

## Advanced IOT based Gas Detection System using Edge Computing and 5G Connectivity

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**Abstract:** The increasing frequency of gas leak incidents in residential and industrial settings highlights the importance of effective safety monitoring. This project introduces an advanced IoT-based smart gas detector and notification system that uses Arduino Uno, ESP8266 Wi-Fi module, GSM module, and LCD display to detect gas leaks and send alerts. The system uses MQ-series gas sensors to identify hazardous gases such as LPG, methane, or CO<sub>2</sub>. By incorporating edge computing, the system processes sensor data locally on an Arduino or microcontroller, which reduces latency and improves data security. This approach enables faster decision-making in emergency situations. If a gas leak is detected, the system activates an alert via LCD display and buzzer. At the same time, the ESP8266 module sends real-time notifications to a cloud-based IoT platform, while the GSM module provides SMS alerts to pre-programmed phone numbers. The use of edge computing reduces the dependency on cloud services, ensuring that real-time decisions are made locally. This dual-communication approach ensures timely and reliable response, helping to prevent accidents. The system, powered by regulated power, is designed for efficient operation in both domestic and industrial environments. The proposed solution provides real-time monitoring, automation, and remote access, providing an effective and cost-effective method for gas leak detection and notification.

### 1. INTRODUCTION

Gas leakage incidents have become a significant hazard in residential and industrial settings today. Leaks from gases such as LPG, methane, and carbon monoxide can cause fires, explosions, and health hazards, making continuous monitoring essential. Traditional gas detectors typically provide localized alarms and are ineffective if no one is present to take immediate action.

To address this issue, an IoT-based smart gas detector and notification system combines Internet of Things (IoT) and GSM technologies to provide real-time alerts and remotely monitor gas leaks. Using the MQ-x gas sensor, the system detects gas leaks and notifies users through various communication channels for a quick and efficient response.

The system uses an Arduino Uno as the central controller, which is connected to an ESP8266 Wi-Fi module for cloud-based data transfer and a GSM module for SMS notifications. If a gas leak is detected, the system immediately activates a buzzer alarm, updates the LCD display, and sends alerts via SMS and IoT platforms such as Thing Speak or Blynk. This dual notification system ensures that users are alerted immediately, even when they are not on site.

In addition, the system has a relay module that can activate an exhaust fan to help remove the leaked gas, thus reducing potential hazards. This smart gas detection solution offers several benefits, including remote monitoring, real-time data logging, and automation, making it an affordable and efficient option for gas leak detection. IoT integration allows users to monitor gas levels from any location, reducing the chance of accidents and property damage.

The system is suitable for homes, restaurants, factories, and gas stations where early detection of gas leaks is critical. Unlike traditional gas detectors that rely solely on alarms, the system ensures that alerts are sent to multiple stakeholders for a quick response.

With advances in IoT, embedded systems, and wireless communications, such smart security solutions are becoming more accessible and efficient. Combining low-cost components, wireless connectivity, and automation, this system provides a practical and scalable solution for gas leak detection. It not only improves security, but also supports the development of smart home and industrial automation technologies.

## 2. LITERATURE REVIEW

Various research studies and practical applications have explored the combination of IoT and gas detection technologies to improve safety in hazardous environments. Traditional gas detection devices typically rely on localized components such as buzzers or display modules to alert users. However, these systems require human presence and lack remote monitoring capabilities, limiting their use in unattended or remote areas.

Recent developments in IoT-based gas detection systems have incorporated wireless connectivity, allowing sensor data to be sent to cloud servers for analysis and alerting. For example, systems using ESP8266 or GSM modules can send alerts via SMS or the Internet. However, these cloud-based models rely on a fixed network connection, which can cause latency and reliability issues during emergencies.

To overcome these challenges, modern research has proposed integrating edge computing. Edge computing allows data to be processed locally on the device, reducing the delays between data collection and response. Studies indicate that edge-enabled systems can provide real-time alerts with minimal bandwidth usage and remain operational even during network disruptions.

The literature strongly supports the idea that edge computing improves the responsiveness, performance, and reliability of IoT-based gas detection systems. It reduces communication delays, conserves bandwidth, and ensures timely alerts—critical factors in preventing accidents in residential and industrial environments.

### Challenges

- **Sensor Reliability:** Environmental conditions such as variations in temperature and humidity can lead to sensor drift or trigger false alarms, which can compromise detection accuracy.
- **Network Dependency:** GSM or 5G connections may encounter disruptions or weak signals, causing delays or preventing remote notifications.
- **System Cost:** The acquisition of edge-capable controllers, high-quality gas sensors, and communication modules adds to the overall hardware and development costs.
- **Power Management:** Continuous local processing and sensor operation require a stable power source; battery-powered or off-grid systems may have limited operational times.
- **Limited Autonomy:** While edge nodes can handle basic threshold monitoring, more complex analysis or the integration of multiple sensors still necessitates human intervention or cloud support.

## 3. CASE STUDIES

**Smart Gas Monitoring System using ESP8266 and GSM:** S. Patel et al. (2022) proposed a hybrid gas leak detection system that combined Wi-Fi and GSM communication for dual-mode alerts. The system used the ESP8266 module to transmit real-time data to the cloud and the GSM module for sending SMS notifications. Gas levels were monitored with the MQ5 sensor, and a local buzzer was triggered. The study highlighted how the combination of local and remote alerts provided faster and more reliable responses to gas leaks.

**Edge-Enabled Gas Detection System with AI Integration:** R. Kumar et al. (2023) developed a system that integrated edge computing with AI-based gas detection algorithms. MQ-series sensors were connected to a microcontroller capable of analyzing the data locally. Only critical alerts were sent to the cloud, reducing bandwidth usage and ensuring the system remained operational during network outages. The project demonstrated the benefits of local decision-making in real-time safety-critical applications.

**IoT-Based Gas Leakage Detection Using Arduino Uno:** A project implemented by engineering students utilized an Arduino Uno, MQ2 gas sensor, GSM module, and LCD display to detect LPG leaks in kitchens and industrial

settings. The system triggered a local buzzer and sent SMS alerts when dangerous gas levels were detected. Although the system did not involve cloud processing, it proved to be a reliable and cost-effective solution for small-scale applications.

#### 4. HARDWARE DESCRIPTION

##### Block Diagram and Its Description

The block diagram of the Advanced IoT-Gas Detection System Using Edge Computing and 5G Connectivity illustrates the functional components of the system and their interconnections. The key modules are:

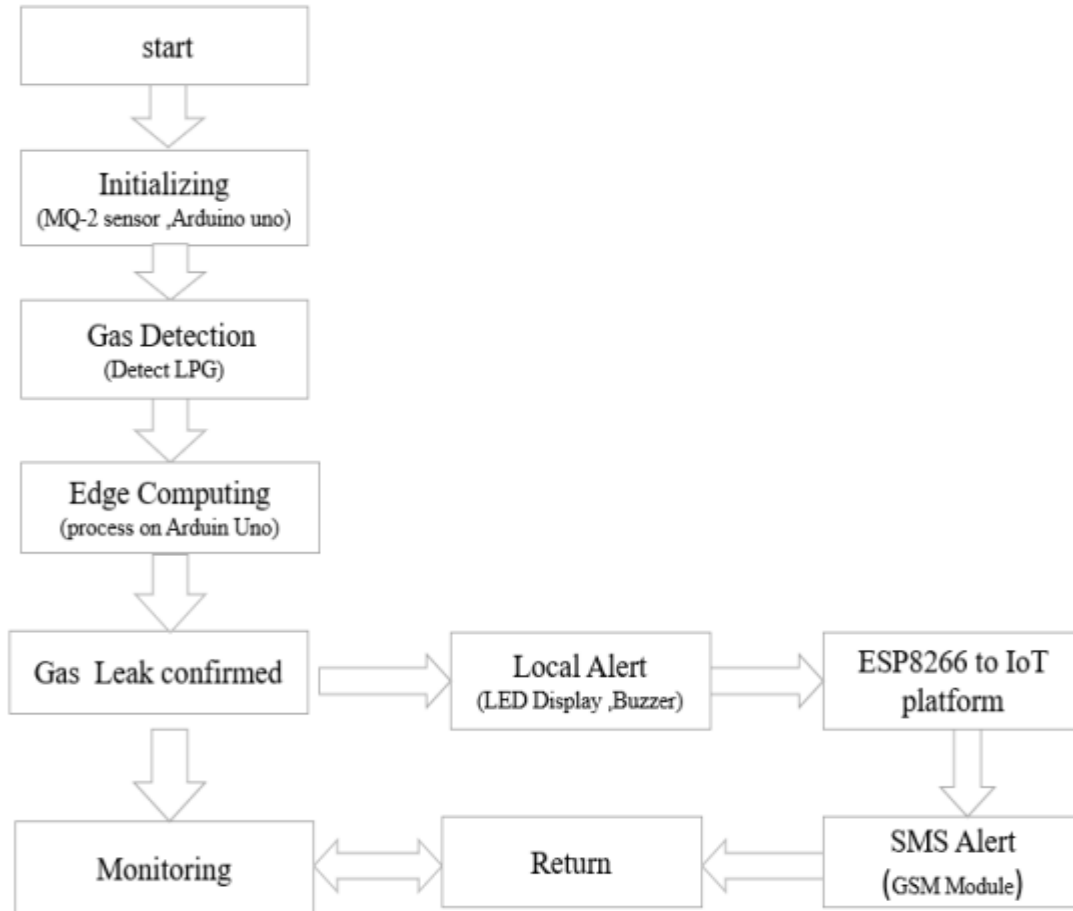
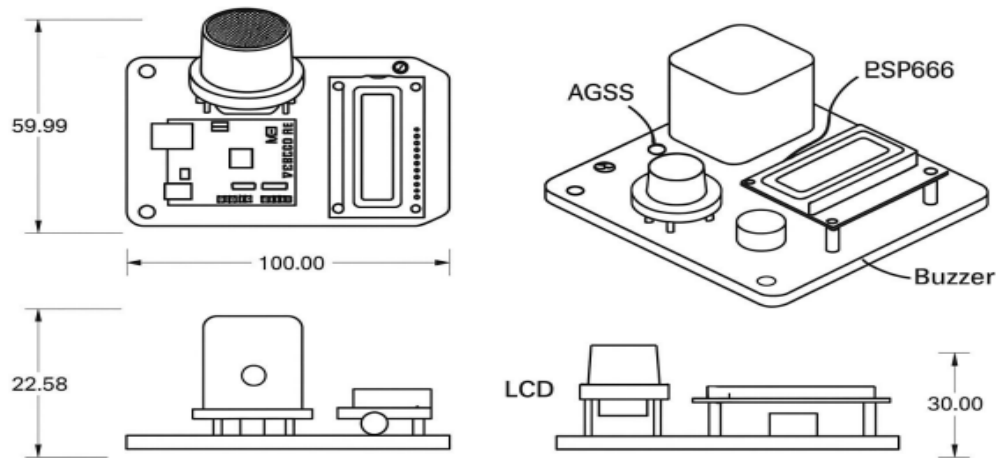


FIGURE 1. Proposed Flowchart

**Working flow:** The proposed project is an advanced IoT-based gas leakage detection system that utilizes edge computing and wireless communication technologies to detect and respond to hazardous gas leaks, particularly LPG. The system begins by initializing the MQ-2 gas sensor and Arduino Uno, which are responsible for continuously monitoring the surrounding air. When the sensor detects the presence of LPG beyond a safe threshold, it immediately sends this data to the Arduino Uno, which processes the information locally through edge computing. This ensures faster decision-making without relying on internet connectivity or cloud services, making the system highly efficient in emergency scenarios. Once a gas leak is confirmed, the system triggers a series of alert mechanisms. A local alert is activated using an LED display and buzzer to inform people nearby about the danger. Simultaneously, the ESP8266 Wi-Fi module sends real-time data to an IoT platform for remote monitoring, while the GSM module sends SMS alerts to registered phone numbers to notify users who are not on-site. After issuing these alerts, the system returns to its monitoring state to ensure continuous protection. This smart safety system is highly suitable for residential kitchens, industrial areas, and gas storage facilities, offering reliable and timely responses to prevent accidents and save lives.

## Operation of the Project



**FIGURE 2.** Prototype of [Implementing a Prototype Autonomous Advanced IoT based Gas Detection system using Edge Computing and 5G Connectivity]

The system operates by continuously monitoring the surrounding environment for harmful gas presence using the AGSS (Advanced Gas Sensing System). Once powered on, the AGSS detects gas concentrations in the air and sends analog signals to the ESP666 microcontroller. This controller processes the sensor data and determines whether the gas levels exceed a predefined safety threshold. If the detected gas concentration is within a safe range, the LCD display shows a "Normal" status message. However, if the gas levels rise above the critical limit, the buzzer is immediately activated to provide an audible alert. Simultaneously, the LCD shows a warning message like "Gas Leak Detected," ensuring quick user awareness. This real-time detection and alert mechanism make the system effective for use in smart homes, industrial safety zones, or enclosed spaces where gas leaks pose a threat.

## Hardware Components:



**FIGURE 3.** Arduino Uno

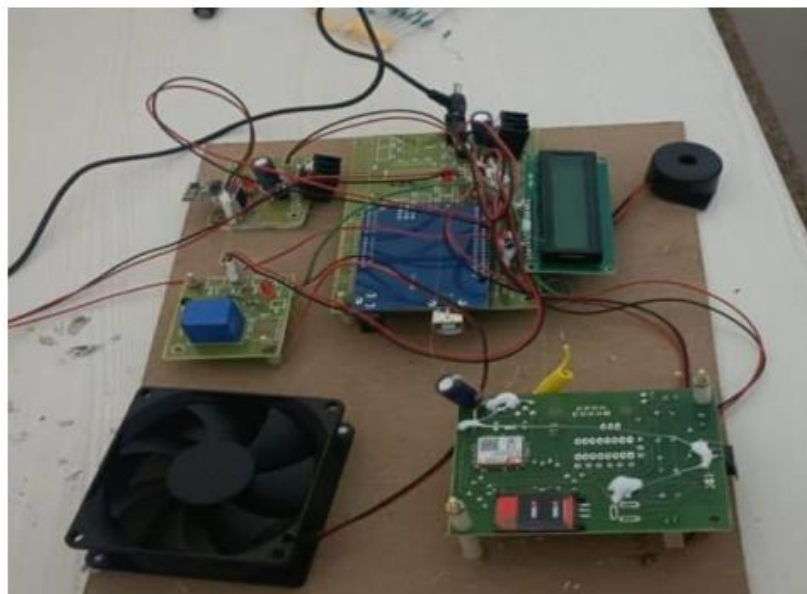
The Arduino Uno is an open-source microcontroller board based on the ATmega328P. It is widely used in electronics projects due to its simple architecture, ease of programming, and wide community support. It has 14 digital input/output pins, 6 analog inputs, a USB connection, a power jack, and an ICSP header. In this project, the Arduino Uno serves as the central processing unit, controlling all the sensors, modules, and output devices. It reads analog data from the MQ-2 gas sensor, processes it, and performs predefined actions like activating the buzzer, updating the LCD, or sending alerts through a Wi-Fi or GSM module. The Arduino's flexibility allows real-time response and local processing, which is critical for edge computing applications. By handling data locally before sending it to the

cloud, it helps reduce latency and ensures timely alerts even if internet connectivity is lost. This makes it ideal for critical safety applications like gas leak detection.

## 5. SOFTWARE

**Algorithm:** The algorithm used here is the “Threshold-Based Decision Algorithm.” Threshold-Based Decision Algorithm: The Threshold-Based Decision Algorithm is a simple yet highly efficient approach commonly used in embedded and real-time systems. In this algorithm, the sensor reading is constantly monitored and compared with a preset threshold value. If the sensor reading exceeds this threshold, the system triggers a specific action; if it does not exceed the threshold, the system continues monitoring without taking any action. This approach is widely applied in safety-critical applications where immediate decisions are essential, such as fire alarms, gas leak detectors, temperature monitoring, and air quality systems. The threshold value is typically determined based on safety guidelines, sensor sensitivity, or environmental conditions. In this project, the MQ-2 gas sensor sends continuous analog values to the Arduino, indicating gas concentration levels. The algorithm evaluates whether these values exceed a defined threshold (e.g., 400 on a scale of 0–1023). Depending on the comparison result, the system either alerts the user or continues normal operation. The Threshold-Based Decision Algorithm in the context of the Advanced IoT-Gas Leakage Detection using Edge Computing follows these steps: Step 1: System Initialization Power on the Arduino Uno and initialize components such as the MQ-2 gas sensor, LCD display, buzzer, fan (via relay), and the ESP8266/GSM module. Set a predefined gas threshold value (e.g., 400 units) to define the safe operating limits. Step 2: Continuous Monitoring (Edge Loop Begins) The Arduino enters a continuous loop where it consistently reads gas concentration levels from the MQ-2 sensor via its analog input. This ongoing monitoring allows the system to detect changes in the environment in real time. Step 3: Edge-Level Threshold Comparison The system compares the analog value from the sensor against the predefined threshold directly on the Arduino. If the gas concentration is below the threshold: The LCD displays the message “Environment Safe.” The buzzer and fan remain off to indicate that no action is required. If the gas concentration exceeds the threshold: The LCD displays “Gas Leak Detected!” The buzzer and fan are activated immediately via the relay to address the potential hazard. An alert is then prepared and sent either through the GSM module via SMS or through the ESP8266 to a cloud or remote server for further action. Step 4: Selective Reporting to Cloud Unlike traditional systems that constantly rely on the cloud, this system only sends critical data to the cloud or remote server. This selective reporting helps reduce bandwidth usage and ensures a quicker local response to emergencies. Step 5: Repeat Process The entire process repeats continuously, ensuring that gas detection and monitoring continue without interruption. This edge-level processing also ensures that the system functions effectively even if the internet connection is temporarily unavailable.

## 6. RESULTS



**FIGURE 4.** Prototype Model

**Input Images**



**FIGURE 5.** Smoke Fig and Low Fire



**FIGURE 6.** High Fire

The Threshold-Based Decision Algorithm plays a crucial role in the Advanced IoT-Based Gas Leakage Detection System by enabling real-time detection and automated response to hazardous gas levels. This algorithm continuously monitors the data from gas sensors and compares the readings against a predefined threshold value. When the detected gas concentration exceeds the threshold, it immediately triggers safety mechanisms such as activating a buzzer, turning on a fan for ventilation, and sending alert notifications via the GSM module or cloud using the ESP8266. By processing data locally through edge computing, the algorithm ensures faster response, minimal latency, and high reliability, making it a vital component for preventing accidents and enhancing safety in environments prone to gas leakage.

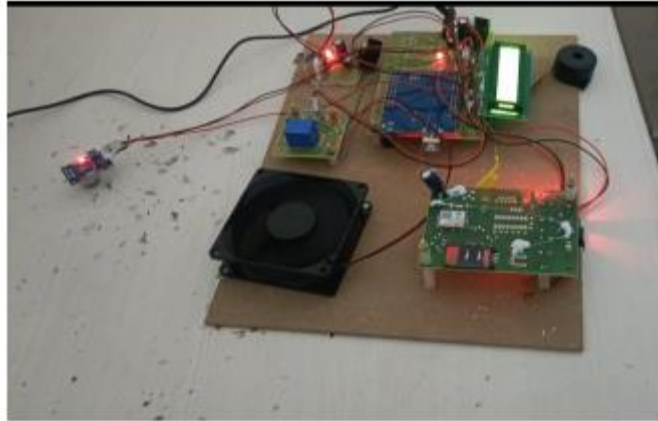


FIGURE 7. MQ-2 Sensor Active

### Output

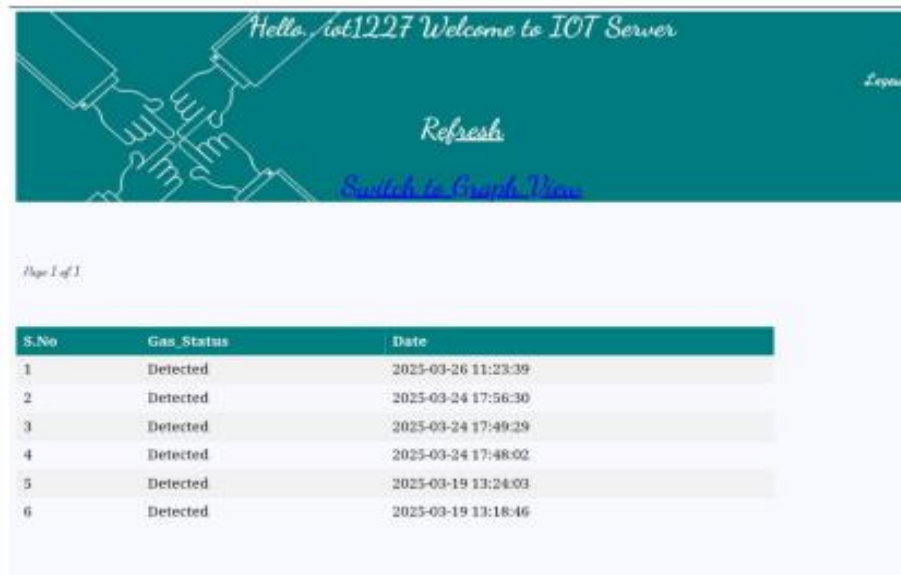


FIGURE 8. Notification of Smoke Detection

The project successfully detects hazardous gas leaks using the MQ-2 sensor and sends real-time alerts to a cloud-based IoT server via the ESP8266 module when gas concentration exceeds a threshold. The detected gas status along with the exact date and time is logged and displayed on a web dashboard for user monitoring and further action

## 7. ADVANTAGES, DISADVANTAGES AND APPLICATIONS

**Advantages:** This project offers several key benefits, beginning with real-time gas monitoring and alerting. Utilizing the MQ-2 sensor, the system constantly tracks gas concentrations. If the levels exceed the predefined safety threshold, it instantly activates a buzzer, updates the LCD display, and sends remote notifications. This rapid response mechanism ensures immediate awareness and enhances user safety. A significant improvement over conventional cloud-based models is the integration of edge computing, which enables local data processing on the Arduino Uno. This approach significantly reduces latency, allowing the system to react instantly without needing cloud confirmation. As a result, the system remains reliable even during network outages—making decisions locally means it can function seamlessly in areas with poor or unstable connectivity. Moreover, the system is cost-effective and energy-efficient. Built using affordable and readily available components like the Arduino Uno, MQ-2 sensor,

GSM or ESP8266 module, and buzzer, it operates with low power consumption, making it ideal for battery-powered or solar-driven applications. The compact hardware and simple design also mean that the system is easy to install and scalable. It can be deployed in homes, labs, kitchens, and industrial settings with minimal effort and can be extended to include more sensors or integrated with mobile apps and smart systems. Additionally, the system minimizes data transfer to the cloud, transmitting only critical alerts instead of continuous sensor data. This not only conserves bandwidth but also improves efficiency in IoT environments with data limitations. Lastly, its dual alerting capability—local (via buzzer and display) and remote (via SMS or Wi-Fi)—ensures both on-site users and off-site stakeholders are promptly informed, enhancing overall safety and responsiveness.

**Disadvantages:** Despite its advantages, the system has certain limitations. One challenge is the limited processing capability of microcontrollers like the Arduino Uno. While suitable for threshold-based logic, they lack the power to handle complex data processing or machine learning tasks on the edge.

Another issue is sensor degradation over time. MQ-series gas sensors may become less accurate due to factors like dust, temperature, and humidity, which could lead to false alarms or missed detections if not calibrated regularly. Also, network dependency for remote alerts remains vulnerability. While edge computing allows local action, users still rely on GSM or Wi-Fi networks for receiving SMS or cloud notifications. In the absence of network connectivity, remote alerts may fail to reach the user.

## Applications

**This smart gas detection system can be effectively deployed across various sectors:**

- Residential Homes and Apartments – Ideal for kitchens and enclosed areas where LPG or methane is used. The system helps prevent fires and suffocation by alerting residents promptly in the event of a leak.
- Restaurants and Commercial Kitchens – These environments use multiple gas burners, increasing leak risks. Real-time monitoring improves safety and helps establishments comply with safety regulations.
- Industries and Chemical Plants – In places dealing with flammable or toxic gases, early leak detection is critical. The system ensures continuous monitoring and can automatically activate alarms or ventilation using edge logic.
- Gas Storage Units and Filling Stations – For areas handling gas cylinders or refilling processes, the system helps detect leaks early, preventing pressure buildup and potential explosions.
- Hospitals and Laboratories – In locations handling medical gases like oxygen or nitrous oxide, the system maintains safety for healthcare professionals and patients by ensuring leak-free environments.
- Public Transport Depots – At bus depots or CNG refueling stations, the system can detect gas leaks from vehicles or filling lines, improving safety for both commuters and maintenance staff.
- Smart Cities and Smart Homes – The system can be integrated into broader smart infrastructure, offering live environmental data, automated emergency responses, and real-time notifications, thereby contributing to safer urban and residential spaces.

## 8. CONCLUSION AND FUTURE SCOPE

The developed IoT-based gas leakage detection system, enhanced with Edge Computing and 5G connectivity, stands out as a robust and intelligent safety solution for real-time gas monitoring. It effectively bridges the gap between sensing and emergency response, significantly reducing the risk of hazards caused by flammable gas leaks. By employing edge computing, the system processes data locally, enabling swift and accurate decision-making with minimal delay. This local processing capability ensures the system remains responsive even in the absence of network connectivity. The system utilizes the MQ-2 sensor to detect gases such as LPG, methane, and smoke, and promptly activates a buzzer and fan to mitigate danger. Simultaneously, it sends remote alerts via Wi-Fi or GSM using the ESP8266 module, providing both local and remote safety mechanisms. Designed for low latency and high reliability, the solution reduces the need for manual supervision while enhancing operational efficiency. Its application in both residential and industrial settings demonstrates its value in preventing gas-related accidents and improving public safety. Overall, the project showcases how the integration of IoT and edge computing can deliver an affordable, scalable, and highly effective safety system. Future enhancements of this IoT-based gas detection system aim to incorporate advanced technologies such as artificial intelligence, cloud analytics, and automation to

further improve its intelligence, responsiveness, and safety features. These advancements will enhance both the accuracy of detection and the system's ability to autonomously respond to critical situations. AI-Based Gas Type Identification: The integration of machine learning models will enable the system to distinguish between various gases (e.g., LPG, methane, carbon monoxide) and assess the severity of leaks, leading to more precise and context-aware responses. Cloud Connectivity and Real-Time Dashboards Through cloud integration, sensor data can be logged, visualized, and accessed remotely in real time. This will allow users and authorities to continuously monitor gas levels from any location, enhancing situational awareness. Edge AI Integration Combining edge computing with embedded AI algorithms will allow the device to detect irregular patterns and initiate actions immediately at the device level, further reducing reliance on the cloud and improving response time. Smart Home and Industrial Automation The system can be extended to interact with smart devices to automate safety measures such as shutting off gas valves, activating exhaust systems, or alerting emergency services—thus reducing human intervention and mitigating risk more effectively. 5G-Based Emergency Communication: Leveraging 5G technology will enable ultra-low latency communication with emergency responders, ensuring faster reaction times and improved coordination during hazardous gas leakage incidents.

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