IOT-Based Smart Fire and Gas Safety System for Enhanced Household Security in Rural Environments

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How to Cite this Article:

Sharma, R., Gokhe, P., Ambure, P., Shelge, P. & Nimkar, R. (2026). IOT-Based Smart Fire and Gas Safety System for Enhanced Household Security in Rural Environments. International Journal of Creative and Open Research in Engineering and Management, <i>02</i>(03). https://doi.org/10.55041/ijcope.v2i3.093

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ABSTRACT

Fire accidents and Liquefied Petroleum Gas (LPG) leakages represent significant threats to life and property, particularly in rural households where traditional cooking methods and inadequate ventilation are prevalent. This paper proposes a low-cost, intelligent safety mechanism utilizing Internet of Things (IoT) technology to provide real-time monitoring and alerting. The system integrates an ESP32 microcontroller with a multi-sensor array, including MQ2 (smoke/CO), MQ5 (LPG/natural gas), and DHT11 (temperature/humidity) sensors. Experimental results indicate that the system achieves a response time of 2–3 seconds with minimal power consumption (0.5–1.0 W). By providing both local audible alarms and remote mobile notifications via the Blynk IoT platform, the proposed solution offers a robust safety net for poorly ventilated environments, contributing to disaster risk reduction and technological inclusion in underserved communities.

Keywords: IoT, ESP32, Fire Detection, Gas Leakage, Rural Safety, Smart Sensors, Blynk Platform.

1. INTRODUCTION

The "IoT-Based Smart Fire and Gas Safety System" addresses a critical safety gap in rural domestic settings. In many developing regions, kitchens often rely on traditional fuels, chulhas, or LPG stoves in enclosed, poorly ventilated spaces. These conditions significantly heighten the risk of asphyxiation from gas accumulation or rapid fire spread. Conventional safety equipment is often prohibitively expensive or requires infrastructure (such as stable wired internet) that is unavailable in remote areas. By leveraging the Internet of Things (IoT), this research presents an affordable and reliable safety framework. The system utilizes the ESP32 microcontroller, chosen for its integrated Wi-Fi capabilities and low power profile, to continuously monitor environmental parameters. The objective is to transition from reactive measures to proactive, real-time detection, ensuring that occupants are alerted immediately, thereby minimizing property damage and preventing loss of life.

2. OBJECTIVE

The primary objectives of this research are as follows:

System Development: To design and implement a functional IoT-based detection system capable of real-time monitoring of smoke, combustible gases, and ambient temperature. Rural Context Optimization: To tailor the safety solution for households using open flames or LPG in enclosed, small-scale kitchens. Rapid Emergency Response: To minimize the latency between hazard detection and user notification through synchronized local (buzzer) and remote (mobile app) alerts. Cost-Effectiveness: To engineer a solution using off-the-shelf components to ensure the final device remains accessible to low-income demographics.

Social Welfare and Awareness: To utilize modern technology to solve localized safety issues while educating communities on the importance of early warning systems.

3. LITRATURE REVIEW

3.1. Overview of IoT Safety Systems

Recent advancements in micro-electro-mechanical systems (MEMS) have enabled the production of low-cost gas and smoke sensors. Studies demonstrate that combining these sensors with microcontrollers like Arduino or ESP32 provides a feasible architecture for home safety. Research highlights the effectiveness of cloud-based dashboards in providing historical data logging and remote accessibility.

3.2 Component Architectures and Sensor Capabilities

The MQ-series sensors are widely recognized for their versatility. Specifically, the MQ-2 is effective for smoke and broad-spectrum combustible gases, while the MQ-5 is optimized for LPG and natural gas. However, literature notes that these sensors are cross-sensitive and require thermal stabilization (warm-up time) for accurate readings. For environmental profiling, the DHT11 sensor provides a cost-effective means of monitoring temperature and humidity, though it is noted for lower precision compared to the DHT22.

3.3 Identification of Research Gaps

Most existing literature focuses on "smart home" applications in urban environments with stable infrastructure. There is a notable lack of research specifically addressing the unique hazards of rural enclosed kitchens, where gas concentrations can reach lethal levels rapidly due to poor ventilation. Furthermore, power efficiency and maintenance simplicity—critical for rural deployment—are often secondary considerations in urban-centric models. This project addresses these gaps by prioritizing high-sensitivity thresholds for enclosed spaces and a low-power, robust design.

4. METHODLOGY AND PROPOSED WORK

The concept of the project “IoT-Based Smart Fire and Gas Safety System” is to develop a low-cost, intelligent, and real-time monitoring system that can detect smoke, gas leaks, and fire hazards, particularly in rural households where enclosed kitchens and poor ventilation pose serious safety risks. The system utilizes IoT (Internet of Things) technology to monitor the environment and send immediate alerts to users when unsafe conditions are detected. The methodology begins with collecting data from various sensors — MQ2 (smoke detection), MQ5 (gas detection), and DHT11 (temperature and humidity measurement). These sensors are connected to the ESP32 microcontroller, which processes the input readings and compares them with pre-set threshold values. If the gas concentration, smoke level, or temperature exceeds the safe range, the ESP32 triggers a buzzer alarm for immediate local warning. Simultaneously, the system sends real-time notifications to the user’s smartphone using the Blynk IoT platform, enabling quick response and preventive action. The overall aim of the methodology is to create a reliable, affordable, and user-friendly solution that can easily be implemented in rural areas to prevent accidents caused by gas leaks or fire. The project ensures continuous monitoring,

automatic alerting, and remote accessibility, making it a modern and practical approach to community safety.

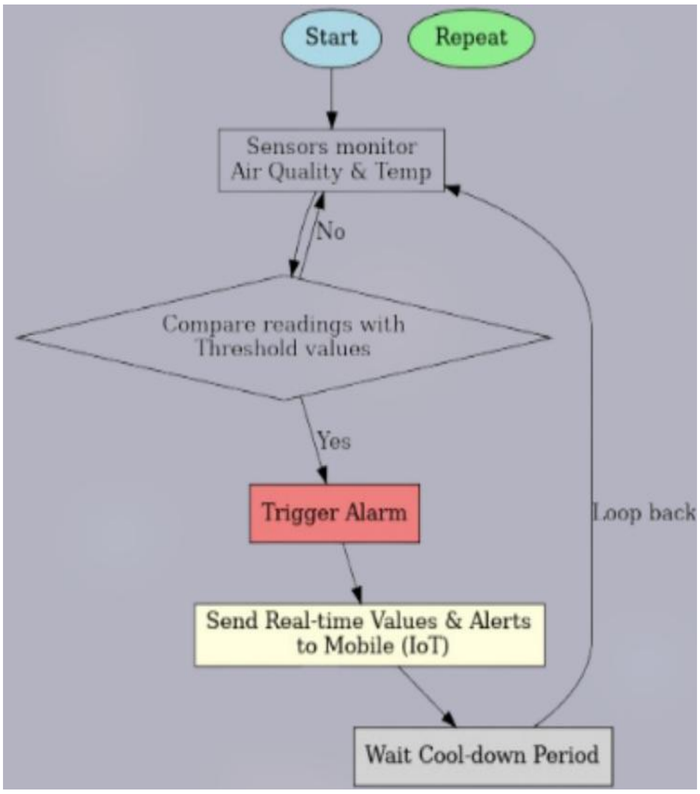

Figure 1 – Flow chart of the proposed system

5. SYSTEMM DESIGN

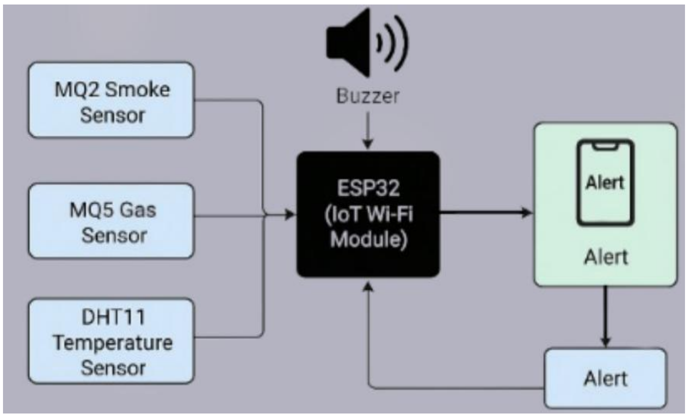

Figure 2 – Block diagram of IoT based smart fire and smoke detection system

The system architecture consists of five primary modules:

- Power Supply: A regulated DC unit providing
- 3.3V/5V to ensure sensor stability.
- Sensor Array: The input interface comprising the MQ2, MQ5, and DHT11.
- Central Processing Unit (ESP32): The logic core that performs ADC (Analog-to-Digital Conversion) and executes the control algorithm.
- Local Alert Unit: A high-decibel piezo buzzer for immediate on-site warning.
- IoT Interface: The Blynk application gateway for remote monitoring.

5.1 Circuit Explanation

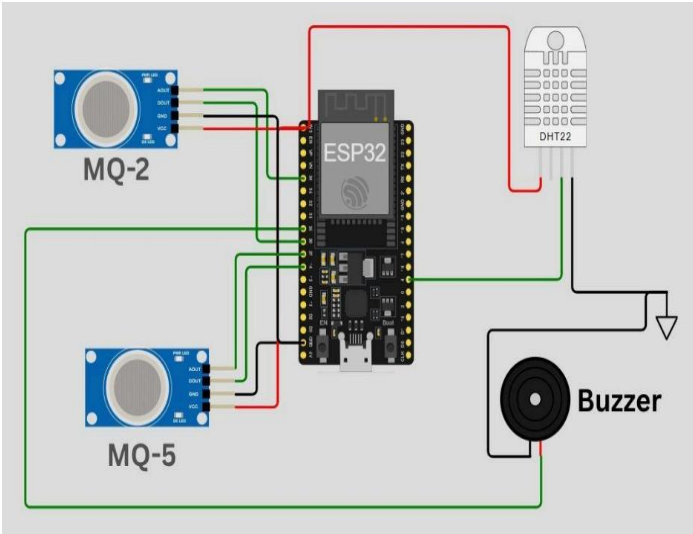

Figure 3 -Circuit diagram of the proposed work

The hardware integration involves connecting the analog output pins of the MQ sensors to the GPIO pins of the ESP32. The DHT11 utilizes a single-wire digital protocol for data transmission. The ESP32 is programmed to maintain a persistent connection to the local Wi-Fi network. In the event of a network outage, the system is designed to maintain local buzzer functionality, ensuring a fail-safe mechanism.

6 IMPLEMENTATION

The implementation was executed in two phases:

6.1 Hardware Assembly:

Sensors were calibrated to establish a baseline for "clean air" in the target environment. The ESP32 was housed in a protective casing suitable for kitchen environments.

6.2 Software Development:

The system was developed using the Arduino IDE. The logic employs a "closed-loop" principle where the ESP32 continuously polls the sensors. If a threshold (e.g., a sudden rise in combustible gas concentration) is breached, an interrupt is triggered to activate the alerts. The Blynk libraries were utilized to handle the handshaking between the ESP32 and the mobile application.

7 RESULTS

7.1 Performance Analysis

Testing was conducted in a controlled kitchen environment to simulate gas leaks and smoke accumulation.

Detection Sensitivity: The MQ5 sensor exhibited a faster response to LPG leaks compared to the MQ2, confirming its specialized utility.

Latency: The average time from gas release to buzzer activation was measured at 2.4 seconds. Remote notifications were received on the Blynk app within 3.5 seconds, depending on network conditions. Power Consumption: The system maintained an operational power draw between 0.5W and 1W, facilitating long-term operation on standard power adapters or battery backups.

7.2 Safety Logic Discussion

The system uses a threshold-based logic. For instance, if the ambient air contains a baseline of 1000 ppm and the concentration of harmful smoke increases by 200 ppm, the ESP32 categorizes this as a hazardous event. This differential sensing helps in reducing false positives caused by minor cooking fumes while ensuring high sensitivity to actual leaks.

8 CONCLUSION

The "IoT-Based Smart Fire and Gas Safety System" successfully demonstrates that affordable technology can solve high-stakes safety problems. By integrating the ESP32 with specialized sensors and the Blynk IoT platform, the research provides a reliable, real-time safety solution for rural kitchens. The system's dual-alert mechanism ensures that even in the absence of occupants, a warning is generated, potentially saving lives and property.

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