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Advanced Drone-Integrated IoT System for Early Fire Detection and Response

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Abstract

Fire incidents in forests, industrial zones, and isolated regions present significant risks to human safety, infrastructure, and the environment. Conventional fire monitoring approaches depend on manual observation or stationary surveillance systems, which often suffer from limited coverage and delayed response. This work presents a drone-based fire detection and emergency response system that combines sensor technology with Internet of Things (IoT) communication for real-time hazard identification. The system employs a NodeMCU (ESP8266) microcontroller integrated with an MQ-2 gas sensor and a flame sensor to identify smoke, flammable gases, and flame emissions. These sensors continuously track environmental conditions and transmit the data to the microcontroller for analysis. Using its inbuilt Wi-Fi capability, the NodeMCU sends the data to the ThingSpeak cloud platform for remote monitoring. Mounted on a drone, the sensing unit can reach large or dangerous areas where direct human supervision is challenging, offering an efficient and economical solution for early fire detection.

Keywords: Drone-based fire detection, IoT, NodeMCU(ESP8266), MQ-2 Gas Sensor, Flame Sensor, Remote Monitoring.

1 Introduction

The Drone-Based Fire Detection and Emergency Response System is a modern IoT-driven monitoring approach developed to identify fire hazards in real time and enhance the effectiveness of emergency response [2][12]. It replaces conventional fire surveillance methods, which rely heavily on manual inspection or fixed monitoring systems, with intelligent sensing and automated communication [4][13]. Traditional techniques such as human patrols, stationary smoke detectors, and camera-based surveillance often face

challenges like limited area coverage, slow response, and increased risk in hazardous environments [10]. By combining unmanned aerial vehicles, environmental sensors, and cloud-based platforms, the proposed system enables quick detection of fire-related conditions such as smoke, flammable gases, and flame emissions, even in remote or hard-to-reach areas [9][14]. The system incorporates a NodeMCU ESP8266 microcontroller along with MQ-2 gas and flame sensors to gather environmental data and transmit it wirelessly to the ThingSpeak cloud platform for continuous monitoring and analysis [3][11].

The system supports real-time fire monitoring through sensors mounted on a drone, which continuously observe parameters like gas concentration, smoke presence, and infrared radiation from flames. The MQ-2 sensor is capable of detecting gases such as LPG, methane, and smoke [7], while the flame sensor identifies fire through infrared signals [1]. These inputs are processed by the microcontroller, allowing early detection of potential hazards before they develop into severe incidents [5]. The use of a drone significantly improves coverage by enabling surveillance over large areas such as forests, industrial sites, and disaster-prone regions where manual monitoring is difficult [10][14].

Wireless communication plays a crucial role in the system. The NodeMCU uses its built-in Wi-Fi capability to send collected data to the ThingSpeak cloud platform. This enables remote monitoring through web or mobile interfaces, where the data is stored and displayed in graphical form [8]. Such visualization helps authorities and monitoring personnel track environmental changes continuously and take immediate action when abnormal conditions are observed.

Another important feature is mobile environmental surveillance. Unlike fixed systems, the integration of a drone allows flexible and dynamic monitoring across different locations [9][14]. The drone can move freely and scan vast regions, making the system highly suitable for applications like forest fire detection, industrial safety checks, and emergency response operations [10]. This mobility ensures efficient monitoring in areas where installing permanent infrastructure is not practical.

Early warning capability is essential in reducing the impact of fire accidents. By combining gas and flame detection methods, the system improves accuracy and minimizes

false alarms [1][15]. Real-time alerts and cloud-based monitoring support quick decision-making, enabling timely intervention before a fire spreads [3][8]. The system also enhances safety and sustainability by reducing the need for human involvement in dangerous environments. Its use of low-cost sensors, wireless communication, and scalable cloud services makes it an economical and efficient solution [12]. Overall, this system demonstrates a significant advancement in smart fire monitoring by integrating IoT technology, drone mobility, and real-time data analysis to improve safety, environmental protection, and disaster management [9][10].

2 Existing System

Conventional fire detection methods mainly rely on fixed smoke sensors, manual supervision, or camera-based monitoring [13]. While these approaches are commonly implemented in buildings and industrial settings, they face several challenges when used in vast or remote locations. Many existing systems do not offer mobility, making it difficult to cover large geographical areas efficiently [10]. Manual surveillance requires constant human involvement, which can be unsafe in hazardous conditions. Likewise, stationary sensor systems are restricted to specific zones and may not detect fires that occur beyond their designated range [4].

Although some advanced solutions incorporate IoT sensors and cloud-based monitoring [3][11], they are generally deployed at fixed points and lack the ability to perform dynamic environmental scanning. These drawbacks highlight the necessity for a mobile fire detection solution that can cover extensive areas while providing real-time data transmission [9].

3 Proposed Approach

The proposed Drone-Based Fire Detection and Emergency Response System combines sensing technology, IoT-based communication, and drone mobility to identify fire hazards effectively [9][14]. The system includes a NodeMCU ESP8266 microcontroller, an MQ-2 gas sensor, a flame detection sensor, a 3.7V battery supply, and a wireless communication setup linked to the ThingSpeak cloud platform [3][5]. The MQ-2 gas sensor is used to sense smoke and flammable gases such as LPG, methane, and propane, which are

typically associated with fire incidents 7][15]. Meanwhile, the flame sensor detects infrared radiation emitted by fire [1]. These sensors continuously observe environmental conditions and transmit their outputs to the NodeMCU microcontroller.

The microcontroller processes the received data and utilizes its integrated Wi-Fi capability to send the information to the ThingSpeak IoT cloud platform [5][8]. This allows users to monitor sensor data remotely through web-based dashboards or mobile devices. The sensing module is installed on a drone, enabling it to travel across various locations and survey large areas 9][14]. This mobility allows the system to identify fire risks in places that are difficult or unsafe for human access.

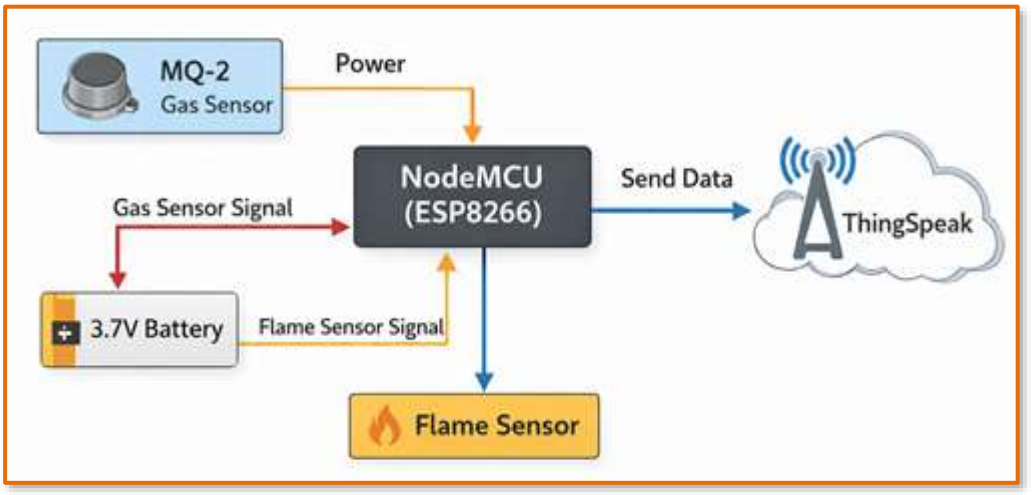

Figure 1: Block Diagram of the Proposed System

4 Results and Discussions

The results show that the system is capable of continuously monitoring environmental conditions related to fire hazards such as smoke, combustible gases, and flame radiation. The MQ-2 gas sensor effectively detected changes in gas levels, including LPG, methane, and smoke. During testing, an increase in gas concentration was observed when combustible materials were present, indicating its ability to detect early fire conditions. The flame sensor successfully identified infrared radiation from flames, allowing quick detection of fire sources.

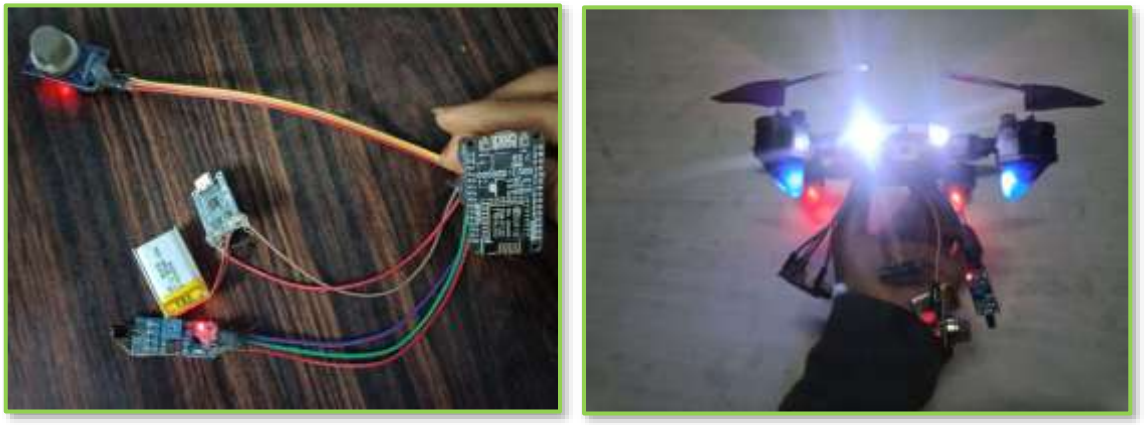

Figure 2: (a) Experimental Setup (b) Drone Flying Mode

The NodeMCU ESP8266 processed the sensor data and transmitted it to the ThingSpeak cloud platform using Wi-Fi. The data was displayed correctly in graphical form, enabling remote monitoring. When gas levels crossed set limits or flame was detected, updates were sent instantly, showing reliable communication. The combination of gas and flame sensors improved detection accuracy and reduced false alerts. The drone-based setup allowed monitoring of large and hard-to-reach areas. Overall, the system showed stable performance with efficient power usage and timely data transmission.

5 Conclusion

The Drone-Based Fire Detection and Emergency Response System provides an effective solution for fire monitoring by combining IoT technology, sensor-based detection, and drone mobility. The system uses MQ-2 gas sensors and flame sensors to identify smoke, flammable gases, and fire radiation. The NodeMCU ESP8266 microcontroller processes the sensor data and transmits it to the ThingSpeak cloud platform through wireless communication, enabling real-time monitoring and remote access to environmental conditions.

Mounting the sensing unit on a drone enhances mobility, allowing efficient monitoring of large and hazardous areas. This approach improves early fire detection, minimizes human exposure to risk, and offers a cost-effective solution for environmental monitoring and emergency response.

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