Advancements in gas leakage detection and risk assessment: a comprehensive survey

Y. Bhavani, Sanjusree Vodapally, Dinesh Bokka, Harshitha Varma Muddasani, Deepika Kasturi
Department of Information Technology, Kakatiya Institute of Technology and Science, Warangal, India

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ABSTRACT

Gas leakage is the main problem that harms the environment, infrastructure and public safety. Technology is increasing rapidly nowadays. So, there must be advancements in the methods used. Many methods have been come across to solve this problem. This survey paper explores various methods and technology used to solve the problem. Many methodologies have been suggested to reduce the risk of gas leaks and improve detection systems. It investigates cutting-edge models for estimating the effects of liquefied natured gas (LNG) leakage accidents, comprehensive wireless sensor network (WSN) is set up for detecting gas leaks in advance, and neural network and Kalman filter-based gas leakage early warning systems. Current developments include factors like point of interest (PoI), human data movement and gas pipelines. As technology increases, there would be major threat of authentication. So, it also looks on methods for user authentication based on different patterns to mobile applications. Especially in smart home environments, there is a need to improve security. This survey provides complete understanding of present and future directions for the researchers in gas leakage detection and risk management through various methods and their evaluation.

Corresponding Author:

Y. Bhavani
Department of Information Technology, Kakatiya Institute of Technology and Science
Warangal, Telangana, India
Email: yerram.bh@gmail.com

1. INTRODUCTION

Integrating technology into our homes to make them smart and secure is crucial. Safeguarding our homes from potential damage and accidents is paramount. In many countries, liquid petroleum gas (LPG) is widely used for economic reasons. However, detecting gas leaks is a major concern for users, as it can lead to frightening outcomes. Installing fire detection and security systems, along with gas leak detection systems, is essential. These automated security measures not only protect people from hazardous explosions but also help prevent accidents altogether.

Gas leakage leads to various hazards and provides many difficulties. It is very important to identify the suitable method for gas leakage detection. The methods that are existing require more human labor. This can cause many errors in the system, or the result may not be accurate. By using pipeline network [1] [2], which includes all factors like data, human motion, and point of interest (PoI) risk factors can be detected. This network is complex to construct and unknown leakages may happen. To avoid these limitations urban sensing techniques are used which helps to extract the environmental data from patterns of human movements. Neural networks are created by combining all the factors used to evaluate risk. This helps to identify the possible leak locations through practical experiments. All these methodologies increase the efficiency and accuracy of gas leak detection and provide accurate results of risk assessment.

The demand for liquefied natured gas (LNG) has increased. The leakage hazards also increased as more LNG gas is produced [3]. Control system will provide adjustments for the systems that help to detect the extent of leakage. But emergency requirements are not fulfilled i.e., if there is an increase in the extent of leakage, it will not stop automatically. Leakage volumes and consequences should be properly estimated to analyze the risks. HYSYS and FLACS models [4], [5] are used to estimate spill flow rates and generate forecast outcomes like vapor explosion and pool fires. This strategy is also compared with the traditional methods and proved to generate more accurate results by taking different factors into consideration.

The existing methods explained have many disadvantages where the construction of gas leakage system is complex for the existing methods, and the results of a few methods are not accurate. With respect to the earlier methods, we suggested an internet of things (IoT) network that detects gas leakages in the atmosphere. The network construction is not complex as compared to the existing systems. This helps to detect gas leaks prior and avoid major consequences. This method is an integration of software and hardware components. The gas leaks are detected with the help of sensor in the IoT network. If the sensor detects the gas leaks, then a smart ventilation system will be enabled to prevent damage. This ventilation system can be operated through the web application. The system ensures security with authentication techniques. The data related to the system will be available in the cloud so that it can be used remotely. This method can be easily understandable to the user as it does not include complex models and patterns.

This paper is organized as follows, introduction is given in section 1, section 2 elucidates methodology. Section 3 compares and illustrates existing work and section 4 results and discussion. Section 5 provides conclusion.

2. METHOD

Practical trials are very important for the verification of accurate results. Intelligent risk assessment system requires real world situations to be implemented in an efficient manner. The efficiency of the system increases with practical experience. The outcomes of these tests will specify the importance of the system and provide the ability to improve utility network. Real time experiments help to demonstrate the gas leakage risk and identify the possible leakage locations ensuring safety.

The proposed system integrates both software and hardware components. An IoT network is constructed with the help of devices like MQ5 sensor, DC motor, ESP 8266, load cells, relay, global system for mobile (GSM) module, capacitors, load cells connected to electric circuit, transistors, resistors, and battery. ESP 8266 module enables the system to connect to Wi-Fi. Load cells are used for the calculation of weight. GSM module is used for sending short message service (SMS) to the user, a sim is to be inserted into it for user interaction. MQ5 sensor is responsible for the detection of gas leaks. DC motor works as the ventilation system in the prototype of the network construction. Load cells are used to find the weight of the gas, for example we can know the weight of the gas contained in the gas cylinder with the help of load cells. Relay module helps to switch electrical devices.

Arduino IDE is used for coding to the IoT network. Required libraries like ArduinoIoTCloud, Arduino_ConnectionHandler, Arduino_ESP32_OTA, GSM, Arduino_DebugUtils, ArduinoMqttClient, Esplora, Arduino_AVRSTL are to be installed in Arduino IDE. We need to set up a board ESP8266 in the Arduino IDE. This software system is connected to the IoT network. Both ESP and the system should be connected to the same Wi-Fi network to ensure authentication. After execution of the code we can know the value of gas which is below or above threshold, weight of the gas remaining and status of the system. The complete sketch will be saved in the Arduino cloud, and it can be used anywhere through the cloud. A particular username and password will be given to the cloud to ensure security. In Arduino cloud, a device can be created from the dashboard so that it can be operated through the mobile application. A specific Wi-Fi name and password should be given so that only authenticated users can operate the system.

Firstly, the system and ESP 8266 should be connected to the specified Wi-Fi. If there is any gas leakage detected by the sensor then immediately the light will “on” in the relay module. The smart ventilation system i.e., DC motor in the prototype will be enabled. The weight of the gas is calculated by the load cells. If the weight of the gas is less than the specified threshold value, then an alert of gas booking is sent to the user. Alerts are sent to the user to the specified mobile number. We can know the gas value, gas weight, whether the SMS is sent, whether the system and device is connected to Wi-Fi and the working of the system through serial monitor in Arduino IDE with the help of port.

According to the survey, various methods are used for the demonstration of gas leaks, risk analysis, advancements in the gas leakage detection systems, authentication using mobile application patterns. Each method has its own advantages as well as disadvantages. Some of the methods which were in the existing papers are described below.

2.1. Gas leakage risk assessment in utility networks

Gas leakage is one of the major risks in utility networks [6]. These systems use human labor procedures which reduce efficiency. The risks should be reduced but these systems reduce the scope of assessments inside the gas pipeline network. Hence it is mandatory to create automated technologies that evaluate the network accurately and identify the high-risk locations quickly. Research [7] suggests an intelligent system for assessing the risk which overcomes the disadvantages of previous methods. This system uses exclusive multi source data.

2.2. Challenges in gas leakage risk assessment

An effective risk assessment system is very complex to construct as it has to deal with various factors. The leakage mechanism may not be clear to predict the risk [8], [9]. Environmental conditions are also considered as major challenges. The nature of pipeline network is also a major factor to be considered. Internal features and external environmental features should be combined to address these challenges. This technique [10] builds a joint learning neural network that helps for accessing leakage risk efficiency using Internal features and external environmental features. All these challenges are to be faced to develop a flawless system with high performance capability and monitoring ability.

2.3. Advancements in gas leakage detection systems

Previous methods of gas leakage detection systems employed individual nodes without coordination or enhancement. To address this, a fully integrated wireless sensor network (WSN) system has been introduced [11], incorporating IoT technology for improved monitoring and early warning capabilities. This integrated system enhances performance, providing greater precision in identifying and alerting to gas leak occurrences.

2.4. Innovations in gas leakage early warning systems

The main outcome of any system will be accuracy. Accuracy and precision are limited to a specific extent for the traditional approaches [12]. To improve the accuracy a unique approach is identified based on back propagation neural networks (BPNNs) and Kalman filters. This approach uses long short-term memory (LSTM) and support vector machine (SVM) models for the improvement of the accuracy and to predict gas concentration.

2.5. Continuous authentication using mobile application patterns

Authentication is the major problem in building a device [13]. There are many ways to malfunction the data by accessing the data in an unauthorized manner. To protect the data from such activities, we need to provide security for the data. It is possible by authentication techniques. Authentication techniques which depend on static credentials will increase the security risks. This study suggests a method for user authentication and identity based on mobile application patterns to increase the authentication capability. The security protocols are improved with the high precision values. Inside smart home setting, this model analyses the patterns which are identified by application. Hence a high precision value to be produced that helps to strengthen the security protocols.

2.6. Optimization in IoT environments for smart home systems

IoT uses efficient processing of sensor data [14], [15]. IoT technology uses multiple sensors for the effective communication between the devices. IoT completely works with the internet facility. The data can be accessed from anywhere with the help of internet. This helps smart home systems to respond effectively to user needs. Several join operators are optimized, and SVM classification technologies are used to improve the effectiveness of processing sensor data. This system identifies various conditions and helps to manage devices. The system improves convenience and efficiency in smart home environments, resulting in enhancement.

3. RELATED WORK

Many researchers proposed different methods gas leakage detection and risk assessment. In this paper we provided a complete understanding of present and future directions for the researchers who can perform their experiments in a right direction and achieve the goal of finding better algorithms for detection of gas leakage. Liu *et al.* [16] discussed the serious problem of sulfur hexafluoride (SF6) gas leaks in cities, emphasizing the risk of mass fatalities and suffocation. It suggests a methodical procedure for keeping an eye on, alerting, and responding to SF6 leaks in substations in an emergency. The concentration distribution of SF6 gas that has escaped is examined using computational fluid dynamics (CFD) models to pinpoint vulnerable regions and establish sensor monitoring locations. The development of an efficient emergency response system is made possible by the establishment of a prediction model for SF6 diffusion concentration. The technique incorporates safety management data to enable prompt identification of necessary emergency actions when they arise. Bu *et al.* [17] employed computational modeling to investigate how natural gas leaks and spreads within utility tunnels under different operational scenarios, including varying pressures, leak sizes, ventilation configurations, and leak locations. Their study sought to offer valuable insights into routine maintenance practices and strategies for preventing accidents.

Salameh *et al.* [18] experimental testing demonstrates the robust and reliable performance of the integrated WSN system, which is an important feature. Remarkably, the system maintains effective data transmission and communication between network nodes with a packet loss rate of less than 5%. Furthermore, the system responds very quickly; in just 50 milliseconds, gas leaks can be detected. Gas concentration measurements have an impressive 97% accuracy rate, which is particularly noteworthy. Overall, the experimental findings support the viability of the suggested system and demonstrate how much it may improve early warning gas detection and monitoring capabilities.

Ralevski and Stojkoska [19] devised an economical IoT system aimed at swiftly identifying household fire and gas leaks. They demonstrated a simulated scenario wherein detect the escalating risk of a kitchen fire by monitoring temperature and gas concentrations. To streamline communication and minimize data transmission, they implemented a time series forecasting method using a moving average prediction scheme.

Juwari *et al.* [20] investigated the external elements affecting the spread and explosion potential of natural gas, employing FLACS software. They examined variables such as wind direction, the width of vented enclosure holes, and the existence of obstacles. Meanwhile, Bauwens *et al.* [21] carried out experiments involving ventilated explosions with propane-air mixtures. Their research focused on studying how vent size, ignition location and obstacles influenced the progress of explosions that are buildup of pressure.

Zandi *et al.* [22] investigated natural gas leaks resulting from pipeline. Examine the features that contribute to increased gas concentration in each environment and their impact on the explosion zone. To validate the accuracy conducted real-life tests with the Isfahan Gas Company in Iran and compared experimental results with numerical solutions. Variables like burst size, pipeline pressure, wind velocity, and soil permeability are crucial features influencing this issue. Their simulations reveal that higher pipeline pressures and larger rupture diameters lead to boost in the height of the explosion zone. DeFriend *et al.* [23] suggested a novel approach for detecting and assessing the risk from various representative leakage scenarios rather than relying solely on worst-case evaluations.

Wang *et al.* [24] in their approach presents a digital twin model of pipelines, utilizing pressure signals generated by leaks to enhance leak detection. A visual model is created that provides real-time display of spatial data from pipeline physical information alongside digital twin output data. Upon leak detection, an alarm is activated, triggering an emergency response plan. Additionally, a pipeline leak identification model is developed by analyzing finite element model of the pipeline. The test data is collected, preprocessed, and feature vectors are extracted. SVM training models are employed to classify operational conditions. Theoretical analysis and investigational results show the high detection accuracy of their method, indicating the feasibility of using digital twin predictions for gas pipeline leak detection.

Zheng *et al.* [25], concerns regarding possible leakage risks during off-loading procedures are brought to light by the growing number of LNG facilities being built. To address this, a thorough strategy combines the FLACS and HYSYS models for precise evaluation. To begin with, a HYSYS model determines spill flow rates in various scenarios both with and without the assistance of a basic process control system (BPCS). Second depending on spill flow rates, weather, and substrate type, FLACS model forecasts outcome including vapor bursts and pool fires. Simulations show that the HYSYS–FLACS model outperforms other methods in forecasting bigger equivalent stoichiometric clouds (Q9) and pooling regions via six scenarios. This integrated model helps with emergency response and mitigation efforts by offering a more accurate evaluation of the dangers related to unscheduled LNG emissions.

Wang *et al.* [26] studied the processes involved in the release and spread of gas from small openings under both natural airflow and forced ventilation conditions using fluent software. Liu *et al.* [27] utilized CFD to restrict natural gas leaks in three distinct configurations. Their study evaluated gas concentration levels and identified potentially hazardous zones, providing insights for the design of buildings and pipelines.

Zhao's method merges the altered gaussian plume model with unmanned aerial vehicles (UAVs) equipped with laser methane sensors, alongside the Markov chain Monte Carlo method based on Bayesian inference [28]. Unlike conventional approaches, their method enables simultaneous determination of both the location and magnitude of pipeline leaks. They conducted convergence diagnostics and model assessments on the inversion model to verify its rationality and viability. Liu *et al.* [4], employed FLACS to model how various factors, such as leak locations, weather conditions, and process parameters, influence gas dispersion.

They utilized mixed integer linear programming (MILP) to optimize the placement of gas detectors in petrochemical facilities based on their simulations.

Vázquez-Román *et al.* [29] simulated leakage scenarios using Ansys-Fluent and recommended detecting potential releases 2 meters away from the source to prevent gas concentrations above 20%. Zhou *et al.* [30] introduced multi-objective optimization technique by placing detectors, which considers both leakage scenarios and consequence modeling to achieve an optimized placement strategy. Kelsey *et al.* [31] conducted simulations to optimize a network of gas detectors, considering factors such as detector alarm levels and response times to get better results for detection system.

Jeon *et al.* [32] employed a deep neural network-based surrogate model along with MILP to optimize the allocation of detectors. Rad *et al.* [33] optimized detector layouts based on risk assessments and detector arrangements. Vianna [34] suggested a method to enhance the efficiency of gas detector deployment by utilizing the color pattern of the set coverage problem graph. Table 1 [25], [35]-[42] shows some more gas leakage detection and risk assessment systems with advantages and disadvantages. Furthermore, scholars like Zhang *et al.* [43], [44], Benavides-Serrano *et al.* [45], Cheng *et al.* [46], Seo *et al.* [47], and Sun *et al.* [48] combined CFD simulation with stochastic programming (SP) to propose optimal detector layout schemes.

Table 1. Comparison of some advanced gas leakage protection systems

Author	Methodology	Advantage	Disadvantage
Hassan *et al.* [35]	Effective user application protocols are used with a key agreement. It uses various cryptographic techniques to ensure and provide security.	It deals with various cryptographic techniques in a flexible manner.	Traditional security checks will not provide efficient results in handling unauthorized access and results in cryptographic weaknesses.
Liu *et al.* [36]	The early warning system for gas leakage is used to reduce the unwanted data in sensors and measured gas levels using Kalman filter technique.	It filters all the unwanted data from the sensor measurements with its thorough monitoring and deals with the variations in the gas concentrations by forecasting them in an understandable manner.	Various circumstances and detection of gas properties may create impact on the efficiency and accuracy of the system.
Zheng *et al.* [25]	It combines two primary models: a HYSYS model and FLACS model to determine spill flow rate under various operational scenarios and generate forecasts based on the flow rates.	The entire processing results in estimating the amounts of LNG gas leakages. It also forecasts the effects of material accidents and cautions how hazardous they are.	The resultant values like accuracy and dependability of LNG will be dependent on the correctness and completeness of the system's internal data and assumptions.
Kim *et al.* [37]	IoT maximizes the sensor data processing by using various MJoin operators and optimization queries that helps to result in the efficient manner.	This method helps to improve the query performance and to handle the continuous sensor data using several MJoin operations in IoT settings.	This SVM classification algorithm increases the possible complexity and resource needs when it performs in real-time.
Ain *et al.* [38]	The use of HVAC system increases as it uses energy-efficient fuzzy inference method in the cyber-physical infrastructure which results in high performance.	Its creative use of a fuzzy inference system in IoT within the cyber-physical infrastructure system which helps to save energy at the same time.	It is not applicable for all kind of systems as the personal tastes can differ greatly when it comes to thermal comfort and lighting.
Tao *et al.* [39]	A large-scale multi-source data integration process is used in the gas leakage risk assessment system. This data comes from gas pipelines, Points of Interest (POIs), and human mobility.	This method performs thorough examination, and it makes use of various kinds of data from multiple sources, such as gas pipeline, PoI.	As this method performs thorough examination of amounts of data from multiple sources, such as gas pipeline, PoI, it may take much time to provide results.
Zuo *et al.* [40]	This methodology suggests a distributed optical fiber acoustic sensing system-based method for tracking gas pipeline leaks.	It precisely detects the pipeline leaks, locate leak locations. This ability of the system helps to enhance the critical performance of the system.	This method does not specify any restrictions of problems occurred during the processing time or in providing the specified results.
Liu *et al.* [41]	This methodology helps in the creation of a multi-step system for the thorough monitoring and early warning of sulfur hexafluoride gas leaks.	It verifies overall performance of the system that includes emergency disposal models, sensor-based monitoring, early-warning systems.	This method does not specify any restrictions of problems occurred during the processing time or in providing the specified results.
Liu *et al.* [42]	early-warning and emergency response system	It an early-warning and emergency response system for SF6 gas leakage in substations is its potential to prevent fatalities and mitigate the risk of large-scale casualties in populous urban areas	One potential disadvantage is its reliance on CFD simulations for analyzing the concentration distribution of leaked SF6 gas within substations

4. RESULTS AND DISCUSSIONS

Various methodologies were developed for detection of gas leakages. These methods will be helpful for future developments. They act as a base for improvements in the gas leakage detection systems. The proposed system is based on IoT network connection that helps in detecting gas leaks. It also ensures security for the system. No complex networks or patterns are required for this prototype. As compared to the earlier methods, this method is simple to understand for a user and also it is easy to construct the gas leakage detection network with the help of IoT devices. Review of preview methods is essential for implementation of a new methodology. It enables us to overcome the disadvantages of the previous methods. Major problems with the previous methods are accuracy, complex networks, and lack of security. Hence the future developments should mainly focus on the accuracy of the system, advancements of the existing methods and how to ensure security for the system.

All the previous findings will be helpful to rectify the mistakes that happened earlier. So, study of earlier methods will also be worthy. If a new method was introduced, then it should be compared with the previous methods to know its advantages over the previous methods. The study of all the methods will generate new innovative ideas that lead to future developments. let us consider some of the results of earlier methods. These results help for the generation of new ideas and also for compassion with new innovations.

Most power supply facilities will rely on sulfur hexafluoride equipment. A sulfur hexafluoride gas leak can cause serious health concerns. Therefore, Liu's method [41] suggests a sulfur hexafluoride gas leak detection method. Here, a stable state is fixed for the sulfur hexafluoride that is 1,000 ppm. Sulfur hexafluoride is stabilized below 1,000 pm under a certain air extraction pressure. A regression model is developed that compares the values of air extracting pressure of the system and time required for sulfur hexafluoride to be stabilized. The graph in Figure 1 shows the time required for sulfur hexafluoride to reach stability under various values of pressure.

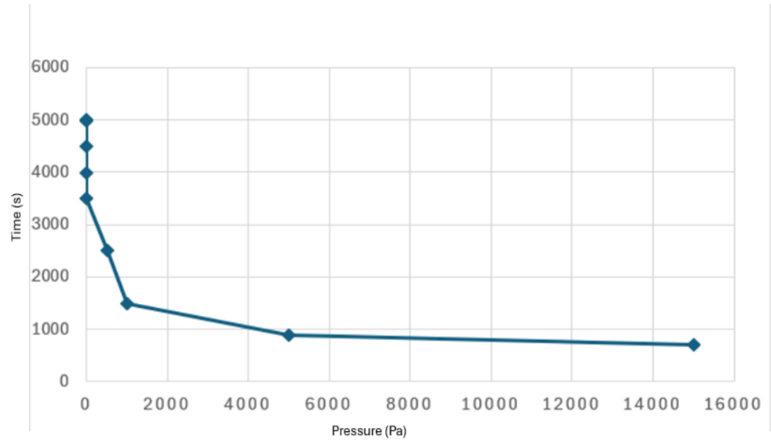

Figure 1. Comparison of pressure of gas with time

Zheng's method [25] suggests a chemical process that estimates the consequences of vapour explosions. There is a basic process control system that monitors and controls process to ensure it operates safely and within normal parameters. This model is used to find the flow rate according to the various operating conditions that are with and without process control. The adjustment in the control system will affect the size of leakage amount. So, there are different leakage sizes. Pressure for different leakage sizes, with and without BPCS is shown in the above graph. It depicts the difference in the flow rate for various values of pressure with respect to time. From the graph in Figure 2 we can observe that the pressure affects the control system to increase the flow rate.

4.1. Advancements in gas pipeline safety systems

The introduction section deals with the major developments in gas pipeline safety systems. Detection of gas leakages in prior ensures the safety of the public [49]. Safety is the major factor in building any system. Various factors are integrated to overcome the disadvantages of previous methods. PoIs, human mobility, and gas pipelines are integrated and resulted in an efficient approach for risk assessment. With the usage of cutting-edge technologies and combined neural network architectures, there is a huge increase in emergency responses and efficient results. This integrated system led to the development of urban sensing techniques with advanced infrastructure which offers real time leakage risk assessment.

Sarnin *et al.* [50] developed a system to detect, monitor, and control LPG leaks from household gas cylinders. This technique uses MQ-2 gas sensor for detecting LPG leaks. The monitoring function was accomplished through LED and piezo buzzer alerts, and remotely via the Blynk application. Control was made available through a stepper motor to shut off the gas cylinder regulator when gas levels become dangerously high. This system operates with the help of a NodeMCU ESP8266 controller and Wi-Fi communication technology.

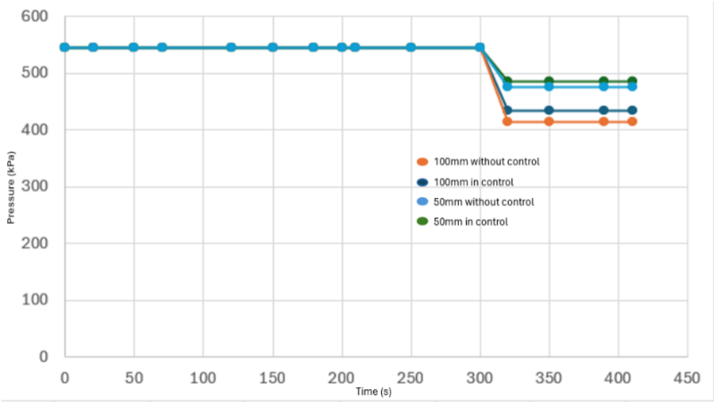

Figure 2. Pressure affecting the control system

4.2. Integration of end-to-end WSN systems

The survey explores various methods regarding gas leakage detection and risks assessment. One of those methods is the integration of end-to-end WSNs. This method specifies the importance of the network in monitoring the devices and providing early warning of gas leaks. Researchers created many hardware and software solutions to enhance performance of network and improve the system efficiency. IoT methodologies are used for detection of various events [51]. With the communication network and low packet loss rates, we can specify the importance of the system. It satisfies the needs of its various applications.

4.3. Security and usability in smart home systems

Continuous authentication methods are utilized to ensure privacy of the system. To build any communication network or any system, there is always a threat of authentication. Privacy and authentication are given top priority to prevent unauthorized access and data malfunction. The suggested methods provide strong protection against various factors in IoT environments. It also ensures high accuracy. These smart home systems establish standard technologies for the improvement of the living environments in future.

4.4. Gas leakage monitoring system for use in hospitals

Hussien *et al.* [52] approach discusses a system designed to detect gas leaks from cylinders, which alerts users via the GSM network. This system provides an LPG gas leakage detector that sends a signal to an Arduino Uno microcontroller when gas leakage is detected. It uses GSM network to send notifications, an LCD screen to display the warning, and also a buzzer to sound an alert.

5. CONCLUSION

This paper demonstrates the various techniques used in the development of intelligent systems for gas pipeline safety. With the integration of various data sources, the proposed system provides a real time complete method to evaluate leakage hazards. Various inclusive and exclusive factors are included which made the methodology more sophisticated. This research helps to learn about the earlier methods used for detection of gas leaks and improvements in the methodologies. Joint learning neural network provides a novel module. This allows us to monitor various situations effectively and helps in giving prompt responses. Urban sensing techniques help in analyzing human motion data that uses advanced infrastructure. The other study discusses the hardware and software compression in WSN systems. This provides advancement in the early detection of gas leakage and tracks the gas leaks to avoid major consequences. This integrated technique uses IoT characteristics to improve the efficiency in detection of various events and also improve network performance. The system monitors different physical conditions that improve its importance in using the system. Due to its low packet loss rate and stable communication, this extends its value across various domains for future use. Critical components in IoT environments focused on it to ensure security and stability in smart home systems. User authentication and identification strategy increases the efficiency of user experience by using continuous authentication based on user patterns. This system raises security standards in IoT environments and increases decision accuracy. Several sensors are integrated and that led to the development of an effective task-performing system. This helps the advancement of smart home systems and monitoring services in smart home systems. These advancements help define the future.

The proposed method will detect the gas leakages and enable smart ventilation systems to reduce the damage associated with gas leaks. This method also checks if the weight of the gas is less than a specified threshold value to send an alert message to the user for gas booking and specifies the weight of the gas remaining. This method is mainly developed for smart homes. As an extension, it can be modified for usage in hospitals. The remaining gas in the oxygen cylinders can be calculated with the help of load cells and intimated to the user. So that it will be very helpful and avoids major consequences. In the proposed method, MQ5 sensor is used which majorly detects LPG, LNG, and methane gases. To detect oxygen gas, we have to use a device like Zirconia sensor. This is one of the modifications that can be made to the proposed system for future developments.

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AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Y. Bhavani	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓	
Sanjusree Vodapally	✓	✓				✓		✓	✓	✓	✓	✓	✓	
Dinesh Bokka			✓	✓			✓			✓	✓			
Harshitha Varma Muddasani					✓		✓		✓	✓	✓			
Deepika Kasturi					✓		✓			✓				

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing -**O**riginal Draft
E : Writing - Review &**E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

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BIOGRAPHIES OF AUTHORS

Dr. Y. Bhavani is Associate Professor at Kakatiya Institute of Technology, Warangal, India She holds a Ph.D. degree in computer science and engineering, with specialization in security and IoT from JNTU University Hyderabad, Telengana, India. She completed her M.Tech. degree from Kakatiya University, Warangal in 2010 and secured University third rank. Her research interests are in networks, network security, IoT, and web security. She has published various research papers in referred international conferences and international journals. She can be contacted at email: yerram.bh@gmail.com.

Sanjusree Vodapally is a graduate with a Bachelor of technology in information technology from Kakatiya Institute of Technology and Science, Warangal. She is currently working as a Senior Associate ASP at Genpact in Hyderabad, where she applies her technical expertise and commitment to excellence. With a strong passion for continuous learning, she actively seeks opportunities to enhance her skills and knowledge. She is particularly interested in exploring emerging technologies and innovative solutions in her field. Her curiosity and adaptability drive her to embrace challenges and pursue professional growth. She can be contacted at email: b20it075@kitsw.ac.in.

Dinesh Bokka is a graduate with a Bachelor of Technology from Kakatiya Institute of Technology and Science, Warangal. He is currently working as a Salesforce Developer at Enabled Analytics, where he applies his technical expertise and commitment to excellence. With a strong passion for continuous learning, he actively seeks opportunities to enhance his skills and knowledge. He is particularly interested in exploring emerging technologies and innovative solutions in his field. His curiosity and adaptability drive him to embrace challenges and pursue professional growth. He can be contacted at email: b20it083@kitsw.ac.in.

Harshitha Varma Muddasani is a skilled IT professional who has completed her Bachelor of Technology in information technology from Kakatiya Institute of Technology and Science, Warangal. Currently, she is working as a Packaged Application Development Associate at Accenture in Chennai. Contributes to the development, ensuring that they meet business requirements and technical standards. Her expertise lies in leveraging technology solutions to streamline processes, improve efficiency, and help clients achieve their business goals. She is part of a team that works on various packaged applications, handling both technical and functional aspects of software development. She can be contacted at email: b20it078@kitsw.ac.in.

Deepika Kasturi is graduated with a Bachelor of Technology in information technology from Kakatiya Institute of Technology and Science, Warangal. Currently pursuing a Master of Science in data science in United Kingdom, she is deeply committed to expanding her knowledge and expertise in the field of data analytics and machine learning. As a student, Deepika actively engages in hands-on projects and research, focusing on innovative solutions in predictive modeling, big data analytics, and artificial intelligence. Her curiosity, adaptability, and problem-solving mindset drive her to explore complex challenges. She can be contacted at email: b20it0115@kitsw.ac.in.