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The research and development of an IoT device for early detection of fire and explosion risks and monitoring air quality in computer labs

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***Abstract:** In recent times, fire hazards and air pollution in computer labs have become growing concerns. These issues not only impact the learning environment but also pose risks to the health of students and faculty, as well as the safety of equipment within the labs. Early detection and continuous monitoring of air quality in computer labs are crucial measures to prevent incidents and ensure a safe working environment. This paper presents the design and development of an IoT system aimed at the early detection of fire risks and the continuous monitoring of air quality in computer labs.*

The system uses sensors to measure parameters such as temperature, humidity, and concentrations of gases like CO2, CO, NO2, and SO2. The collected data is then transmitted in real-time to a server for analysis. If the readings exceed safe thresholds, the system automatically triggers an alert. Furthermore, the collected data is stored for analysis to predict and prevent potential risks.

This IoT system offers an automated solution for continuous monitoring, ensuring the safety of both equipment and the health of those using the lab. The system's flexibility and scalability allow it to be applied in various environments, including educational institutions, industrial settings, and laboratories. This research highlights the necessity of adopting IoT-based safety management systems and underscores their role in enhancing workplace safety and management efficiency.

***Keywords:** IoT, fire, explosion risks, air quality, computer labs.*

I. INTRODUCTION

In recent years, the issue of air pollution and the risk of fire and explosion in laboratories has been on the rise. Monitoring environmental factors such as air quality, temperature, and humidity is crucial to ensuring the safety of users. One potential solution to address this problem is the application of IoT technology in classroom environment monitoring systems.

IoT technology allows for continuous monitoring of environmental parameters, enabling early detection of hazardous factors such as the buildup of toxic gases or fire risks [1]. This system not only improves air quality but also reduces health risks caused by pollution. Several studies have demonstrated that IoT-based air monitoring systems can be effectively deployed at low cost while providing reliable monitoring results [2].

The deployment of IoT monitoring systems also opens up opportunities for integrating wireless sensors and real-time tracking solutions. These systems can detect air pollution levels and provide immediate alerts to prevent accidents due to fires and toxic gases [3]. According to research by Arnold et al., electronic sensor-based air monitoring systems have been successfully developed and applied to detect fires in public areas [4].

Additionally, some IoT-based air quality monitoring systems integrate wireless sensor networks, allowing for environmental parameter tracking even in difficult terrain conditions [5]. Jiangy et al. developed a personal mobile sensor system that enables users to monitor indoor air quality, allowing them to adjust their living environment accordingly [6]. This proves that the application of IoT technology not only enhances monitoring efficiency but also provides practical benefits in protecting public health.

In summary, the research and development of IoT-based monitoring systems is a promising and urgent direction to ensure a safe learning environment. These systems not only enable early detection of air pollution and fire risks but also offer effective solutions for maintaining safety in educational institutions [7].

II. Design and Implementation

2.1. System Design

2.1.1. Algorithm Flowchart

a) Flowchart for the program on the transmitter circuit

- Step 1: System Initialization

Initialize pins (LED, buzzer, DHT, MQ2, KY026);

Initialize the LCD screen and related devices;

Initialize ESP-NOW wireless communication for transmitting and receiving data.

- Step 2: Main Loop

Read temperature and humidity values from the DHT11 sensor;

Read gas status from the MQ2 sensor;

Read fire status from the KY026 sensor.

- Step 3: Send Data via ESP-NOW

Transmit the collected data (temperature, humidity, gas, and fire status) to the predefined MAC address via ESP-NOW.

- Step 4: Display Data on LCD

Display temperature, humidity, gas, fire status, and warning thresholds on the LCD screen.

- Step 5: Check Alert Conditions

Compare the measured values with the alert thresholds received from ESP-NOW. If the measured values exceed the threshold for humidity, temperature, or if gas and fire are detected, activate the buzzer and LED alert. If all values are within the safe range, deactivate the alert.

- Step 6: End Loop

Return to Step 2 and repeat the process.

b) Flowchart for the program on the receiver circuit

- Step 1: System Initialization

Initialize LED and buzzer;

Connect to WiFi;

Initialize Blynk and ESP-NOW;

Register callbacks for sending and receiving data via ESP-NOW.

- Step 2: Main Loop

Update the current time;

Run Blynk;

Send temperature and humidity warning thresholds via ESP-NOW;

Update data received from sensors (temperature, humidity, fire detection, gas detection) on Blynk;

Check the received values: if humidity exceeds the threshold, set the flag ktHum = 1; if the temperature exceeds the threshold, set the flag ktTemp = 1. Update the flags ktHum and ktTemp on Blynk.

- Step 3: Alert

If the flag kt = 0 and any value exceeds the threshold (temperature, humidity, fire, gas), trigger an alert by activating the buzzer and LED, send an alert to Blynk with the corresponding events, and reset the flag kt = 1.

If the flag kt = 1 and all values are back within the threshold, turn off the buzzer and LED alert, and reset the flag kt = 0.

- Step 4: End Loop

Return to the start of the loop at Step 2 and continue checking conditions.

2.1.2. System schematic design

a) Transmitter circuit schematic design

Below is the description of the connections for the components in the transmitter system:

- ESP8266 (WiFi Module): ESP8266 is the main microcontroller in the system, responsible for wireless communication and controlling other components.

D4: Connect to the TX pin of a SIM module or another UART device.

D5: Connect to the RX pin of a SIM module or another UART device.

D7: Connect to the positive terminal of the buzzer.

GND: Connect to the negative terminal of the buzzer and the LED.

D8: Connect to the positive terminal of the LED.

- Temperature and Humidity Sensor (DHT11/DHT22): The temperature and humidity sensor typically has 3 pins (Vcc, GND, Data), and sometimes an additional unconnected pin.

Vcc: Connect to the 3.3V or 5V pin of the ESP8266 (depending on the sensor type).

GND: Connect to the GND pin of the ESP8266.

Data: Connect to a digital pin (e.g., D4 or D2) on the ESP8266.

- Gas Sensor (MQ-2 or MQ-135): The gas sensor has the following pins: Vcc, GND, and two output pins (analog or digital).

Vcc: Connect to the 5V pin of the ESP8266.

GND: Connect to the GND pin of the ESP8266.

A0: Connect to the analog pin A0 on the ESP8266.

D0: Connect to a digital pin on the ESP8266.

- Flame Sensor (Fire Detection Sensor): Similar to the gas sensor, the flame sensor has pins for Vcc, GND, and output.

Vcc: Connect to the 5V pin of the ESP8266.

GND: Connect to the GND pin of the ESP8266.

D0: Connect to a digital pin on the ESP8266 (e.g., D8).

- ESP-NOW Protocol: The ESP8266 uses the ESP-NOW protocol to communicate with the receiving devices via MAC addresses. No physical wiring is needed for this protocol as it operates wirelessly.

- Power Supply:

The ESP8266 should be powered using a 5V or 3.3V power supply through its Vcc pin.

All sensors and the ESP8266 must share a common ground (GND) to ensure a complete electrical circuit.

This design facilitates the collection of environmental data such as temperature, humidity, gas, and fire detection, which are then transmitted wirelessly via ESP-NOW for further processing and alert management.

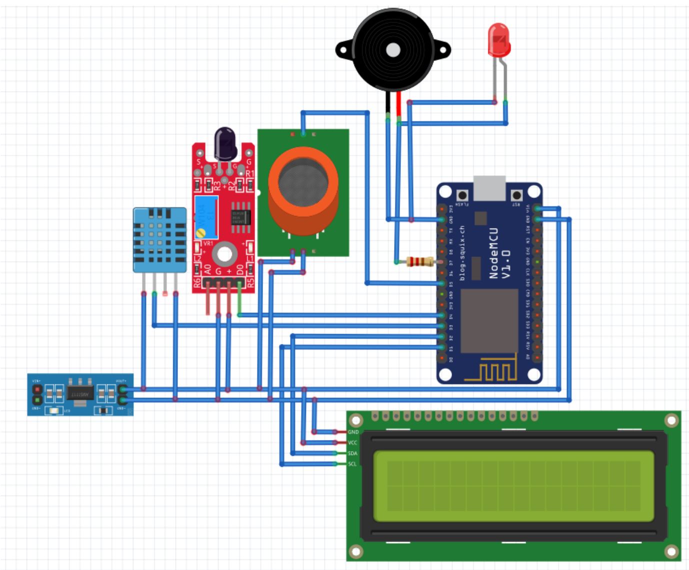

Fig.1 Transmitter circuit

b) Receiver system schematic design

Below is a description of how to connect the component pins in the receiver system:

- DHT11 Sensor:

Vcc: Connect to the 3.3V or 5V pin of the ESP8266.

GND: Connect to the GND of the ESP8266.

Data: Connect to pin D3 on the ESP8266.

- MQ-2 Gas Sensor:

Vcc: Connect to the 5V pin of the ESP8266.

GND: Connect to the GND of the ESP8266.

D0: Connect to pin D5 on the ESP8266.

- KY-026 Flame Sensor:

Vcc: Connect to the 5V pin of the ESP8266.

GND: Connect to the GND of the ESP8266.

D0: Connect to pin D4 on the ESP8266.

- Alarm Buzzer:

Vcc: Connect to pin D8 on the ESP8266.

GND: Connect to the GND of the ESP8266.

- LED:

Vcc: Connect to pin D6 on the ESP8266.

GND: Connect to the GND of the ESP8266.

- I2C LCD Screen:

SCL (Clock Pin): Connect to pin D1 on the ESP8266.

SDA (Data Pin): Connect to pin D2 on the ESP8266.

Vcc: Connect to the 5V pin of the ESP8266.

GND: Connect to the GND of the ESP8266.

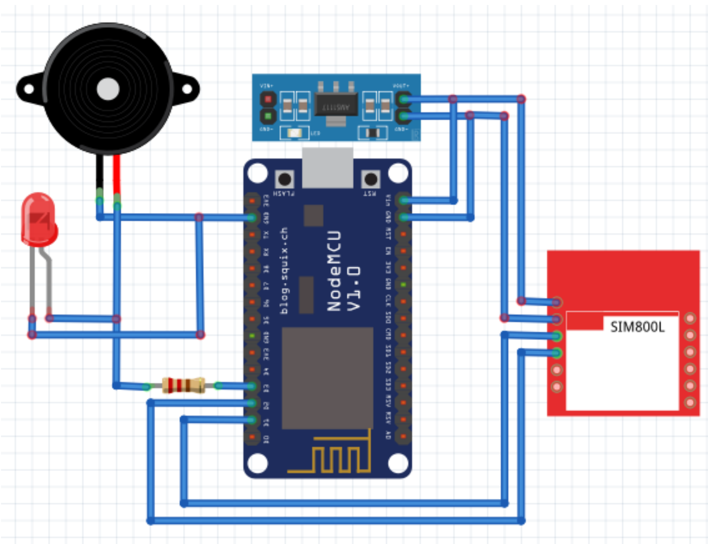

Fig.2 Receiver circuit

2.1.3. Uploading data to webserver using blynk application

To upload data from the sensor system to a Web server using the Blynk application, the study employs the Blynk library combined with the ESP8266 to send and receive data. The Blynk application allows for displaying sensor parameters and controlling devices through a mobile interface.

Blynk is a simple and powerful IoT platform for remote hardware control, sensor data visualization, data storage, and automation tasks. The Blynk mobile app connects to hardware via the Internet to collect data from sensors and control devices.

The benefits of using Blynk include easy data visualization and monitoring. Users can remotely track temperature, humidity, and alert statuses through the Blynk app. Blynk facilitates data collection and device control over the Internet without requiring complex configurations.

With this setup, it is easy to upload data from sensors to a Web server through the Blynk application to remotely monitor environmental parameters.

2.2. Construction, Testing, and Calibration of the System

2.2.1. System Construction

a) Construction of the transmitter system

- Transmitter System: This part collects data from sensors, processes it, and sends the data to the Blynk server via the Internet.

- Hardware:

Microcontroller: Use an ESP8266 microcontroller with Wi-Fi connectivity.

Sensors: Temperature and humidity sensors (DHT11, DHT22), gas sensor (MQ-2), and flame sensor (KY-026).

Power Supply: Ensure a stable power supply for the devices.

LCD: Use an I2C LCD to display data on-site.

- Programming and configuration of the transmission system:

Wi-Fi Configuration: Use the ESP8266WiFi library to connect the microcontroller to the Wi-Fi network.

Blynk Integration: Use the BlynkSimpleEsp8266.h library to send sensor data to the WebServer.

Sensor Data Reading: Program the reading of sensor data.

Sending Data to WebServer/Blynk: After reading data from sensors, use the Blynk.virtualWrite() functions to send data to the WebServer via HTTP or MQTT protocol.

b) Construction of the receiver system

- Receiver System: This part receives data from the transmitter system (or from the WebServer) and performs tasks related to displaying or controlling devices.

- Hardware:

Microcontroller (ESP8266 or ESP32): This component receives data from the transmitter system or WebServer.

Control Devices: Devices such as relays, LEDs, and motors for displaying or performing control tasks.

Display Screen: Use an I2C LCD to display the received data.

- Programming and configuration of the receiver system:

Wi-Fi Connection: The receiver system must also connect to Wi-Fi to receive data from the WebServer.

Blynk or MQTT Integration: Use Blynk or the MQTT protocol to receive data from the server.

Data processing programming: Receive data from the WebServer or Blynk via Virtual Pins, then perform control actions based on the received data (e.g., activate a relay if the temperature exceeds a threshold).

2.2.2. Testing, Quality Evaluation, and Calibration of the System

a) Testing temperature and humidity

- Method: Measure the temperature and humidity in the computer lab at 5 different times during a day. Compare the results obtained from the DHT11 sensor with the values measured by a standard hygrometer.

- Test Results:

Measurement with DHT11 Sensor	Measurement with Hygrometer
Temperature 30.1°C, Humidity 65%	Temperature 30.1°C, Humidity 65%
Temperature 30.1°C, Humidity 64%	Temperature 30.1°C, Humidity 64%
Temperature 31.7°C, Humidity 63%	Temperature 31.7°C, Humidity 63%
Temperature 32.5°C, Humidity 58%	Temperature 32.6°C, Humidity 58%
Temperature 33°C, Humidity 57%	Temperature 33°C, Humidity 57%

- Evaluation: The results show that the DHT11 sensor measures temperature and humidity quite accurately, with minor discrepancies compared to the standard hygrometer. The sensor is suitable for use in monitoring environmental conditions in the computer lab.

b) Testing the MQ2 gas sensor

- Method: Use the MQ2 sensor to detect gases such as alcohol vapor, acetone vapor, insecticide spray, and lighter gas. Display the results on the Blynk application.

- Results: The MQ2 sensor operates effectively, accurately detecting various types of gases.

Figure 3 shows the gas detection results on the Blynk application, demonstrating the sensor's ability to detect and report the presence of gas.

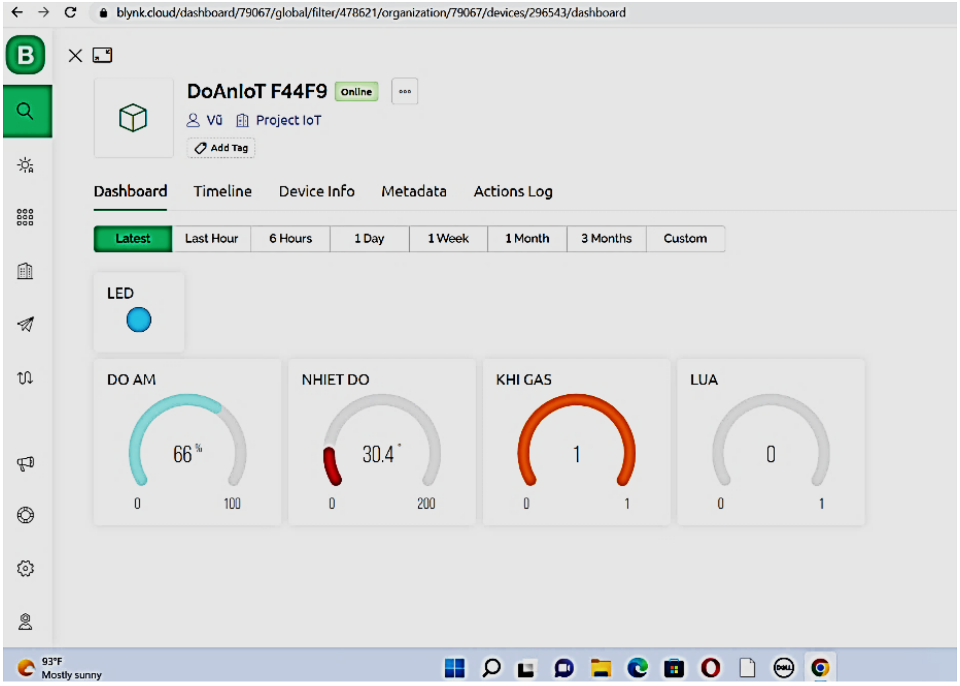

Fig.3 Gas test results displayed on blynk

c) Testing the KY-026 fire sensor

- Method: Test the KY-026 sensor by using flames at various distances. Upload the data to the web server and create alerts through the Blynk application.

- Results: The fire detection sensor performs well at different distances.

Figure 4 illustrates the test results of the KY-026 sensor, with fire data displayed on Blynk and the warning system functioning accurately.

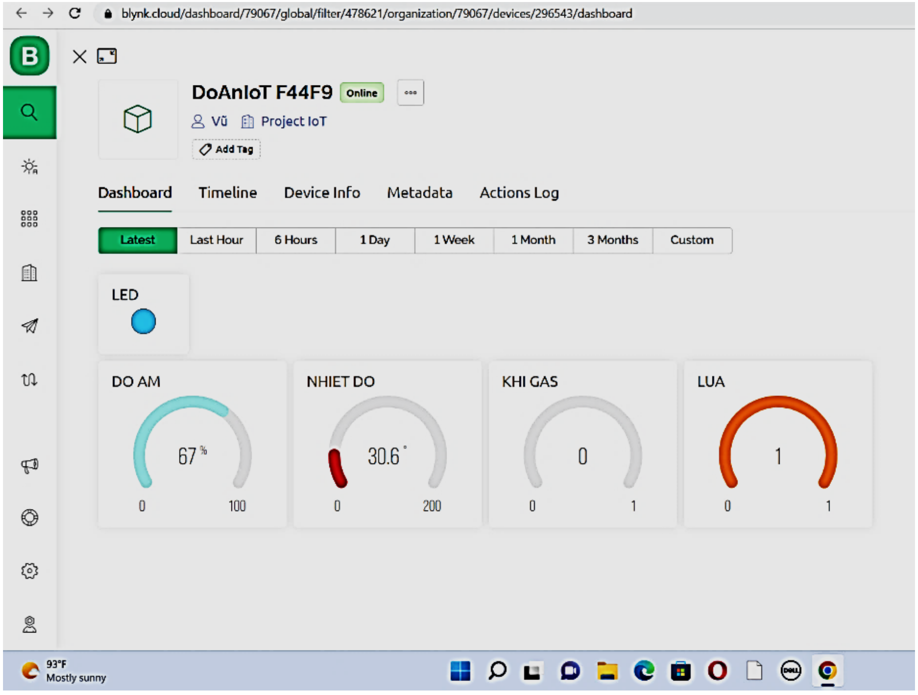

Fig.4 Fire test results displayed on blynk

d) Testing the signal transmission system

- Method: Evaluate the signal transmission capability by changing the distance between the transmitter and receiver units.

- Results: At distances of 10, 100, 200, and 400 meters, the received signal quality is consistently good.

- Evaluation: The signal transmission system operates reliably and effectively over various distances.

e) Testing the Warning System

- Method: The system sends alerts via email when parameters exceed predefined thresholds.

- Results: Figure 5 demonstrates the process of sending warning messages when data exceeds thresholds, ensuring that the warning system functions accurately and promptly.

Fig.5 Warning message sent when data exceeds threshold

Through the quality evaluation tests in the computer lab, the system has shown good performance in measuring temperature, humidity, detecting gas and fire, and transmitting signals. The monitoring and warning system operates effectively, meets the specified requirements, and is suitable for deployment in real-world environments.

III. CONCLUSION

The paper presents a research product on the development of an IoT device for early detection of fire hazards and air quality monitoring in computer labs. The product is highly applicable in educational and practical environments, with notable advantages:

Compact Design: Quick response time.

Ease of Operation: Simple to use and suitable for computer lab environments.

High Accuracy: Ensures safety and effectiveness in detecting fire hazards and monitoring air quality.

Open Design: Allows for the expansion of monitoring additional parameters by integrating compatible sensors.

Simultaneous Monitoring: Capability to monitor multiple computer labs by duplicating the transmitter device.

Stable Operation: Meets all initial technical requirements and allows for customization of environmental parameter thresholds according to specific needs.

The product has potential for future development, such as integrating new sensors, developing specialized control applications, and adding voice control features. These advancements will enhance monitoring effectiveness, improve fire prevention capabilities, and further improve air quality in computer labs.

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