeMCU Wi-Fi module, the system successfully detects abnormal conditions and delivers instant SMS alerts through a cloud-based API without relying on traditional GSM modules. The experimental results confirm that the system provides reliable monitoring, fast response time, and effective alert communication, making it suitable for applications such as industrial safety monitoring, laboratories, server rooms, smart homes, and agricultural environments. In the future, the system can be enhanced by integrating additional sensors such as air quality and smoke sensors, implementing machine learning algorithms for predictive hazard detection, and incorporating mobile or web dashboards for advanced remote monitoring and data visualization. Further improvements may also include energy-efficient designs, GPS-based location tracking, and large-scale IoT network integration to support smart city and industrial automation applications.

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