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Design and Performance Evaluation of a Wireless Gas Leakage Detection System Using MQ-2 Sensor and ESP32

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Abstract
Gas leakage poses significant safety risks in residential, commercial, and industrial environments due to its potential to cause fires, explosions, and health hazards. Early detection and timely notification are essential for minimizing these risks. The paper presents the design and performance evaluation of a wireless gas leakage detection system using an MQ-2 gas sensor and an ESP32 microcontroller with integrated Wi-Fi communication. The developed prototype continuously monitors combustible gases, including liquefied petroleum gas (LPG), methane, propane, and smoke, and provides real-time alerts through a buzzer, an LCD display, and the Blynk mobile application. A quantitative experimental approach was adopted to evaluate the system under different operating environments, including an open area, a university classroom, and a kitchen. System performance was assessed based on gas detection capability, response time, communication functionality, and adaptability to varying environmental conditions. Experimental results demonstrated that the system reliably detected combustible gases with a response time of less than five seconds while successfully transmitting wireless notifications within 5–10 seconds. The adaptive threshold method, based on a 25% increase above the environmental baseline, improved detection reliability by accommodating variations in background gas levels across different locations. The integration of the ESP32 with Wi-Fi communication enabled continuous remote monitoring without requiring additional communication hardware. The findings indicate that the proposed system provides a cost-effective, reliable, and practical solution for real-time gas leakage detection and early warning. The developed prototype offers an effective approach for improving safety in indoor gas-utilizing environments and provides a foundation for future Internet of Things (IoT)-based gas monitoring applications.

Keywords: Gas leakage detection, ESP32, MQ-2 gas sensor, Wireless monitoring, Internet of Things (IoT)

1. Introduction
Liquefied petroleum gas (LPG) and other combustible gases are extensively used in residential, commercial, and industrial environments because of their affordability, efficiency, and clean combustion characteristics. However, gas leakage remains a major safety concern due to its

potential to cause fires, explosions, and health hazards. Since combustible gases are often colorless and may accumulate rapidly in enclosed spaces, early detection is essential for preventing accidents and minimizing damage to lives and property (Adamu et al., 2025; Fuadi et al., 2024).

Traditional gas leakage detection methods, including manual inspection and conventional wired alarm systems, present several limitations. Manual detection depends on human intervention and cannot provide continuous monitoring, while wired systems require complex installation, incur higher maintenance costs, and offer limited flexibility for deployment. Furthermore, many existing systems only provide local alarms, making them ineffective when users are away from the monitored location (Keshamoni & Hemanth, 2017; Chraim et al., 2016).

Recent advances in embedded systems, wireless communication, and the Internet of Things (IoT) have enabled the development of intelligent gas leakage detection systems capable of real-time monitoring and remote notification. The MQ-2 gas sensor has been widely adopted because of its low cost, fast response, and ability to detect combustible gases such as LPG, methane, propane, hydrogen, and smoke (Anchitaalagammai et al., 2023; Vijayalakshmi et al., 2024). Likewise, the ESP32 microcontroller has become a preferred platform for IoT-based monitoring applications because of its integrated Wi-Fi capability, high processing performance, and support for real-time communication without requiring additional hardware (Prananda et al., 2023; Adamu et al., 2025).

Although several studies have proposed IoT-based gas leakage detection systems, most focus primarily on system implementation and basic detection functionality. Relatively few studies provide quantitative evaluations of critical performance metrics such as detection response time, communication delay, and sensing performance under different environmental conditions. Furthermore, existing systems rarely employ adaptive detection mechanisms that compensate for changes in baseline sensor readings caused by variations in temperature, ventilation, and air quality (Fuadi et al., 2024; Prananda et al., 2023; Keshamoni & Hemanth, 2017).

To address these limitations, the paper presents the design and performance evaluation of a wireless gas leakage detection system based on an MQ-2 gas sensor and an ESP32 microcontroller. The proposed system continuously monitors combustible gases and provides both local alerts through a buzzer and LCD display and remote notifications using the Blynk mobile application via Wi-Fi communication. In addition, an adaptive threshold mechanism based on environmental baseline measurements is implemented to improve detection reliability across different operating environments.

The developed prototype is experimentally evaluated in multiple environments, including an open area, a university classroom, and a kitchen, to assess gas detection capability, response time, communication performance, and system reliability. The findings demonstrate that the proposed system provides a practical, low-cost, and reliable solution for real-time gas leakage monitoring while enhancing safety through rapid detection and wireless remote alerting.

The remainder of the paper is organized as follows. Section 2 reviews the related literature and identifies the research gap. Section 3 describes the research methodology and system design. Section 4 presents the experimental results and discussion. Finally, Section 5 concludes the paper and provides recommendations for future work.

2. Literature Review

Recent advances in embedded systems and Internet of Things (IoT) technologies have significantly improved gas leakage detection by enabling real-time monitoring, wireless communication, and remote alerting. Numerous studies have investigated the integration of gas

sensors, microcontrollers, and communication technologies to enhance the reliability and effectiveness of gas monitoring systems.

The MQ-series gas sensors, particularly the MQ-2 sensor, are among the most widely used sensors for detecting combustible gases because of their low cost, high sensitivity, and ease of integration with embedded systems. The MQ-2 sensor is capable of detecting liquefied petroleum gas (LPG), methane, propane, hydrogen, and smoke, making it suitable for residential and industrial safety applications (Anchitaalagammai et al., 2023; Kolar & Routray, 2025). However, the sensor is sensitive to environmental conditions such as temperature, humidity, and ventilation, requiring appropriate calibration and threshold selection to improve detection reliability (Maesyaroh & Marcos, 2025; Vijayalakshmi et al., 2024).

Several embedded platforms have been employed for gas leakage detection. Traditional systems commonly use the Arduino Uno because of its simplicity and extensive development support. However, its lack of built-in wireless communication requires additional hardware, increasing system complexity and power consumption. More recent studies have adopted the ESP32 microcontroller because it integrates Wi-Fi communication, multiple analog input channels, and higher processing capability within a single platform, making it more suitable for real-time IoT monitoring applications (Prananda et al., 2023; Adamu et al., 2025).

Different wireless communication technologies have also been investigated for remote gas monitoring. GSM-based systems provide long-distance notification through SMS but depend on cellular network availability and often experience higher communication latency (Keshamoni & Hemanth, 2017). Bluetooth offers low power consumption but has limited communication range, restricting its applicability in large-scale monitoring environments. LoRa supports long-range communication with low power requirements but provides relatively low data transmission rates that may delay emergency notifications. In contrast, Wi-Fi communication offers higher data throughput, lower latency, and seamless integration with existing Internet infrastructure, making it well suited for real-time gas leakage detection (Praveen Sharma et al., 2023; Kasireddy et al., 2025).

Previous studies have demonstrated the feasibility of wireless gas leakage detection systems using various combinations of sensors and communication technologies. Keshamoni and Hemanth (2017) developed an LPG monitoring system using GSM-based notification but did not evaluate detection latency or sensing range. Chraim et al. (2016) proposed a wireless sensor network for industrial gas monitoring, although the system required complex installation and lacked real-time remote alerting. Prananda et al. (2023) implemented an IoT-based gas monitoring system using the MQ-2 sensor and ESP32 but focused primarily on system functionality rather than quantitative performance evaluation. Similarly, Fuadi et al. (2024) presented a cloud-based wireless monitoring system but did not experimentally analyze detection latency or sensing distance. Adamu et al. (2025) demonstrated an ESP32-based gas detection system with wireless communication; however, the evaluation mainly considered detection capability without detailed analysis of response time under different operating conditions.

Despite these developments, existing studies primarily emphasize system implementation while providing limited quantitative evaluation of critical performance indicators, including detection response time, communication delay, and sensing performance across different environments. Furthermore, relatively few studies investigate adaptive threshold techniques that compensate for variations in baseline sensor readings caused by changing environmental conditions.

To address these limitations, the present study develops a Wi-Fi-enabled gas leakage detection system using an MQ-2 gas sensor and an ESP32 microcontroller. Unlike previous studies, the proposed system incorporates an adaptive threshold mechanism based on

environmental baseline measurements and experimentally evaluates detection response time, communication performance, and sensing reliability under multiple operating environments.

Table 1: Summary of Related Works

Author(s) / Year	**Sensor Used**	**Communication Method**	**Key Limitation**	**Research Gap Identified**
Keshamoni & Hemanth (2017)	MQ-series	GSM (SMS)	High communication latency; depends on cellular network	No evaluation of detection latency or sensing range
Chraim et al. (2016)	Gas sensor network	Wired / Semi-wireless	Complex installation; limited remote monitoring	Lack of real-time performance and latency analysis
Prananda et al. (2023)	MQ-2	Wi-Fi	Focused on functionality rather than performance	No quantitative analysis of response time and range
Fuadi et al. (2024)	MQ-series	Wi-Fi / Cloud	Emphasis on system integration	Detection latency and sensing distance not analyzed
Adamu et al. (2025)	MQ-series	Wi-Fi (ESP32)	Limited performance metrics	No detailed latency and range evaluation
Present Study	MQ-2	Wi-Fi (ESP32)	—	Evaluates detection latency and sensing range experimentally

3. Data and Method

A quantitative experimental approach was adopted to develop and evaluate the proposed wireless gas leakage detection system. The methodology was selected because it enables objective measurement of system performance using measurable parameters such as gas detection response time, communication delay, and sensing reliability under different operating conditions.

The proposed system consists of an MQ-2 gas sensor, an ESP32 microcontroller with integrated Wi-Fi capability, an LCD display, a buzzer, and the Blynk mobile application for remote monitoring. The MQ-2 sensor continuously measures the concentration of combustible gases, including liquefied petroleum gas (LPG), methane, propane, hydrogen, and smoke. The analog output from the sensor is processed by the ESP32, which compares the measured value with a predefined adaptive threshold. When the detected gas concentration exceeds the threshold, the system activates the local alarm through the buzzer and LCD display while simultaneously transmitting a notification to the Blynk application via Wi-Fi.

Unlike conventional fixed-threshold approaches, the proposed system employs an adaptive threshold based on the baseline sensor reading obtained under normal environmental conditions. A gas leakage alert is generated when the measured sensor value increases by approximately 25% above the baseline value. This approach compensates for variations in background gas concentration caused by differences in ventilation, temperature, and surrounding environmental conditions, thereby improving detection reliability. Figure 1 shows the block diagram of the gas leakage detection system, presenting the overall structure and

interconnection of all major components, including the gas sensing unit, wireless communication module, and mobile application interface.

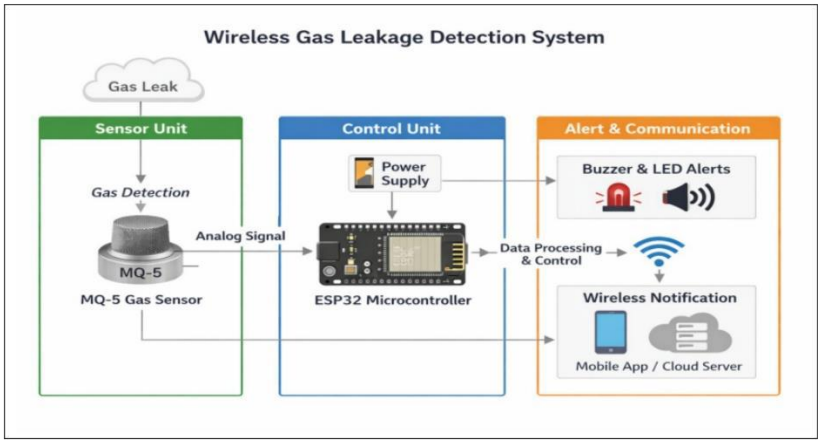


Figure 1. Block diagram of gas leakage detection system

The software was developed using the Arduino Integrated Development Environment (IDE). The control program continuously acquires sensor data, performs threshold comparison, updates the LCD display, activates the buzzer during gas leakage events, and transmits sensor readings and alert notifications through the ESP32's built-in Wi-Fi interface to the Blynk cloud platform. This enables real-time remote monitoring using a smartphone.

Figure 2 shows the signal flow of the proposed gas leak detection system, from gas detection to alert notification. The flow starts at the gas detection stage, where the MQ-2 gas sensor monitors for flammable gases such as methane, smoke and LPG.

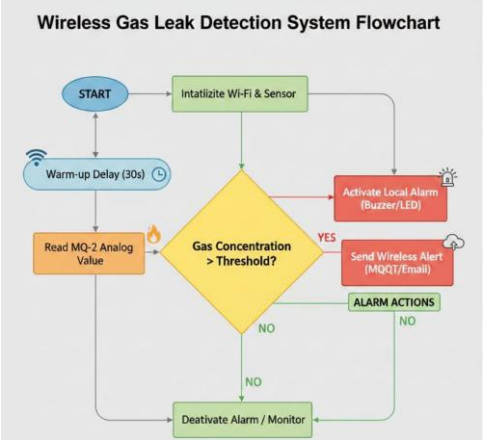


Figure 2. System Flowchart

Experimental evaluation was conducted in three different environments: an open area, a university classroom, and a kitchen. These environments were selected to investigate the influence of varying ventilation and background gas conditions on sensor performance. During each experiment, butane gas was introduced near the sensor, and the system response was observed. The primary performance indicators included gas detection capability, response time, communication delay, and system reliability under different environmental conditions.

The experimental results were analyzed by comparing baseline sensor readings with values recorded during gas exposure. The percentage increase in sensor output relative to the baseline was calculated to verify the effectiveness of the adaptive threshold mechanism. The measured response time and communication delay were also evaluated to determine the suitability of the proposed system for real-time gas leakage detection and wireless monitoring applications.

4. Results and Discussion

The developed wireless gas leakage detection system was successfully implemented and evaluated under three different operating environments: an open area, a university classroom, and a kitchen. The system integrated an MQ-2 gas sensor, an ESP32 microcontroller, an LCD display, a buzzer, and the Blynk mobile application to provide both local and remote gas leakage notifications. Figure 3 shows the experimental setup of the developed wireless gas leakage detection system.

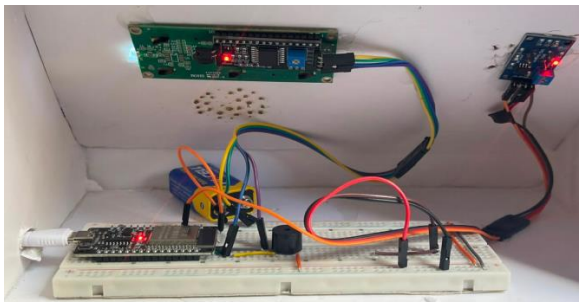


Figure 3. Experimental Setup of the Developed Wireless Gas Leakage Detection System

The MQ-2 gas sensor successfully detected combustible gases in all test environments. Figure 4 shows the response of the MQ-2 gas sensor in an open area environment. The sensor maintained a relatively stable baseline due to good ventilation and lower concentrations of background gases. When butane gas was introduced near the sensor, the readings increased significantly, demonstrating the ability of the sensor to detect combustible gases effectively under outdoor conditions. The performance of the MQ-2 gas sensor was also evaluated in a university classroom environment to determine the effect of indoor conditions on gas detection performance.



Figure 4. MQ-2 Gas Sensor Testing in Open Area

Figure 5 shows the response of the MQ-2 gas sensor under classroom conditions. The sensor produced a different baseline reading due to indoor environmental conditions and ventilation characteristics. Gas exposure caused a noticeable increase in sensor output.

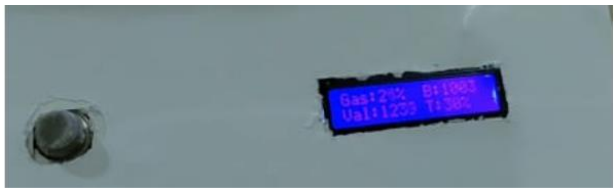


Figure 5. MQ-2 Gas Sensor Testing in University Classroom

Figure 6 shows the sensor response in a kitchen environment where cooking fumes and heat are commonly present. Higher baseline readings were observed compared to other environments; however, the system successfully detected gas leakage and generated the required alerts.



Figure 6. MQ-2 Gas Sensor Testing in the Kitchen

Figure 7 demonstrates the real-time monitoring capability of the developed system using the Blynk application. Gas concentration values and warning notifications were successfully transmitted from the ESP32 to the mobile device with minimal communication delay. The results confirm the effectiveness of the wireless communication system and its suitability for IoT-based gas leakage monitoring applications.

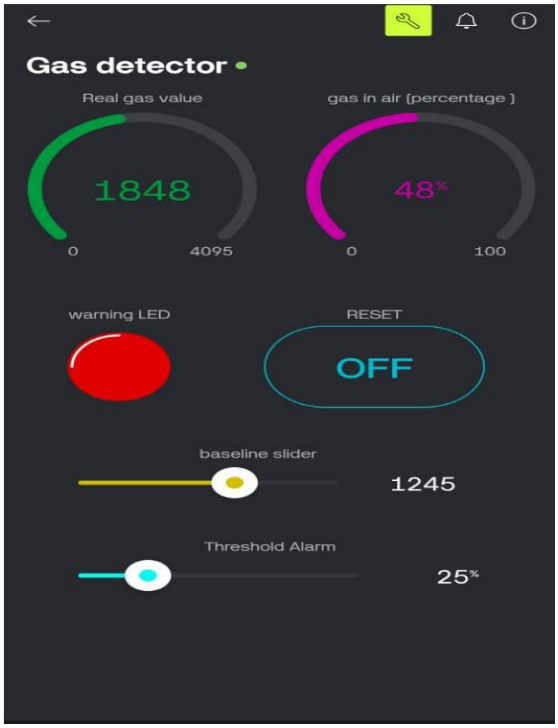


Figure 7. Real-Time Gas Detection Monitoring and Alert Display Using Blynk Application

Table 2 is used to analyze how the MQ-2 sensor responds under different environmental conditions and how the baseline changes depending on location. The table shows that the MQ-2 sensor produced different baseline readings in different environments due to variations in air quality, ventilation, and environmental conditions. Although the absolute sensor values varied across locations, the percentage increase during gas exposure remained relatively consistent, ranging from approximately 22.93% to 24.11%. This demonstrates that the adaptive baseline approach effectively normalizes sensor measurements and improves detection reliability across multiple environments.

Table 2: MQ-2 Sensor Readings and Percentage Increase Across Test Environments

Test Areas	Normal gas (clean air)	Baseline	Gas value (after sensed)	Percentage Increase (%)
Open Area	1000	1245	1543	23.94%
Classroom (University)	1200	1003	1233	22.93%
Kitchen	1020	1003	1297	24.11%

To further quantify the gas concentration level relative to the environment, a percentage-based calculation was used. This allows the system to convert raw sensor readings into meaningful relative values based on the baseline. The gas level percentage is calculated using the following formula:

$$\text{Gas Level (\%)} = \frac{\text{Gas Value} - \text{Baseline Value}}{\text{Baseline Value}} \times \mathbf{100}$$

Where;

- Gas value = sensor reading during gas exposure.
- Baseline value = sensor reading under normal environmental conditions.

Although the baseline sensor readings varied because of differences in ventilation, temperature, and surrounding air quality, a significant increase in sensor output was consistently observed

when butane gas was introduced. These results demonstrate that the sensor can effectively distinguish between normal environmental conditions and hazardous gas leakage.

The adaptive threshold mechanism proved effective in improving detection reliability. Instead of relying on a fixed sensor value, the system generated an alarm when the measured gas concentration increased by approximately 25% above the environmental baseline. This approach compensated for variations in baseline readings across different environments and reduced the likelihood of false alarms while maintaining consistent detection performance.
Experimental evaluation showed that the proposed system achieved a gas detection response time of less than 5 seconds, enabling rapid identification of gas leakage events. Wireless notifications transmitted through the Blynk platform were delivered within 5–10 seconds, allowing users to receive remote alerts shortly after gas detection. The combination of local audible alarms and wireless notifications enhances the effectiveness of the system by providing immediate warnings both on-site and remotely.

The experimental results also demonstrated that environmental conditions influence the absolute sensor readings. Higher baseline values were observed in the kitchen because of cooking fumes and heat, whereas lower baseline values were recorded in the open area due to better ventilation. Despite these variations, the percentage increase relative to the baseline remained relatively consistent across all testing environments, confirming the effectiveness of the adaptive threshold strategy for maintaining reliable detection performance.

Compared with previous studies, the proposed system provides several practical advantages. While earlier gas leakage detection systems primarily focused on implementation or basic monitoring functionality, the developed prototype experimentally evaluated important performance metrics, including response time, communication delay, and sensing behavior under multiple operating environments. Furthermore, the integration of the ESP32 microcontroller with Wi-Fi communication enables real-time remote monitoring without requiring additional communication hardware, reducing both system complexity and implementation cost.

5. Conclusion

The paper presented the design and performance evaluation of a wireless gas leakage detection system based on an MQ-2 gas sensor and an ESP32 microcontroller with integrated Wi-Fi communication. The primary objective was to develop a low-cost, reliable, and real-time monitoring system capable of detecting combustible gases and providing both local and remote alerts to improve safety in residential and similar indoor environments.

A quantitative experimental approach was adopted to evaluate the system under different environmental conditions, including an open area, a university classroom, and a kitchen. The developed prototype continuously monitored gas concentration using the MQ-2 sensor and employed an adaptive threshold mechanism based on the environmental baseline to improve detection reliability. Local alerts were provided through a buzzer and LCD display, while remote notifications were transmitted via the Blynk mobile application using Wi-Fi communication.

Experimental results demonstrated that the proposed system successfully detected combustible gases with a response time of less than five seconds and delivered remote notifications within 5–10 seconds. The adaptive threshold approach effectively compensated for variations in environmental conditions, reducing false alarms and improving detection consistency across different testing environments. The integration of the ESP32 with built-in Wi-Fi also simplified the system architecture by eliminating the need for additional communication modules.

The findings indicate that the proposed system provides an effective, low-cost, and practical solution for real-time gas leakage detection and wireless monitoring. The developed

prototype has the potential to enhance safety through early warning and rapid response while providing a foundation for future IoT-based smart safety systems with cloud data analytics, additional environmental sensors, and advanced notification mechanisms.

Overall, the experimental findings demonstrate that the proposed wireless gas leakage detection system provides reliable gas sensing, rapid response, and effective remote monitoring. The combination of adaptive thresholding, real-time wireless communication, and low-cost hardware makes the system suitable for residential, educational, and small industrial environments where early gas leakage detection is essential for improving operational safety.

Conflict of Interest

The authors declare that there is no conflict of interest.

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