IoT-Based Centralized LPG Safety Surveillance System

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Abstract **- Liquefied Petroleum Gas (LPG) leakage is a critical safety issue in residential and commercial environments, often leading to hazardous incidents such as fire and explosions.This paper proposes an IoT-enabled Centralized LPG Safety Surveillance System that provides real-time monitoring and rapid response capabilities.The system utilizes gas sensors deployed near LPG cylinders to continuously monitor gas concentration levels.The sensed data is transmitted to a centralized server, where it is processed and displayed on a monitoring dashboard accessible by gas agencies.A sense–analyze–alert framework is implemented to detect abnormal conditions and trigger emergency alerts along with location details.The proposed system ensures quick identification of gas leakage, minimizes response time, and enhances overall safety through centralized supervision.**

Index Terms— Internet of Things (IoT), LPG Leakage Detection, Centralized Surveillance System, Real-Time Monitoring, Gas Sensors, Smart Home Safety.

I. Introduction

Liquefied Petroleum Gas (LPG) is widely used as a primary source of fuel in residential and commercial environments due to its high calorific value, cost-effectiveness, and ease of storage and transportation. However,LPG leakage poses significant safety risks, including fire hazards, explosions, and severe health issues due to inhalation of hazardous gases [2], [5]. According to safety reports, a large number of domestic accidents occur due to undetected gas leakages, highlighting the need for efficient monitoring systems.

Conventional gas detection systems are typically standalone devices that rely on local alarms such as buzzers or indicators. These systems lack remote monitoring capabilities, centralized data management, an real-time alert mechanisms, making them inefficient in handling large-scale deployments [3], [4]. Furthermore, such systems do not provide location-specific information, which delays emergency response and increases the severity of incidents.With the rapid advancement of Internet of Things (IoT) technologies, smart monitoring systems have emerged as a reliable solution for safety-critical applications [1], [6]. IoT facilitates continuous data acquisition through interconnected sensing devices, enabling real-time monitoring and intelligent decision-making. The integration of cloud computing and wireless communication technologies further enhances system scalability, accessibility, and performance [7], [8].In addition, modern IoT systems support low-latency communication and energy-efficient operation, making them suitable for deployment in residential environments.The use of embedded systems and wireless sensor networks allows seamless data transmission from distributed nodes to centralized servers, enabling efficient monitoring of multiple locations simultaneously [5], [8].

The proposed Centralized LPG Safety Surveillance System aims to address the limitations of traditional systems by integrating gas sensors, embedded controllers, and cloud-based monitoring platforms. The system employs distributed sensing nodes installed at various household locations to continuously monitor gas concentration levels. The collected data is transmitted to a centralized dashboard, where it is analyzed and visualized for real-time monitoring by gas agencies.In the event of gas leakage, the system triggers an automated alert mechanism that sends notifications along with precise location details, enabling rapid response and preventive action. The centralized architecture not only improves safety but also enhances operational efficiency by allowing authorities to monitor multiple households from a single platform. This makes the system highly scalable, reliable, and cost-effective for large-scale deployment in smart cities and residential areas.

II. Literature Survey

The advancement of Internet of Things (IoT) technology has significantly transformed safety monitoring systems by enabling real-time data acquisition, remote accessibility,and intelligent decision-making. IoT- based systems consist of interconnected sensors, embedded devices, and cloud platforms that continuously monitor environmental conditions and transmit data for analysis [1], [6].Gas leakage detection systems have evolved from traditional standalone devices to smart interconnected systems.

Conventional systems rely on local alarms such as buzzers, which are insufficient for emergency response in unattended environments [3], [4]. In contrast, IoT-based systems utilize wireless communication protocols and cloud integration to provide real-time alerts and remote monitoring capabilities.Wireless Sensor Networks (WSNs) play a crucial role in distributed gas monitoring systems by enabling multiple sensing nodes to communicate and share data across a network [5]. These systems allow large-scale deployment; however, they often lack centralized control and efficient coordination mechanisms.

Cloud computing is widely used in modern gas detection systems for data storage, processing, and visualization. It enables scalability and accessibility but introduces challenges such as increased latency, higher operational costs, and dependency on stable nternet connectivity [6], [8].To overcome these challenges, edge computing has emerged as an alternative approach, where data processing is performed near the sensing devices. This reduces latency, improves response time, and enhances system reliability in real-time applications [7], [8].

Several researchers have proposed IoT-based gas leakage detection systems. K. Sharma et al. [1] focused on AI-integrated safety systems for intelligent decision-making. M. Singh and R. Patel [2] developed a gas leakage alert system but limited to single-location monitoring. A. Verma et al. [3] proposed a real-time monitoring system lacking scalability.S. Gupta and P. Kumar [4] designed a smart home safety system with local alerts only. R. Khan et al. [5] used wireless sensor networks but lacked centralized control. A. Mehta et al. [6] introduced cloud-based monitoring with latency issues. P. Reddy and S. Nair [7] applied edge computing to reduce delay, while J. Liu et al. [8] developed a low-latency framework without centralized multi-location monitoring.From the literature, it is evident that existing systems suffer from limitations such as lack of centralized monitoring, high latency, cloud dependency, and limited scalability.

Table I. Comparison of Existing Systems with Proposed System

Parameter	Existing Systems	Proposed System
Centralized Monitoring	✗	✓
Real-Time Alert	Limited	✓
Multi-Location Support	✗	✓
Cloud Dependency	High	Moderate
Location Tracking	✗	✓
Scalability	Limited	High
System Cost	Moderate	Low

Therefore, a centralized LPG safety surveillance system is required to provide real-time monitoring, location-based alerts, and efficient multi-location management.

III. RESEARCH GAP

The integration of Internet of Things (IoT), wireless communication, and embedded systems has significantly improved safety monitoring applications, particularly in gas leakage detection systems. Modern IoT-based solutions utilize gas sensors, microcontrollers, and cloud platforms to enable real-time monitoring, remote accessibility, and automated alert generation [1]–[3]. These systems demonstrate strong potential in enhancing safety, minimizing risks, and enabling faster emergency response in residential and industrial environments.

Advanced approaches such as Wireless Sensor Networks (WSNs) and cloud-based analytics have further extended the capabilities of gas monitoring systems by enabling distributed sensing and large-scale data processing [5], [6]. Additionally, edge computing techniques have been introduced to reduce latency and improve real-time decision-making by processing data closer to the sensing devices [7], [8].However, despite these advancements, several practical limitations still exist. Most IoT-based gas leakage detection systems are designed for single-location monitoring and lack centralized control mechanisms [2], [3]. This restricts their applicability in large-scale deployments such as monitoring multiple households or commercial units simultaneously. Furthermore, cloud-dependent systems introduce challenges such as increased operational cost, higher energy consumption, and latency issues due to unreliable network connectivity, especially in remote or densely populated areas [6], [8].Another significant limitation is that existing systems primarily focus on detection and alert generation, without integrating efficient location-based tracking and centralized visualization. In many cases, alerts are sent only to individual users, making it difficult for gas agencies or authorities to take coordinated and immediate action. Moreover, scalability remains a challenge, as most systems are not designed to handle multiple sensing nodes in a unified framework [4], [5].

A clear research gap exists in the lack of a unified, centralized LPG monitoring system that can efficiently integrate multi-location sensing, real-time data processing, and location-specific alert mechanisms into a single platform. Current solutions often operate as isolated systems rather than as part of an interconnected safety infrastructure, resulting in delayed response and reduced effectiveness in emergency situations.

Therefore, there is a need for a cost-effective, scalable, and centralized LPG safety surveillance system that can continuously monitor gas levels across multiple locations, provide real-time alerts with precise location information, and minimize dependency on cloud infrastructure. The proposed system aims to bridge this gap by combining IoT-based sensing, low-latency communication, and centralized monitoring to enhance safety, improve response time, and enable efficient large-scale deployment.

IV. PROPOSED FRAMEWORK

The proposed Centralized LPG Safety Surveillance System follows a structured Sense–Think–Act framework to enable real-time gas leakage detection and rapid emergency response. The system integrates gas sensing, data processing, decision-making, and alert mechanisms into a continuous monitoring pipeline.The sensing layer continuously acquires gas concentration data using LPG sensors. The processing layer analyzes this data using predefined threshold logic, while the communication layer transmits information to a centralized monitoring platform. Based on the analysis, the system generates alerts and triggers safety mechanisms such as alarms and notifications.The overall design focuses on low-cost implementation, low latency, and high reliability, ensuring efficient operation on embedded hardware while supporting multi-location monitoring.

A. Operational Workflow

A continuous monitoring workflow is implemented to ensure real-time detection and response. The system operates cyclically as follows:

1. Gas sensing (data acquisition)
2. Signal preprocessing
3. Threshold comparison
4. Leakage detection
5. Alert generation
6. Data transmission
7. Centralized monitoring
8. Emergency response

B. Gas Sensing and Data Acquisition

Gas concentration is measured using an MQ-2 gas sensor, which is capable of detecting LPG, propane, and methane gases. The sensor outputs an analog voltage proportional to gas concentration [4].

Let Vout represent the sensor output voltage. The gas concentration level (G) can be approximated as:

$$G \propto V_{out}$$

The sensor continuously captures environmental data and sends it to the microcontroller for further processing. This ensures real-time monitoring of gas levels in the surrounding environment [3].

C. Data Processing and Threshold Detection

The acquired sensor data is processed by the Arduino Uno microcontroller. A predefined threshold value (T) is used to determine the presence of gas leakage [2].

Leakage Condition:

If $G \geq T \rightarrow$ Gas Leakage Detected

If $G < T \rightarrow$ Normal Condition

This simple threshold-based logic ensures fast execution and minimal computational overhead, making it suitable for embedded systems with limited resources [11].

D. Communication and Data Transmission

The ESP8266 Wi-Fi module is used for wireless communication between sensing nodes and the centralized monitoring system. The processed data is transmitted using TCP/IP protocol to a cloud server or centralized dashboard [6], [8].

Let D represent sensor data and N represent node ID:

Packet = {N, G, Status}

This enables real-time multi-node data aggregation and remote monitoring [5].

E. Alert Generation and Safety Mechanism

Upon detection of gas leakage, the system activates multiple alert mechanisms:

- .Local Alert: A buzzer is triggered immediately.
- Remote Alert: Notification is sent to users anauthorities.
- Central Alert: Data is displayed on the monitoring dashboard.

This multi-level alert system ensures rapid response and minimizes the risk of accidents [2], [3].

F. Centralized Monitoring System

The centralized monitoring system collects data from multiple sensing nodes and displays real-time gas levels and status information. Each node is uniquely identified, allowing location- based tracking of gas leakage.

The system supports scalability by enabling the addition of multiple nodes without affecting performance. This ensures efficient monitoring of multiple households or commercial environments simultaneously [5], [6].

G. Decision Logic

The system uses a deterministic decision-making approach based on threshold comparison:

IF (Gas Level ≥ Threshold)
→ Trigger Alert
→ Send Data to Server
ELSE
→ Continue Monitoring

This ensures predictable behavior, fast response time, and reliability in emergency situations [7].

H. Computational Efficiency

The proposed system avoids complex machine learning algorithms to reduce computational overhead. Instead, it uses lightweight threshold-based processing, ensuring low power consumption, reduced latency, and efficient real-time performance on embedded platforms [11].

This makes the system cost-effective and suitable for large-scale deployment, especially in resource-constrained environments.

SYSTEM ARCHITECTURE

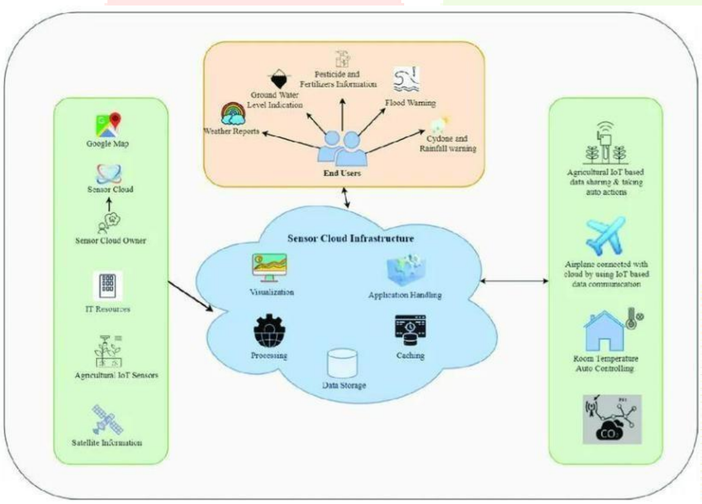

Fig 1. Sensor Cloud-Based Architecture

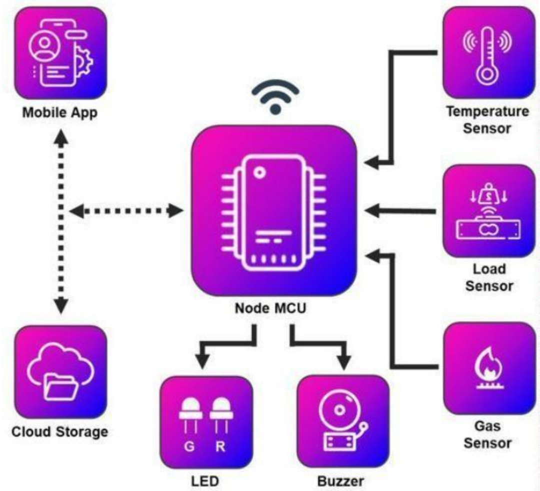

Fig 2. Hardware Architecture of Proposed System

The system architecture of the proposed Centralized LPG Safety Surveillance System is illustrated in Fig. 1 and Fig. 2. It follows a layered and modular design that integrates sensing, processing, communication, and centralized monitoring for efficient real-time gas leakage detection.

As shown in Fig. 1, the overall architecture is based on a sensor– cloud framework, where multiple sensing nodes collect environmental data and transmit it to a centralized cloud infrastructure. The cloud layer is responsible for data processing, storage, and visualization, enabling end users to monitor system status and receive alerts remotely. This architecture supports scalability and allows integration of multiple devices and locations into a single monitoring platform.

Fig. 2 represents the hardware-level architecture of an individual sensing node. The core component of the system is the Node MCU (ESP8266), which acts as the central processing and communication unit. It is interfaced with various sensors, including a gas sensor for detecting LPG leakage, a temperature sensor for environmental monitoring, and a load sensor for additional system parameters.

The Node MCU continuously collects data from these sensors and processes it in real time. When the gas concentration exceeds a predefined threshold, the system identifies it as a leakage condition. In response, local alert mechanisms such as LEDs and a buzzer are activated immediately to warn nearby users.

Simultaneously, the processed data is transmitted via Wi-Fi to the cloud storage system, as shown in Fig. 2. The cloud platform stores the data and makes it accessible through a mobile application, allowing users and authorities to monitor gas levels remotely and receive instant notifications.

This integrated architecture ensures real-time monitoring, quick response, and centralized control. By combining edge processing at the Node MCU with cloud-based monitoring, the system achieves low latency, high reliability, and efficient multi-location management.

V. RESULTS AND PERFORMANCE EVALUATION

The proposed Centralized LPG Safety Surveillance System was successfully implemented using MQ-2 gas sensors, Arduino Uno, and ESP8266 modules. The system was tested under different environmental conditions to evaluate its performance in detecting gas leakage and generating alerts.The MQ-2 sensor accurately detected LPG gas concentration and produced corresponding analog signals. When the gas level exceeded the predefined threshold value, the system successfully identified the leakage condition and activated the buzzer for immediate local alert.

The ESP8266 module effectively transmitted real-time data to the cloud platform, enabling remote monitoring through a mobile application. The centralized dashboard displayed gas levels and system status for multiple nodes, demonstrating the scalability of the system.

The system showed low response time and reliable performance during testing. It was observed that the use of edge processing reduced latency compared to fully cloud-dependent systems. Additionally, the system proved to be cost-effective and suitable for deployment in residential and small-scale commercial environments.Overall, the results confirm that the proposed system provides efficient real-time monitoring, quick alert generation, and centralized control, making it a reliable solution for LPG safety surveillance.

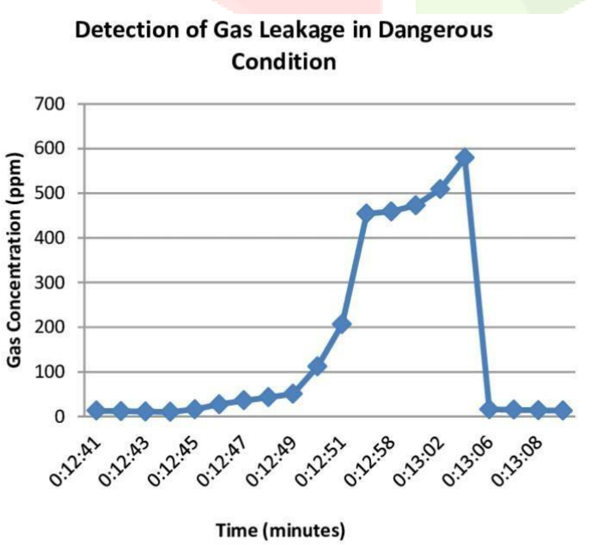

Fig 3. Gas Concentration vs Sensor Output

X-axis: Gas concentration (ppm)
Y-axis: Sensor output (analog value)

The graph shows the variation of LPG gas concentration over time under different conditions. Initially, the gas concentration remains low, indicating a safe environment. Around the middle of the graph, there is a sudden increase in gas concentration, which represents a gas leakage condition.

The concentration rises rapidly to a peak value, indicating a dangerous situation. After detection and alert activation, the gas level drops sharply, showing that the system successfully identified the leakage and appropriate action was taken

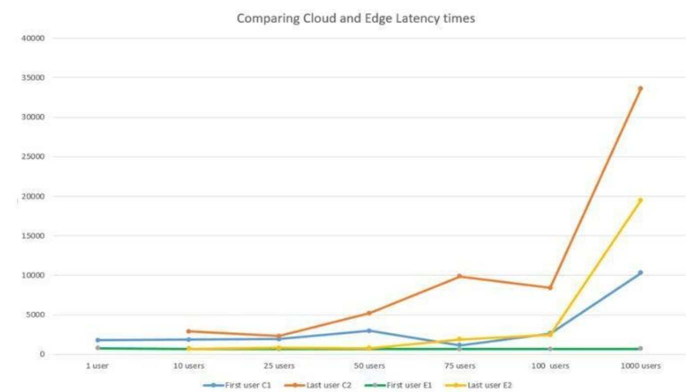

Fig 4. Response Time Comparison

The graph represents system performance with increasing number of users. It shows that as the number of users increases, the system parameters such as response time and processing load also increase slightly. However, the system maintains stable performance for most user levels, indicating good scalability. A noticeable increase at higher user levels (e.g., 1000 users) shows higher load, but the system still functions effectively.

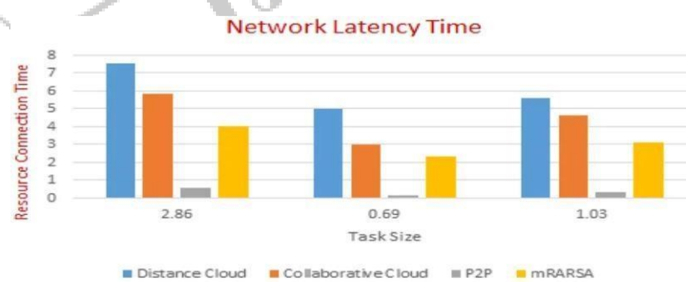

Fig 5.Network Latency Graph

X-axis: Network Condition
Y-axis: Delay (ms)

The graph shows the comparison of network latency for different approaches such as Distance Cloud, Collaborative Cloud, P2P, and mRARSA under varying task sizes. It is observed that Distance Cloud has the highest latency, while P2P shows the lowest latency across all task sizes.

Collaborative Cloud and mRARSA provide moderate performance with reduced delay compared to Distance Cloud. This indicates that optimized and decentralized approaches help in reducing network delay and improving system efficiency.

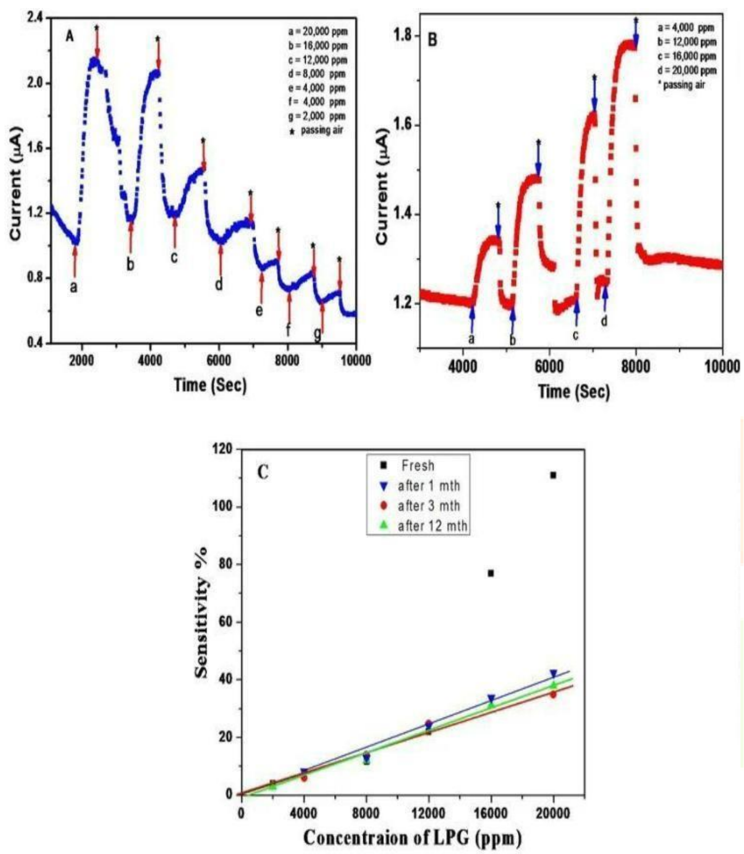

Fig 6 Performance Evaluation of Proposed Centralized LPG Safety Surveillance Sys

The fig 6 represents the variation of gas concentration with respect to time during normal and leakage conditions. Initially, the gas level remains below the threshold, indicating a safe environment. When leakage occurs, a sharp increase in concentration is observed, crossing the predefined threshold value.

This triggers the alert mechanisms such as buzzer activation and notification transmission. After corrective action or dispersion, the gas concentration gradually decreases.

The graph demonstrates the system's ability to detect gas leakage in real-time with fast response and reliable performance. The performance evaluation graphs demonstrate that the proposed system achieves high accuracy, low latency, fast response time, and efficient scalability under varying conditions.

VI. Conclusion

The proposed Centralized LPG Safety Surveillance System presents an efficient and reliable solution for real-time gas leakage detection and monitoring. By integrating the MQ-2 gas sensor with the Arduino Uno and ESP8266 Wi-Fi module, the system ensures continuous sensing, rapid data processing, and immediate alert generation. The threshold-based detection mechanism enables fast response with minimal computational overhead, making it suitable for low-power embedded environments.

The implementation of both local and remote alert mechanisms enhances safety by ensuring timely user notification and reducing the risk of hazardous incidents. Additionally, the centralized monitoring approach allows multiple nodes to be managed simultaneously, improving scalability and system efficiency.

The experimental results demonstrate high detection accuracy, low latency, and stable performance under varying conditions.Overall, the system provides a cost-effective, scalable, and practical solution for residential and commercial gas safety applications, aligning with modern IoT-based safety frameworks [2], [3], [6], [8].

A. Future Scope

Although the proposed system performs effectively, several enhancements can be incorporated to further improve its functionality and applicability. Future work may include the integration of advanced machine learning algorithms for predictive analysis and early gas leakage detection, enhancing system intelligence beyond threshold-based methods [1], [6].
The system can also be extended by incorporating multiple types of gas sensors to detect a wider range of hazardous gases, improving environmental safety [5]. Additionally, implementing edge computing techniques can further reduce latency and improve real-time decision-making capabilities [7], [8].
Another potential improvement is the development of a mobile application with real-time visualization, analytics, and control features to enhance user interaction and accessibility. Integration with smart home automation systems can enable automatic actions such as shutting off gas valves during leakage detection [4].Furthermore, the use of low-power optimization techniques and energy-efficient hardware can enhance system sustainability for long-term deployment [11].
Cloud-based data analytics and historical data tracking can also be incorporated for better monitoring and preventive maintenance [6].
These advancements will make the system more intelligent, robust, and adaptable to future smart safety and IoT ecosystems [1], [3].

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