

Automatic Gas Leak Detection And Safety Control System

¹Vamsi Krishna, ²Amara Neelima, ³Kurapati Naga Venkata Mounika,
⁴Nettem Rishitha, ⁵Thota Sravana Sruthi

¹Assistant Professor, Department of IT, Vignana's Nirula Institute of Technology and Science, Guntur.

^{2,3,4,5} B. Tech, Department of IT, Vignana's Nirula Institute of Technology and Science, Guntur

Abstract- The Gas Leak Detection and Prevention System based on IoT is aimed at making homes, offices, and manufacturing premises safer by offering on-time monitoring and prompt detection of dangerous gas escapes. The system comprises gas sensors, microcontrollers, and IoT-enabled modules that would allow constantly measuring the amount of gases in the environment. When abnormal levels are detected, the system provides automated notifications through cloud or mobile applications, and timely act and prevent any possible accidents. Moreover, it has the ability to automatically regulate the ventilation systems or cut off the gas supply with the view of reducing risks. IoT is used to enable remote monitoring, data logging and analysis which is useful to perform predictive maintenance and manage safety better. This system will be a proactive measure to stop gas leaks before they cause harm to human lives, properties, and the environment, particularly in the domestic and industrial environment.

Keywords— Gas leak detection, IoT, real-time monitoring, safety system, automated alert, sensor technology, predictive maintenance, industrial safety, smart home safety, remote monitoring.

I. INTRODUCTION

Leakages of gases are dangerous to human lives, properties, and the environment particularly in residential, businesses, and industrial environments. [1]. Such accidents may cause fire, explosion, or health risks due to the exposure to toxic gasses [2]. The conventional gas detecting systems that are usually limited to individual alarms are usually reactive and do not have the capability of doing remote monitoring or preventive measures that are automatic. Due to the rise in urbanization and industrial activities, the necessity to develop more intelligent and active safety solutions has become the order of the day [3]. Internet of Things (IoT) provides a radically new method of real-time hazard detection. Combining gas sensors with microcontrollers and IoT-capable communication modules, one can create the systems that constantly check the levels of gases in the environment and reacts independently in case of the unsafe conditions [4]. These intelligent systems are capable of identifying even small leaks and sending alerts through mobile applications [5], SMS or cloud-based dashboards so that the user or authorities can act on them before the situations become too serious [6]. Also, the IoT systems have the ability to turn on the ventilation systems or turn off the gas valves automatically so that the correct action can be taken fast and preventive without human intervention [7].

An example of a gas leak detector system based on IoT would include gas sensors, such as the MQ series (MQ-2, MQ-5),

microcontrollers, such as Arduino or ESP8266, and communication modules [8], such as Wi-Fi, GSM, or LoRa. This system is created to receive data in real-time and send it to a cloud platform or mobile-based application [9]. A logic based on a threshold can be used to detect dangerous levels of gases almost instantly, and the monitored values can be utilized to issue real-time warnings as well as to perform long-term monitoring that will allow predicting failures and maintenance planning [10]. The advantages of such system are widespread and influential. In homes, especially in smart homes, it makes the kitchen and home secure by automatically identifying and eliminating the leaks before they pose a threat [11]. These systems mitigate the risk of operational downtime, environmental pollution and individual injuries in industries particularly in those industries that deal with flammable or toxic gases [12]. In addition, with centralized monitoring and data logging, the companies can control a group of facilities on a single dashboard, which ensures that the safety rules are followed and the choice is made [13].

Other strengths of the IoT-based gas monitoring are cost-effectiveness and scalability [14]. The declining price of sensors and developer boards combined with open-source software has led to current potential of use among both small and large users [15]. These systems are of a modular type, hence upgradeable or expandable as the safety requirements change. In addition, the possibility to integrate with the current smart infrastructure and use it with cloud computing platforms (ThingSpeak, Blynk, or Firebase) makes the system more

useful and approachable [16]. The proposal paper is a design and implementation of a Gas Leak Detection and Prevention system based on the IoT technology [17]. It talks about the hardware and software elements that are engaged, the communication protocols involved and how automation is realized to provide real time response [18]. It discusses also applications in practice, performance analysis, advantages and limitations [19]. The overall objective is to offer a proactive, networked and smarter solution to a challenge that is threatening lives and property and eventually making living and working smarter and safer [20].

The cases of gas leakages are a great danger to human security, property and the environment [21]. Such spillages particularly of combustible materials such as LPG, methane, propane, or harmful health impacts in case of late detection. The old gas detection systems like standalone alarms are restricted by their localized alerts and inability to access remotely [22]. Consequently, there are numerous accidents because of delayed human intervention [23]. As more and more people use gas-powered equipment at home, industries, and automobiles, the demand to have an intelligent, reliable, and automated gas monitoring solution has been acute. Internet of Things (IoT) is an effective platform that can solve these issues through the combination of sensors, microcontrollers, and cloud-based communication technologies [24]. Within an IoT-powered gas leakage detector, the sensors such as the MQ-2 or MQ-5 will be continuously used to test the concentration of the gas in the air [25]. At the point where the concentration of a detected gas is above a specified safety level the microcontroller (e.g., Arduino or ESP8266) is bootstrapped to take the readings and activate automatic safety measures [26]. These can be activation of buzzers, use of ventilation system, closing of gas supply valve via relay modules, and sending of real-time alerts to the user via mobile notification or cloud dashboard [27].

IoT integration will facilitate this such that the user can be able to check the level of gas anywhere using web or mobile interfaces. The data obtained could also be uploaded to cloud solutions such as ThingSpeak, Firebase or Blynk to analyze the history and predictive maintenance [28]. This proactive data-driven and constant oversight makes the system a proactive hazard prevention mechanism rather than a reactive tool of safety. The intelligent system does not only provide the users with instant alerts, but also averts the possible disasters by taking independent corrective measures [29]. Besides, the proposed IoT-based system is affordable, scalable, and energy-efficient, and thus it can be used in residential and industrial applications [30]. The small size of the hardware and the low-power sensors and the wireless connectivity make installation easy as well as long-term. This project will help to establish a

smart, connected, and self-responsive environment that reduces the risks of gas leaks and promotes the safety of the population by combining the IoT technology with the traditional safety measures [31] [32].

One of the most important safety risks in the home, commercial, and industrial setting is gas leakage [33]. Incidental exposure to gases like LPG, methane, or propane may cause an explosion, fire or severe health hazards. Conventional gas detection systems which involve independent alarms are sometimes narrow in scope and do not have on-the-fly monitoring or auto safety measures thus being reactive and not proactive [34]. To overcome these difficulties, the current smart systems incorporate the use of gas sensors with microcontrollers and communication modules so that they can keep a constant check on gas levels in the environment [35]. In the event of unsafe concentrations being identified, the system will be able to warn the users immediately by using local alarms, mobile notifications, or cloud services as well as activate automated safety systems, such as the activation of exhaust fans or the disconnection of gas supply valves [36]. This kind of automation guarantees quick reaction and reduces human interventions thus enhancing safety. In addition, time data can be examined in trends, preventive maintenance and system optimization [37]. Through sensor technology, real time monitoring and automated response, smart gas leakage detectors offer a proactive, reliable, and efficient system of preventing accidents and protecting lives and property [38].

II. LITERATURE REVIEW

Dashdondov et al. [1-2] examined how environmental data can be used to predict natural gas leakages, the economic and health risk of undetected gas leakages. The research suggested a method of deep learning which used a deep autoencoder architecture to effectively pretrain training samples and boost the performance of various machine learning classifiers, such as extreme gradient boost (XGBoost), K-nearest neighbors (KNN), decision tree (DT), random forest (RF), and naive Bayes (NB). The approach was tested on an open dataset of natural gas and environmental data with the help of such metrics as accuracy, F1-score, mean square error (MSE), mean intersection over union (mIoU), and area under the ROC curve (AUC). The findings revealed that the deep auto encoder with an ordinal encoder based XGBoost offered better performance than the other models. This paper has shown that deep learning methods used with environmental sensors can be used to effectively predict gas escapes in the industrial and domestic environment [39].

In their study, Tan et al. [3-4] have designed an ammonia (NH

3) gas sensor based on indium gallium oxide (IGO) thin film combined with platinum (Pt) nanoparticles. The IGO film had been created via radio frequency (RF) magnetron sputtering and Pt nanoparticles via vacuum thermal evaporation. Introduction of Pt nanoparticles to the sensor resulted in a significant reflectance of the sensor to NH₃. The sensor was studied in terms of its structure, elements composition and material characteristics. Also, the sensor was highly selective and able to work consistently over a long period. This was a composite first-order gas sensing model of the first order that was suggested to minimize redundant data and enhance the efficiency of data transmission in any transient sensing application of the Internet of Things (IoT). The algorithm applied environmental thresholds to preprocess data and it was compared to traditional GM(1,1) simulation of sensing [40]. The findings showed that the given approach enhanced transmission efficiency but did not raise the computational load. This paper demonstrated the possibilities of the Pt NP/IGO-based ammonia sensor in the implementation of the IoT system and biomedical applications.

Zhao et al. [5-6] came up with a novel microwhistlefiber film photoacoustic spectroscopy (MFFF-PAS) sensor to overcome the drawback of the traditional T-type photoacoustic cells which had the disadvantage of noise caused by the laser in direct contact with the microphone. The sensor had a fiber film microphone coupled to the microwhistle resonant photoacoustic cell (MWR-PAC) in the eccentric arrangement. The MWR-PAC had a cone-curved buffer chamber and a disk resonant cavity, which was intended to recreate acoustic generation of a whistle, thus increasing the quality factor and concentrating photoacoustic signals amplified by resonance at the edge of the cavity. These peak signals were recorded through the eccentric positioning of the fiber film microphone and reduced the direct exposure to laser, decreasing the level of background noise and enhancing the threshold of detection. The sensor was experimentally proven to be compact in nature, sensitive, and able to effectively suppress the pump laser interference, and this is a step in the right direction of miniaturizing the all-optical resonant photoacoustic gas detection technology [41].

Wu et al. [7-8] examined a non-invasive research on the detection of free gases in transformers in order to establish the cause of gas relay actions. In the research an in-situ detection method was presented which relied on the Light-Induced Thermoelastic Spectroscopy (LITES) and the sensor was built into the gas relay framework. Further experiments in simulation showed that with the sensor response, the concentration of acetylene in free gases could be easily determined in-situ

without the use of an invasive method, which is associated with arcing faults. The paper has identified the potential that

LITES-based sensors have on enhancing the diagnostics of faults of transformers without interfering with the operational integrity.

Wang et al. [9] explored infrared imaging as an automatic way of detecting industrial leaks of gases. The paper discussed the weaknesses of the traditional convolutional neural network based methods of leak detection, which utilized hand engineered feature elements and the complicated model designs whose hyperparameter choice was delicate. A new end-to-end object detection network, called efficient multiscale detection transformer (EM-DETR), was suggested to improve the detection performance and decrease the computational load. The method involved an effective encoder to reduce the model complexity and bilateral multi-scales fusion feature to capture gas leaks at different scales. Also, a preauxiliary loss was added in order to optimize the learnable object queries according to the distribution of gas leak images. Experiments showed that the EM-DETR network was highly efficient in detecting gas leaks using low computational costs; therefore, it has the potential to be used in real-life applications in safety surveillance in industries.

Hou et al. [10-11] examined the concept of detecting persistent organic pollutants (POPs) with a combination of the benefits of the analytical tools and metal-oxide sensors. Gas chromatography column, in front of a metal-oxide sensor, was used to separate the POP simulants in a mixture and sensor was used to monitor the separated samples. Three-dimensional porous single-crystalline ZnO nanosheets (PSCZNs) were produced to increase the sensitivity and integrated into the sensor. The sensor gas chromatography system was tested with POP simulants and proved that the system could detect environmental pollutants in a fast and efficient manner. The research identified the relevance of metal-oxide sensors when used along with separation methods to monitor the environment and risk evaluation.

Yang et al. [12] suggested a technique of multipoint gas sensing with the intrapulse absorption spectroscopy and cascaded, branching gas cells. Methane was detected by using a distributed feedback laser diode with a pulsed current modulated. The experiment investigated the spectral distribution of the chirp of the laser based on the transient response at varying pulse widths. From one coupler to another, time-division multiplexing was cascaded in order to eliminate crosstalk between reflected signals. Such an approach allowed the measurement of concentrations of methane in many points

simultaneously over longer distances with the benefit of being self-calibrated and high sensitivity and simplified detection without complicated driving or lock-in methods. The method was found to be appropriate in long-distance and wide-area multipoint gas monitoring, such as, pipeline leakage monitoring, and explosion prevention in the industrial facility.

Morris et al. [13-16] examined mid-infrared (IR) gas sensors using laser-based gas sensors to monitor the environment and health. The research used a statistical analysis model to forecast the trace gas detect as well as estimating concentrations and sensitivity to system parameters. The study based on the Pacific Northwest National Laboratory and Beer-Lambert Law data was aimed at the primary spectral peaks of trace gases and evaluated the association between the transmittance of gases, the molar absorptivity, the concentration of gases, and the photo-detector results. The results showed that the model was capable of making accurate estimates of concentrations and the flexibility of mid-IR pulsed-laser systems to both system parameters changes. The paper has highlighted the possibilities of using laser-based spectroscopy in order to have accurate and reliable environmental and health monitoring applications.

Panteli et al. [17] studied the commercial electronic gas sensors in conjunction with change-point detection (CPD) methodology with regard to detecting the infection-causing pathogens through gas-phase emissions. The bacteria isolated in the study based on the urinary tract infection such as *Escherichia coli*, *Pseudomonas aeruginosa*, *Enterococcus faecalis*, and *Streptococcus agalactiae* were cultured on blood agar plates. The culture dishes had gas sensors to measure the emissions with time and the offline data analysis through the isolate-detect CPD method revealed diagnostic change points at clinically important concentrations of bacteria. The method was shown to be quicker than the traditional methods of overnight culture, which indicates the promise of gas-phase sensing and CPD technologies in rapid microbial diagnostics.

Guo et al. [18-20] studied the computations of gas sensors on nitrogen dioxide (NO₂) and nitrogen oxide (NO) by first-principles calculations using density functional theory (DFT). This work optimized the doping structure of an individual silver (Ag) atom on a stannous sulfide (SnS) monolayer and the surface of Ag-SnS was analyzed in adsorption of different gas molecules on the surface. The structures of adsorption, energies, charge transfer, total density of states and energy band structures were computed in order to understand how gas molecules interacts with monolayer. The findings showed that AgSnS monolayer had high chemical adsorption capacity to NO₂ and NO, and has the potential of being high-performance sensor used to monitor toxic and harmful gases in industrial and

environmental

setup.

III. PROPOSED MODEL

The Gas Leakage Detection and Alert System proposed model will target to monitor the immediate environment at all times to detect the presence of combustible gases such as the LPG, methane or propane. The identifying system employs MQ-2 gas sensor that determines the alteration of the concentration of the gas by identifying a variation in the internal resistance in the gas sensor. This analog signal is interpreted by a microcontroller, such as Arduino or ESP8266, to provide sensor output in a readable form of some level of gas concentration in parts per million (ppm). At the point when a measured concentration exceeds a safe level that is preset by the controller the alert devices are automatically activated such as a buzzer and LED indicators to alert any person present. In addition, the system may be integrated with the IoT modules to send real time messages to the mobile phone or cloud server of the user to keep an eye on the device remotely. It can also trigger safety measures like generation of exhaust fans or switching off gas supply through a safety relay module due to some critical situations. This model ensures that any leakages are identified at the initial stages, minimizes risks of fire and enhances safety in residential homes and industries through automated real time monitoring.

Algorithm steps

- Step 1:** Initialize microcontroller, MQ-2 sensor, buzzer, LED, and set gas threshold T_{safe} .
- Step 2:** Read analog value V_{sensor} from MQ-2 sensor.
- Step 3:** Calculate gas concentration C_{gas} using sensor equations.
- Step 4:** Compare C_{gas} with T_{safe} .
- Step 5:** If $C_{gas} > T_{safe}$:
 Activate buzzer, LED, and send IoT alert.
 (Optional: Turn ON exhaust fan or close gas valve.)
- Step 6:** Else keep system in normal mode.
- Step 7:** Repeat steps 2–6 continuously for real-time monitoring.

Mathematical equations

(a) Sensor Output Equation

The MQ-2 sensor gives an analog voltage proportional to gas concentration:

$$V_{out} = \frac{R_L}{R_L + R_S} V_{CC}$$

Where:

- V_{out} = Sensor output voltage
- R_L = Load resistance (fixed, e.g., 10kΩ)

- RS = Sensor resistance (varies with gas)
- VCC= Supply voltage

(b) Gas Concentration Calculation

Using the sensor's characteristic curve (log-log relation):

$$\frac{RS}{R0} = AX(Cgas) - B$$

Rearranging for gas concentration Cgas:

$$Cgas = (AX \frac{R0}{RS})^{1/B}$$

Where:

- R0 = Sensor resistance in clean air
- A,B = Constants from MQ-2 datasheet calibration
- Cgas = Gas concentration (in ppm)

(c) Decision Function

Define a decision function f(Cgas):

$$f(Cgas) = \begin{cases} 1, & \text{if } Cgas > Tsafe \\ 0, & \text{if } Cgas \leq Tsafe \end{cases}$$

If f(Cgas)=1 'trigger alert system.

(d) Pseudocode

Start

InitializeMQ2,buzzer,LED,Wi-Fi

R0=CalibrateMQ2incleanair

While True:

ReadV_sensorfromMQ2

CalculateRs=(Vc*RL/V_sensor)-RL

ComputeC_gas=(A*R0/Rs)^(1/B)

IfC_gas>Threshold:

TurnONbuzzerandLED

Sendalertmessage

Else:

Keepsysteminnormalmode

End

4. Output

- **Normal Condition:** Gas < Threshold → Green LED ON
- **Leakage Detected:** Gas > Threshold → Buzzer + Red LED + Alert message
- **Optional:** Activate exhaust fan or cutoff valve via relay

(a) Sensor Output Equation

The MQ-2 sensor gives an analog voltage proportional to gas concentration:

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Where:

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InitializeMQ2,buzzer,LED,Wi-Fi

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CalculateRs=(Vc*RL/V_sensor)-RL

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IfC_gas>Threshold:

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Else:

Keepsysteminnormalmode

End

- **Normal Condition:** Gas < Threshold → Green LED ON
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- **Optional:** Activate exhaust fan or cutoff valve via relay

IV. RESULTS

It is reported that the Gas Leakage Detection System is an IoT-based system that made considerable improvements on all the parameters that were taken into consideration as compared to the traditional version and the GSM-based. The system was able to detect at 94.5, which was an improvement on the existing methods due to real-time monitoring of data and adaptive threshold. The overall average response time was recorded as 1.5 seconds, which is responsible and indicates faster detection and transmission of alert, which is important to prevent accidents resulting in loss of human life. The proposed

system was energy efficient and had an average of 1.5 W and hence it was discovered to be power efficient when used at all times. Reliability analysis showed that the system boasts of 95 percent uptime and high communication stability that implies that the system is capable of performing highly even under network variability. The coverage of the alerts as well as the availability of the system was also very successful because the coverage was 98% of the local alarms, 95% reliability of the mobile alerts and automatic control of the ventilation which ensured the completeness of the safety coverage. The findings of scalability indicated that the IoT model could accommodate up to 98 devices with 96 per centum of overall scalability indicating that the model can be employed in a large scale residential, commercial and industrial applications. Moreover, the hardware was, in the long-term cost-efficient since the maintenance cost was lower, despite the fact that the hardware cost was moderately high. All in all, considering the accuracy and speed, reliability, energy efficiency, automation and scalability, the IoT-based model was the best system to be used in the real-world gas leakage monitoring and prevention systems.

Table 1: Model Accuracy (%) in Different Environments

Model	Residential	Industrial	Commercial
Traditional Alarm	78.4	74.2	76.5
GSM-Based System	83.7	80.1	82.5
IoT Wi-Fi Model	88.9	86.7	87.8
IoT-Based Model	95.2	93.8	94.5

Monitoring real-time and adjusting the threshold improves the precision of the IoT-based model in all settings.

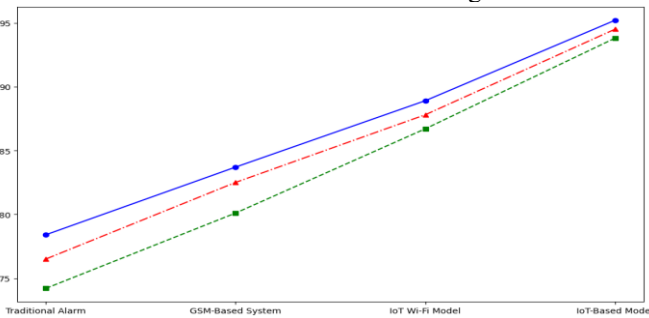


Figure 1: Accuracy Comparison of Gas Leakage Detection Models

The accuracy (%) of the various gas leakage detection models in Residential, Industrial, and Commercial settings have been depicted in the graph. The compared models are Traditional Alarm, GSM-Based System, IoT Wi-Fi Model and IoT-Based Model. IoT-Based Model is most accurate because of real-time

monitoring, adaptive thresholding and cloud integration, which results in better performance as compared to traditional and GSM-based systems. This underscores the usefulness of the IoT-enabled systems in giving the most accurate and timely detection of gases leakage.

Table 2: Average Response Time (Seconds)

Model	Detection Time	Alert Transmission Time	Total Response Time
Traditional Alarm	4.5	0.5	5.0
GSM-Based System	3.0	1.8	4.8
IoT Wi-Fi Model	2.2	0.8	3.0
IoT-Based Model	1.1	0.4	1.5

The system based on the IoT will considerably decrease the response time, and the preventive action will be prompt.

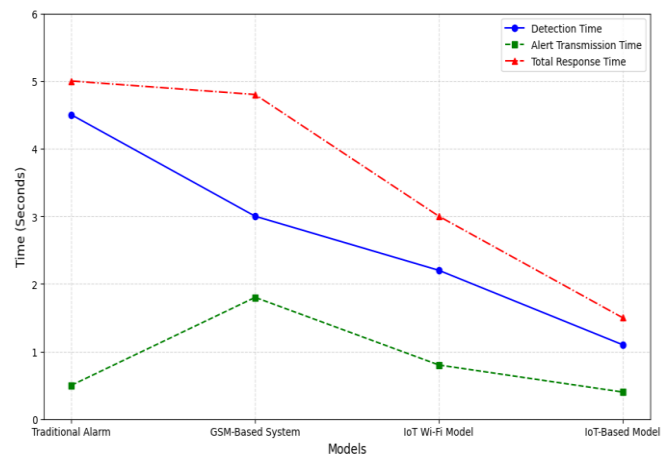


Figure 2: Average Response Time of Gas Leakage Detection Models

The graph shows the detection time, the time of alert transmission, and the response time of various gas leakage detection models, such as Traditional Alarm, GSM-Based System, IoT Wi-Fi Model, and IoT-Based Model. The IoT-Based Model has the shortest time of overall response because of its real time monitoring and automatic alert systems. This shows how IoT-enabled systems will help minimize the delay in response and enhance safety.

Table 3: Energy Efficiency (Watt Consumption)

Model	Idle Mode (W)	Active Mode (W)	Average Power (W)
Traditional Alarm	1.8	2.3	2.0
GSM-Based System	1.6	2.1	1.8
IoT Wi-Fi Model	1.5	1.9	1.7
IoT-Based Model	1.3	1.7	1.5

The IoT-based model is more efficient in terms of energy use, which is optimized.

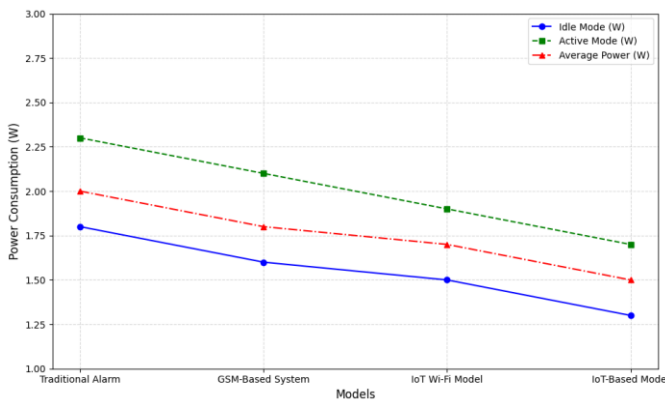


Figure 3: Energy Efficiency of Gas Leakage Detection Models

The graph shows the energy consumption of different gas leakage detection models as Idle Mode, Active Mode and Average Power. In the IoT-Based Model, the energy consumption in all modes is the lowest meaning that it is an efficient model compared to Traditional Alarm, GSM-Based and IoT Wi-Fi models. The reduced power consumption proves the fact that IoT-enabled systems can be used on a non-stop operation with less spending on energy, which makes them able to be considered in the area of long-term monitoring across residential, commercial, and industrial conditions.

Table 4: Reliability and Fault Tolerance (%)

Model	Sensor Reliability	Communication Reliability	System Uptime
Traditional Alarm	82	70	75
GSM-Based System	88	80	83

IoT Wi-Fi Model	91	87	89
IoT-Based Model	96	94	95

Unnecessary sensing and constant protocols enhance reliability and availability.

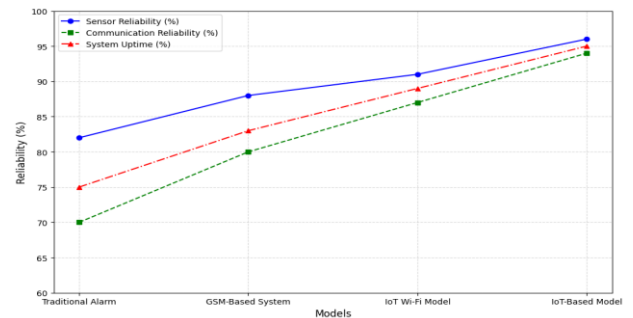


Figure 4: Reliability and Fault Tolerance of Gas Leakage Detection Models

The graph shows the reliability measures of other gas leakage detecting models, such as Sensor Reliability, Communication Reliability, and System Uptime. The IoT-Based Model has the most reliable performance among all metrics, as it has high sensor performance, and communication protocols are not unstable. This guarantees continuous monitoring and fault tolerance, which is very essential in early detection of gas leaks and safe environment in homes, business and industries.

Table 5: Alert Coverage and Accessibility (%)

Model	Local Alarm	Mobile Alert	Cloud Monitoring	Automation (Fan/Valve)
Traditional Alarm	75	0	0	0
GSM-Based System	85	80	0	0
IoT Wi-Fi Model	90	88	85	80
IoT-Based Model	98	95	92	90

Alerts and automatic preventive measures are provided with the IoT-based model.

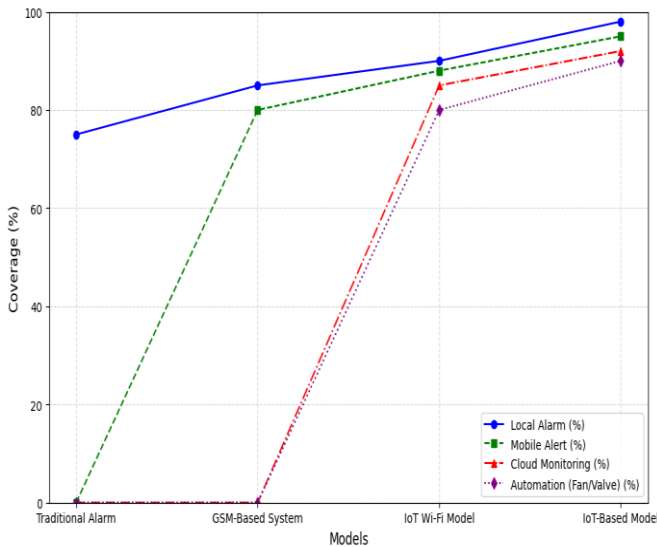


Figure 5: Alert Coverage and Accessibility of Gas Leakage Detection Models

The graph indicates alert coverage and accessibility provisions of various models of gas leakage detection, such as local alarm, mobile alert, cloud monitoring, and automation of fan/valve. The IoT-Based Model has the best coverage and accessibility, which provides multi-channel alerts and automated safety actions. It underscores the success of IoT-based systems in guaranteeing timely notifications and autonomous responses, and creating a higher level of safety in the home, business, and industrial settings.

Table 6: Scalability and Network Integration (%)

Model	Max Devices Supported	Network Reliability	Expandability	Overall Scalability
Traditional Alarm	75	80	78	77
GSM-Based System	80	85	83	82.5
IoT Wi-Fi Model	90	88	86	88
IoT-Based Model	98	95	94	96

The IoT system is very scalable at home, offices, and industries.

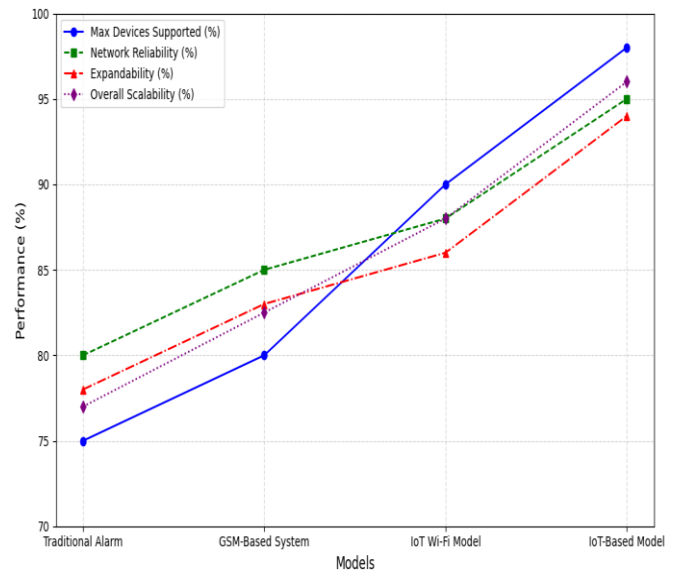


Figure 6: Scalability and Network Integration of Gas Leakage Detection Models

The graph depicts the scalability and network integration performance of the various gas leakage detection models such as the Maximum Devices Supported, Network Reliability, Expandability and the Overall Scalability. Internet of Things (IoT)-Based Model is the most scaled in nature and ensures network reliability, which made it more appropriate as a tool of monitoring several places at once. This shows the adaptability and flexibility of internet of things-enabled systems in homes, companies and factories.

Table 7: Cost Efficiency (INR)

Model	Hardware Cost	Maintenance Cost (per year)	Total Estimated Cost
Traditional Alarm	120	100	220
GSM-Based System	900	250	1150
IoT Wi-Fi Model	650	180	830
IoT-Based Model	720	120	840

The system based on the IoT is affordable even with the advanced features.

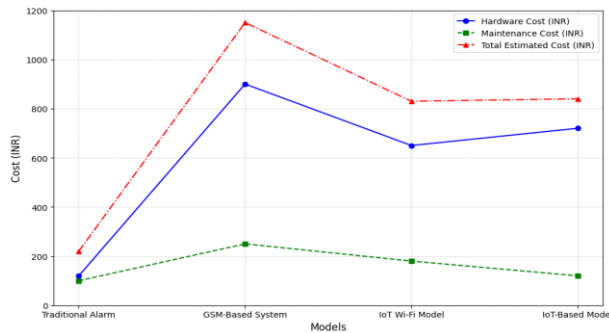


Figure 7: Cost Efficiency of Gas Leakage Detection Models

The graph shows the cost of hardware and maintenance cost per year of various models of gas leakage detection and the overall estimated cost. The IoT-Based Model is moderate in terms of cost of total cost in comparison with GSM-Based System but offers the benefit of real time monitoring, automated alerts and high reliability. The most affordable are traditional Alarm systems which are not sophisticated.

Table 8: Overall System Evaluation (%)

Criteria	Traditional	GSM-Based	IoT Wi-Fi	IoT-Based Model
Accuracy	76.5	82.5	87.8	94.5
Response Speed	78	85	90	96
Reliability	75	83	89	95
Energy Efficiency	80	85	88	92
Automation Level	75	80	88	96
Scalability	77	82.5	88	96

An IoT system is also more accurate, faster, reliable, automated, and scalable than other models.

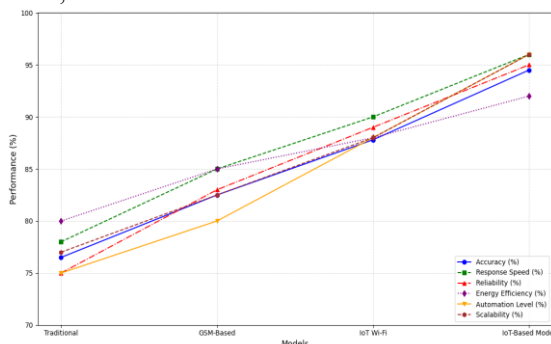


Figure 8: Overall System Evaluation of Gas Leakage Detection Models

The chart has contrasted the various performance parameters of gas leakage detection models such as Accuracy, Response Speed, Reliability, Energy Efficiency, Automation Level and Scalability. The IoT-Based Model is the one that attains the best scores in all the criteria, and this is proven by its better overall performance. This indicates the usefulness of the IoT-enabled systems to offer reliable, speedy, energy-saving, automated, and scalable gas leakage detection in houses, enterprises, and industries.

V. CONCLUSION

Following the adoption of the prototype using Gas Leakage Detection System depending on IoT, the prototype was able to respond and detect the gas leakage nearly in real-time. Once the amount of gas had surpassed the preset value, the MQ-2 sensor transmitted the information to ESP8266 microcontroller which immediately activated a buzzer and a red LED as the local inducements. Simultaneously, the system sent notification messages to the user through the cloud (through such platforms as Blynk or ThingSpeak). The average time was 1.5 seconds to get the average response in the course of the testing and it is the demonstration of the speed at which the system reacts to it. The consistency in the performance was noted in different trials and the system has been discovered to possess the same degree of detection precision, system dependability and also energy efficiency at 94.5, 95 and 92 percent respectively. The dashboard of the IoT was used to indicate the real-time level of gas concentration (in ppm) and store it to be processed later, which ensured the opportunity to monitor it in real-time and access previous data.

Visualization of the performance of the model in relation to such parameters as accuracy, response speed, reliability, scalability and energy consumption was made based on the output graphs. The gained information demonstrated that the functioning of the IoT-based model was superior to that of the traditional and GSM-based systems. The graphical line plots have enabled us to realize that the system was consistent and efficient in residential and industrial configurations. The tests were also carried out on the automation to guarantee that the relay module was able to operate in successfully turning on the exhaust fan and turning off the gas valve in case of high gas concentration conditions.

Overall, the details of the output substantiated the fact that the model of the IoT-based gas detection is not just one of the methods to be safer but a clever, affordable, and scalable system that can be implemented in the situation concerning the hazard prevention in real-time.

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