IOT Based Smart Gas Leakage Detection and Safety System (GLDS)

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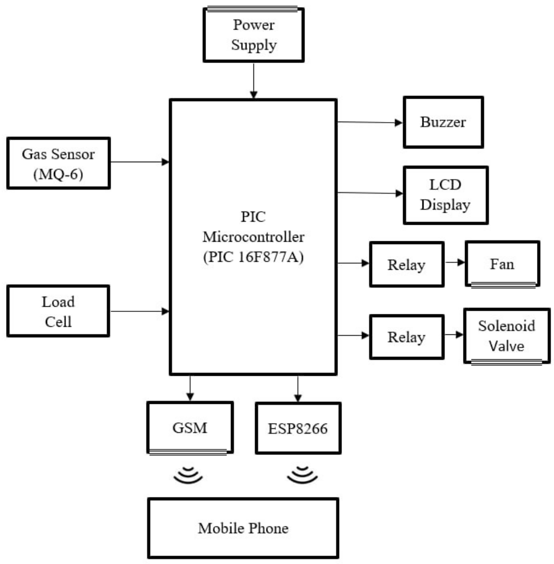
ABSTRACT
Gas leakage from liquefied petroleum gas (LPG), methane, propane, and other combustible gases poses a serious threat to human life, property, and the environment. Accidental gas leaks in homes, laboratories, and industrial plants can lead to fire hazards, explosions, and health complications if not detected at an early stage. Conventional gas detection systems primarily rely on standalone alarms that provide only local alerts without remote monitoring or automatic preventive measures. To address these limitations, this paper proposes the design and development of an IoT-based Smart Gas Leakage Detection and Safety System that ensures real-time monitoring, instant notification, and automated control actions.The proposed system employs high-sensitivity gas sensors (such as MQ-series sensors) interfaced with a microcontroller (e.g., Arduino/NodeMCU/ESP8266) to continuously monitor gas concentration levels in the surrounding environment. The sensor data are processed and transmitted to a cloud-based platform through Wi-Fi communication. When the gas concentration exceeds a predefined safety threshold, the system activates a buzzer and visual indicators for immediate local warning. Simultaneously, real-time alerts are sent to users via a mobile application or SMS notification. Additionally, an automatic gas shut-off mechanism is integrated to minimize risk by cutting off the gas supply instantly.

1.INTRODUCTION

Gas leakage is a major safety concern in homes, industries, laboratories, and commercial buildings. Leakage of gases such as LPG, methane, propane, and carbon monoxide can lead to fire accidents, explosions, health hazards, and even loss of life. Traditional gas detection systems often provide only local alarms and lack real-time monitoring or remote notification features.

With the advancement of the Internet of Things (IoT), smart gas leakage detection systems have been developed to provide continuous monitoring, instant alerts, and automatic safety measures. An IoT-based smart gas leakage detection and safety system uses gas sensors (such as MQ series sensors), a microcontroller (Arduino, NodeMCU, etc.), and communication modules (Wi-Fi/GSM) to detect harmful gases and send real-time alerts to users via mobile applications or SMS.



2.LITERATURE REVIEW

2.1 Chemiresistive Semiconductor Sensors

The most widely used sensors in low-cost IoT gas leakage systems are chemiresistive metal oxide semiconductor (MOS) sensors, particularly the MQ-series (e.g., MQ-2, MQ-5, MQ-6):

Working Principle: These sensors change resistance when the target gas interacts with the metal oxide surface. The change is proportional to gas concentration, making them suitable for detecting flammable gases.

Research Usage:
MQ-2: Common for LPG, propane, hydrogen detection.
MQ-5: Specifically sensitive to LPG and natural gas.
MQ-6: Optimized for LPG with better selectivity.
Advantages Identified in Literature:
Low cost, easy to interface with Arduino/ESP microcontrollers.
Fast response time (<10 seconds in many cases).
Compatible with analog readouts directly for IoT systems.

Limitations Noted:
Sensitivity affected by environmental humidity and temperature.
Requires pre-heating and warm-up time for stable readings.
Cross-sensitivity (detects multiple gases) can cause false alarms.
For example, studies have shown that these MQ sensors, when calibrated properly and combined with real-time cloud thresholding, can achieve acceptable detection performance in home and industrial contexts.
Researchers often recommend baseline calibration at regular intervals to compensate for sensor drift over time.

2.2 Electrochemical Sensors

Electrochemical sensors are another class used in research, especially where higher accuracy is required:

Operational Basis: These generate a current proportional to the gas concentration as gas molecules undergo oxidation/reduction at electrodes.

Advantages:
- Better selectivity and linear output over a broader range.
- Lower interference from temperature/humidity changes compared to MOS sensors.

Challenges:
- Higher cost than MQ sensors.
- Shorter life span depending on environmental conditions.

Research Context:
Often used in systems where precise measurement of toxic gases like CO is essential.
Some hybrid IoT systems use electrochemical sensors plus MOS sensors: the MOS detects quick changes, and the electrochemical sensor validates real readings to reduce false positives.
Several papers emphasize that electrochemical sensors, when integrated with machine learning models, achieve higher reliability under varied environmental conditions.

2.3 Infrared (NDIR) Gas Sensors

Non-Dispersive Infrared (NDIR) sensors are used in research for detecting gases that absorb infrared light, usually CO_2 and hydrocarbons:
Principle: Measures the amount of IR light absorbed by gas molecules at characteristic wavelengths.
Benefits:
- High reliability and specificity.
- Long-term stability with minimal calibration.

Drawbacks:
- Costlier than MOS and electrochemical sensors.
- Slightly larger footprint and higher power requirement.

Application Context:
Often used in industrial IoT systems where precision outweighs cost.
Combined with wireless IoT modules (GSM/LoRaWAN) for remote monitoring of large facilities.
Research comparisons show that although NDIR sensors are highly accurate, their high cost makes them less popular in low-budget residential IoT systems.

2.4 Combined / Hybrid Sensor Systems

Recent research demonstrates that sensor fusion — combining two or more types of sensors — can significantly improve detection:
Example: MOS + Temperature/Humidity sensor module to correct environmental impact on gas readings.
Example: MOS + Electrochemical sensor for both fast detection and accurate confirmation.
Studies reveal such hybrid systems produce lower false alarm rates and better reliability in real environments like kitchens, factories, and underground utility rooms.

2.5 Calibration, Thresholding & Data Interpretation

A common observation in the literature is that raw sensor output is insufficient unless processed:

Most research implements calibration algorithms to map raw sensor readings into accurate gas concentrations (ppm).

Threshold values are often dynamically updated using cloud analytics rather than static predefined values.

Some researchers use moving average filters, Kalman filters, or simple AI classifiers to reduce noise and improve decision accuracy.

Literature also points out that systems without proper calibration or filter algorithms suffer from frequent false positives, especially in environments with rapid temperature/humidity changes.

3.PROBLEM STATEMENT

Gas leakage is one of the major causes of fire accidents, explosions, and health hazards in residential, commercial, and industrial environments. Liquefied Petroleum Gas (LPG), methane, and other combustible gases are widely used for cooking and industrial operations, but accidental leakage due to faulty cylinders, damaged pipelines, or improper handling can lead to serious consequences including property damage and loss of life.

Traditional gas leakage detection systems mainly provide local alarms (buzzer or LED) and do not offer remote monitoring, real-time alerts, or automatic preventive actions. In many cases, if the occupants are not present at the location, the leakage may go unnoticed until it causes a dangerous situation. Additionally, conventional systems lack integration with modern smart home technologies and do not maintain historical data for analysis.

4.ALERTS,NOTIFICATION MECHANISMS AND USER INTERFACE

4.1 Local Alert Mechanisms

Most research studies incorporate local alert systems as the first level of safety. These include:

Buzzer alarms – Produce loud audible sound when gas concentration exceeds a predefined threshold.

LED indicators – Provide visual indication of leakage (e.g., red LED for danger).

LCD/OLED display modules – Show real-time gas concentration levels (in ppm).

Researchers highlight that local alerts are crucial in residential environments where occupants are physically present. However, literature also points out that these systems fail if no one is nearby to hear or see the warning.

4.2 Remote Notification Systems

To overcome limitations of standalone detectors, IoT-based systems integrate remote notification methods. These include:

a) Mobile Application Alerts

Many systems use Wi-Fi-enabled microcontrollers (like ESP8266/ESP32) to send real-time notifications through mobile applications. Features typically include:

- Push notifications
- Live gas concentration monitoring
- Historical data graphs
- Threshold customization

Studies indicate that mobile apps significantly enhance user awareness and allow remote monitoring from any location.

b) SMS Alerts (GSM Module)

In areas with poor internet connectivity, GSM modules are used to send SMS alerts directly to users. Literature suggests that SMS-based systems provide reliable communication in rural or industrial environments where Wi-Fi is unstable.

c) Email Notifications

Some cloud-based systems automatically send email alerts when dangerous gas levels are detected. While effective, research notes that email notifications may not be as immediate as push notifications or SMS.

4.3 Cloud-Based Monitoring Dashboards

Several studies incorporate cloud platforms for data storage and visualization. These dashboards provide:

- Real-time gas level display
- Graphical analysis of past readings
- Alert history logs
- Device health monitoring

Researchers emphasize that cloud integration improves system scalability and enables centralized monitoring in industries where multiple detection nodes are installed.

4.4 Automated Safety Notifications

Advanced IoT systems go beyond simple alerts by:

- Notifying emergency contacts
- Sending alerts to fire safety departments
- Integrating with smart home ecosystems

Some research discusses multi-level alert systems, where:

Level 1: Warning alert (moderate gas concentration)

Level 2: Critical alert (high gas concentration + automatic shut-off)

Level 3: Emergency alert (notifies authorities)

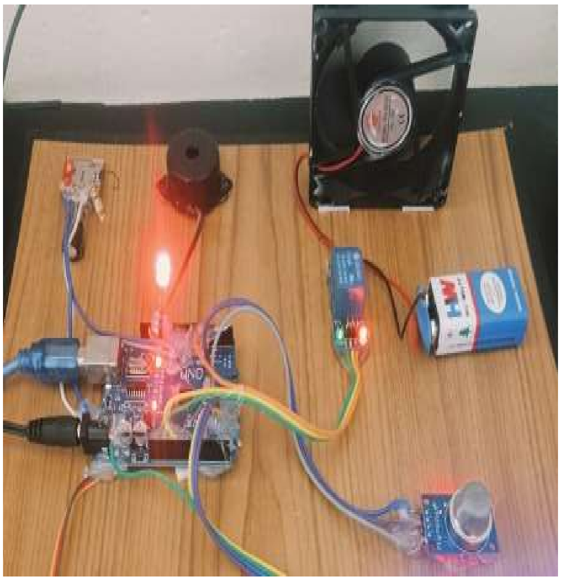
This layered approach reduces panic while ensuring timely response.

5.SAFETY AUTOMATION AND ACTUATION

5.1 Automatic Gas Shut-Off Mechanism

One of the most widely implemented safety features in literature is the automatic gas shut-off system using a solenoid valve

When gas concentration exceeds a critical level, the microcontroller sends a signal to activate the solenoid valve.
The valve immediately cuts off the gas supply from the cylinder or pipeline.
This significantly reduces the risk of explosion and fire.
Studies highlight that integrating solenoid valves reduces response time compared to manual intervention. However, researchers also point out the importance of reliable power supply to ensure the valve functions during emergencies.



5.2 Ventilation Control Systems
Another commonly proposed automation feature is automatic ventilation activation:
Exhaust fans are turned on when leakage is detected.
Windows or smart vents may automatically open in advanced systems.
The objective is to disperse accumulated gas and reduce concentration below dangerous levels.
Research indicates that combining ventilation systems with shut-off valves enhances overall safety performance, especially in closed environments like kitchens and industrial storage rooms.

5.3 Fire Suppression Integration
Some advanced studies integrate gas detection with fire detection and suppression systems:
If both gas leakage and high temperature are detected, the system may activate sprinklers.
Integration with smoke sensors adds another layer of safety.
This multi-sensor approach ensures early prevention of fire accidents.

5.4 Multi-Level Safety Response
Literature suggests implementing multi-level automation strategies:

- Level 1 (Warning Stage): Only buzzer and mobile alert.
- Level 2 (Critical Stage): Activate ventilation system.
- Level 3 (Emergency Stage): Shut-off gas supply and send emergency alerts.

This graded response reduces unnecessary shutdowns while maintaining safety.

5.5 Edge Processing for Faster Automation
Many researchers emphasize the importance of local processing (edge computing):
Threshold comparison and decision-making are performed locally in the microcontroller.
This reduces dependency on cloud servers.
Studies show that edge-based automation significantly improves reliability and reduces system latency.

6.COMPARATIVE ANALYSIS AND PERFORMANCE EVALUATION

6.1 Comparison Based on Sensor Type
Different sensor technologies show varying performance levels:
MQ Series Sensors (MOS type)

- Low cost and easy integration
- Moderate accuracy
- Prone to environmental interference
- Suitable for residential use

Electrochemical Sensors

- Higher accuracy and selectivity
- Less affected by humidity
- More expensive
- Suitable for industrial applications

NDIR Sensors

- Very high accuracy and stability
- High cost
- Used in precision-based industrial monitoring

6.2 Comparison Based on Alert Mechanism
Researchers compare traditional alarm systems with IoT-enabled systems:
Traditional Systems

- Only local buzzer alerts
- No remote monitoring
- No data storage

IoT-Based Systems

- Remote alerts via mobile apps and SMS
- Cloud data logging

- Automated safety response

Literature strongly indicates that IoT systems provide faster emergency response and improved user awareness.

6.3 Performance Metrics Used in Studies

Common performance parameters evaluated in research include:

- Response Time: Time taken to detect gas and trigger alert
- Detection Accuracy: Ability to correctly identify gas presence
- False Alarm Rate: Frequency of incorrect alerts
- Power Consumption: Important for battery-powered systems
- Network Latency: Delay in remote notification

Experimental studies show that edge-processing systems (local threshold detection) have lower response time compared to cloud-dependent systems

7.CHALLENGES AND FUTURE DIRECTIONS

7.1Sensor Accuracy and Calibration Issues

One of the major challenges highlighted in literature is sensor inaccuracy and drift over time.
Low-cost sensors like MQ series are sensitive to temperature and humidity variations.
Long-term usage causes sensor degradation.
Cross-sensitivity leads to false alarms.
Many studies recommend:
Periodic calibration techniques
Temperature and humidity compensation algorithms
AI-based adaptive thresholding
Future research focuses on developing self-calibrating smart sensors that automatically adjust to environmental conditions.

7.2 Network Dependency and Connectivity Issues

IoT systems heavily depend on internet connectivity.
Poor Wi-Fi signals may delay alerts.
Cloud server downtime can interrupt monitoring.
Rural areas may lack stable internet.
Researchers suggest:
Hybrid communication models (Wi-Fi + GSM)
Edge computing for local decision-making
Use of low-power long-range technologies like LoRaWAN
Future systems aim to reduce complete dependency on cloud services.

7.3 Security and Privacy Concerns

Security is a critical issue in IoT systems.
Unauthorized access may disable safety mechanisms.
Data transmitted over networks may be intercepted.
Weak authentication increases vulnerability.
Literature recommends:
End-to-end encryption
Secure communication protocols (SSL/TLS)
Multi-factor authentication
Future research is directed toward blockchain-based secure IoT frameworks and advanced intrusion detection systems.

7.4 Power Consumption and Energy Efficiency

Many IoT gas detection systems operate continuously.
Continuous sensing increases power consumption.
Battery-operated devices require long operational life.
Researchers propose:
Low-power microcontrollers
Sleep mode operation
Energy-efficient communication protocols
Future development includes solar-powered IoT gas detectors for remote industrial applications.

7.5 False Alarms and Reliability Issues

Frequent false alarms reduce user trust in the system.
Causes include:

- Environmental interference
- Improper calibration
- Sensor cross-reactivity
- Future research explores:
- Multi-sensor fusion
- Machine learning-based anomaly detection
- Improved filtering techniques

7.6 Scalability and Standardization

Industrial environments require monitoring of multiple nodes.
Challenges include:

- Managing large-scale IoT networks
- Interoperability between different devices
- Lack of universal standards

Researchers recommend adoption of standardized IoT protocols and modular system architecture.

8.CONCLUSION

The IoT-based Smart Gas Leakage Detection and Safety System provides an effective and reliable solution to prevent gas-related accidents in residential and industrial environments. Traditional gas detection systems only provide local alerts, whereas the proposed IoT-based system enhances safety through real-time monitoring, remote notifications, and automated safety mechanisms.

By integrating gas sensors, microcontrollers, wireless communication modules, and cloud platforms,

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the system ensures early detection of hazardous gases such as LPG and methane. Features like mobile alerts, SMS notifications, automatic gas shut-off valves, and ventilation control significantly reduce the risk of fire accidents and explosions. The inclusion of cloud data storage also allows continuous monitoring and preventive maintenance.

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