Sigma J Eng Nat Sci, Vol. 43, No. 3, pp. 962−980, June, 2025

Sigma Journal of Engineering and Natural Sciences
Web page info: https://sigma.yildiz.edu.tr
DOI: 10.14744/sigma.2025.00084

Research Article

Real-time LPG leakage monitoring system using iot and cloud technology

Ayodeji OKUBANJO[1,*], Alexander OKANDEJI[2], Benjamin AKINLOYE[3], Ignatius OKAKWU[1], Martins OSIFEKO[4]

[1]Department of Electrical and Electronics Engineering, Olabisi Onabanjo University, 120107, Nigeria
[2]Department of Electrical and Electronics Engineering, University of Lagos, 101017, Nigeria
[3]Department of Electrical and Electronics Engineering, Federal University of Petroleum Resources, Effurun, 330102, Nigeria
[4]Department of Computer Engineering, College of Engineering and Environmental Studies, Olabisi Onabanjo University, 120107, Nigeria

ARTICLE INFO

Article history
Received: 12 January 2024
Revised: 15 March 2024
Accepted: 09 June 2024

Keywords:
Bylnk platform; IoT;
Leakage monitoring; LPG;
Microcontroller

ABSTRACT

The explosive nature of liquefied petroleum gas (LPG) and the frequent fatalities related with its usage as a cooking fuel have raised safety issues in developing countries. Consequently, there is a rising emphasis on using Internet of Things technology to address these concerns. In this regard, this study proposes a real time IoT-cloud based leakage monitoring system to enhance safety. The system uses hybrid synergetic combination of Internet of Things and cloud technologies to improve real-time tracking of LPG information. In addition, Bylnk software is used for data analytics and visualization and is hosted in an embedded system NodeMCU. This platform enables remote monitoring of real time information on LPG variables such as gas leakage, temperature, humidity, as well as user access to graphical pictures and numerical data. To address the shortcomings of existing LPG leakage monitoring systems, the model includes novel features such as real-time SMS updates, instant phone calls, alarm notification, real-time visualization of gas leakage data, and dual cellular (3G/4G/5G) and wireless fidelity network connectivity. In terms of system cost, network connectivity, technology employed, model sensitivity, and gas leak detection range, the proposed system outperforms existing models.

Cite this article as: Okubanjo A, Okandeji A, Akinloye B, Okakwu I, Osifeko M. Real-time LPG leakage monitoring system using iot and cloud technology. Sigma J Eng Nat Sci 2025;43(3):962−980.

INTRODUCTION

Growing public awareness of the health concerns posed by liquefied petroleum gas (LPG) leakage in recent decades has highlighted the need for innovative technologies to detect and manage gas leakage in residential buildings [1]–[3]. The use of such technology opens up new areas of study for researchers to explore and develop novel solutions to many societal problems. LPG is a nonrenewable, clean

***Corresponding author.**
*E-mail address: okubanjo.ayodeji@oouagoiwoye.edu.ng

This paper was recommended for publication in revised form by Editor-in-Chief Ahmet Selim Dalkilic

Published by Yıldız Technical University Press, İstanbul, Turkey

fuel utilized in residential applications such as cooking and heating. LPG is popular as a cooking gas for household usage due to its high heating efficiency, convenient storage, ease of transportation, and low emissions. It has no colour or odour and it is completely imperceptible [4]; therefore, Mercaptan is added to LPG to give it a unique, irritating odour that aids in leak detection.[4]–[6]. Liquefied petroleum gas is a combustible gas primarily made up of propane and butane. LPG is a by-product of petrol fractionation and it is synthesised from crude oil. Compared to other types of fuel, it is cost-effective, clean emission, and user-friendly, making it a preferred option for family cooking.

Furthermore, developing nations are using LPG as a clean cooking fuel to lessen their carbon imprint [7]–[9], while LPG is a dominant fuel for automobiles in Germany, the Netherlands, Japan, and India [10]–[17]. Thus, LPG fuels a diverse spectrum of innovative applications in variety of industries. Leaks, on the other hand, are the most typical issue while cooking with LPG. In addition, gas leaks can be a severe safety risk if not properly detected and addressed quickly, resulting in serious damage or fatalities. LPG leaks can occur as a result of a faulty gas regulator [18], a leaking cylinder [19], a weak connection [20], or pipeline network deterioration [21], [22]. Therefore, the high concentration of fuel vapour in an LPG leak makes it susceptible to fire or electric spark. However, there is a rising emphasis on using the Internet of Things (IoT) to improve safety through proactive detection and monitoring of LP gas leaks. Hence, the emergence of Internet of Things offers a novel option for identifying gas leaks faster than conventional methods such as human inspection or chemical sensor. IoT uses various sensors, software, and other technologies to exchange data with other systems or devices over the internet.

The Internet of Things aims to provide remote solutions to contemporary problems. In addition, the Internet of Everything (IoE) is replacing the Internet of Things (IoT) as the next Internet paradigm. IoT demands encompass numerous industries, including energy, buildings, education, healthcare, medical (IoMT), electric vehicles (IoV) and the environment [23–32]. The gas detection system uses MQ-6 sensors to detect the presence of toxic gases like LPG and smoke. With IoT, devices continuously monitor gas concentrations and provide real-time data on gas levels via the cloud platform. The model uses short messaging service (SMS) notification system to notify the gas leakage status to the users.

The motivation of this study lies in the explosive nature of LP gas and the degree of mortality and injuries sustained often by the domestic users. Often times, death and deformation have increased over the years with the use of LP gas as alternative heating fuel. For these reasons, safety management and the use of intelligent technologies has recently become a focus for emerging nations especially Africa. One of such initiatives is the use of disruptive technology, IoT, to provide a real-time monitoring and control of gas leaks concentration of various toxic gasses at household domains. This technology enhances safety and efficiency. The primary aim of this study seeks to ensure safety by detecting gas leaks in real-time. Contrary to the existing studies, the proposed system integrates a cloud technology to enhance real-time gas leaks monitoring. It furthers uses email and SMS notification to improve users' awareness. The contribution of this study is highlighted as follows:

1) An IoT and cloud-based gas leakage monitoring systems is proposed.
2) A real-time monitoring of gas leaks using Bylink application is implemented.
3) Instant SMS messaging and e-mail notification are proposed.
4) The proposed systems enhance remote accessibility and precautionary actions
5) Minimizes gas leaks potential hazards

The growing demand for the Internet of Things, cloud computing, and big data has expanded the use of gas sensors in a variety of industries (Table 1). One major area of interest is air quality control. Gas sensors are used in this industry to detect the concentration of harmful pollutants such as CO, NO, H_2S, LPG, NO_2, CH_4, and PbO. Although the gas sensor is not a novel technology, its high sensitivity makes it useful for a wide range of applications. Gas sensors are essentially electronic-based sensing devices that detect and track gas levels in the atmosphere. Typically used to determine the concentration of specific gases in air. Researchers are focusing on innovative materials to boost sensitivity, such as nanorods, nanoparticles, nanowires, and polymers [33–36]. The different variant of gas sensor is shown in Figure 1 [37].

Among these variants, Metal oxide semiconductor (MOS) sensor technology, for example, is widely utilized in a variety of industries due to its high sensitivity, low power consumption, durability, and quick reaction [37–40]. MOS sensors are sensitive to LPG [41,42]. It is a viable solution for detecting Liquefied petroleum gas. LPG MOS types include MQ-2, MQ-5, MQ-6, and MQ-306A. Tin oxide (SnO_2) is a common detecting element in MOS sensors [41,43]. MOS gas sensors are a low-cost and effective option for monitoring air pollution [44].

The MQ-2 is a solid-state gas sensor that has a high affinity for LPG. The sensor can detect LPG gas concentrations ranging from 200 to 1000ppm [45]. MQ-2 has a sensitive layer of SnO_2 and a small ceramic tube of AlO_3. The MQ-5 and MQ-6 are low-cost semiconductor sensors for propane, butane, and LPG detection. They are suitable for gases with concentrations ranging from 300 to 1000ppm. MQ-5 and MQ-6 use the silicon substance SnO_2 as a sensing element. MQ-306A is a SnO2-sensitive semiconductor gas. It is compact, uses minimal electricity, and is LPG compatible. Authors in [33], demonstrated a groundbreaking high surface area MOS gas sensor based on nanotechnology, making it a feasible alternative for gas detection applications. Work done in [44], studied MOS-based nanomaterials and

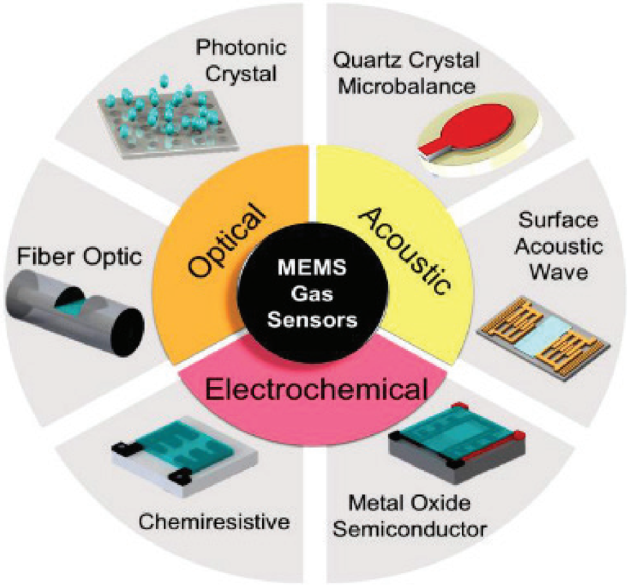

Figure 1. Different variant of gas sensors [From Muhammad et al. [37], with permission from IEEE.]

affirmed that nanoparticle materials improve the thermal and structural stability of MOS gas sensors.

Authors in [39], presented a biomarker gas detector based on MOS. The proposed model can detect the concentration of breathed air and avert hazard in the medical and healthcare industries. In contrast, authors in [36], improved MOS sensitivity and lowered the operating temperature of a ZnO-based MOS gas sensor by doping it with Gold.

Related Works

The explosive nature of LPG when it leaks necessitates advanced monitoring systems. This smart technology can be put into buildings to help users reduce the risk of fire and save lives and property. Such systems use IoT devices such as gas sensors, a communication module, a controller, and Wi-Fi connectivity to detect, transmit, and analyze leakage data. A data link is frequently established between IoT devices and data processing centres using wireless or cellular networks. This simplifies data analysis and improves IoT cloud connections. Therefore, real-time monitoring, a priority in smart buildings, is critical to the development of gas leakage monitoring systems. Several technologies are progressively being used in LPG monitoring systems to improve safety.

These technologies are known as emerging technologies in LPG monitoring systems. Currently, the hybrid combination of IoT sensors and cloud technologies has enabled remote monitoring of LPG gas leaks, allowing users to check gas level status in real time via a cloud platform.

Global System for Mobile Communications (GSM)-based monitoring systems employ GSM to detect and monitor leaks in liquid petroleum gas. GSM has been critical in sending safety alerts during crises such as accidents, fire breakouts, and theft due to its vast coverage and accessibility. The main components of this system are gas sensors, a microcontroller or Arduino board, and a GSM module to offer quick message or SMS notification. The systems uses a cellular network (3G/4G/5G) to initiate calls or send messages.

Authors in [46–49] present the use of a gas sensor with a GSM module. [50], designed a smart leakage system using a microcontroller, GSM module, and a MQ-2 gas sensor. The GSM module serves as a communication link to improve LP gas leak awareness among users. A GSM module is employed in a related study [51] to update consumers about gas concentration levels and leak status. Once the gas leak is identified, a new SMS update is delivered to the users' cell phone. It also activates an alarm system to increase safety awareness. Although the GSM-based LPG monitoring system improves safety, response time, swift messages, and notification, it lacks features such as real-time monitoring and data analytics. Global position system (GPS) based monitoring systems are location-based systems that uses Global Position System to track and monitor the LPG leaks and cylinder. The system combines GPS technology with other components such as gas sensors, communication module, and a cloud services to allow real-time monitoring and tracking of LPG cylinders. This system enables users to access information of the coordinates of gas leaks and cylinder. It further provides extra layer of security and timely cylinder replacement. Recently, authors in [52], integrated gas sensor with GPS to identify gas leaks and leak location remotely to the users. [53], deployed the use of a GPS-enabled smart system to track the location of a leak cylinder. MQ-2 gas sensor is primarily used to detect LPG leakage levels and uses a GSM module to verify SMS updates. The exact position of the leak LPG cylinder in real-time is updated using GPS.

IoT based monitoring systems have garnered significant attention due to their potential to enhance safety and efficiency in various applications. Such systems use a combination of Internet of Things sensors, microcontrollers, and communication modules to detect and monitor toxic gases and other gas leakages. Furthermore, IoT-based LPG monitoring systems aim to give real-time data on gas leakage levels. As a result, these solutions improve safety and comfort. The key components of an IoT based LPG monitoring systems consists of (1) IoT sensors, (2) IoT microcontroller (MCU, Software, and EPS32), and (3) IoT cloud platform. These systems provide real-time monitoring and analysis of data such as LPG levels, gas leakage, LP gas cylinder position, and weight, as well as other IoT sensors such as load sensors, MQ-2, and MQ-6 gas sensors. Wi-Fi, Bluetooth, Radio frequency (RF), ZigBee, LoraWAN, cellular (3G/4G/5G) networks, and LPWANs are used for seamless data transmission and connectivity in these systems.

Artificial intelligence (AI) is becoming increasingly popular in a range of industries for a variety of reasons. One of the key motivations for this is the unique AI-algorithms for data prediction [54]. AI is currently being applied in smart home automation to detect LPG leaks quickly and precisely.

This type of technology is frequently combined with gas sensors to track and identify various sensor data for prediction analysis and insight. Furthermore, the use of AI powered drone technology is presented in [55], [56]. The synergistic combination of these systems improves gas leak detection efficiency in a dangerous environment. Dash et al. [54], estimated LPG leak concentrations and other relevant risks in industrial sectors using AI and IoT technology. AI and IoT hybrid integration can boost efficiency and safety.

Cloud technology is essential for IoT application connectivity, data management, and advanced analytics. This technology has been used with IoT to minimize physical infrastructures, giving remote access to critical information via cloud services. The synergy of technology improves real-time data analytics, management, and storage. Cloud-based IoT systems such as Bylnk, Thingspeak Thingworx, and Grafana allow users to build, deploy, store, manage, and analyze data, as well as access various tools and services. For the sake of brevity, all the reviewed works of literature, along with their major findings are summarized in Table 1.

MATERIALS AND METHODS

Materials

LPG leakage monitoring systems in this study is also referred to as LPG leakage model (LPG-LM). The LPG leakage model is an IoT-cloud based enabled system for detecting and tracking gas leaks especially in domestic domains. The model uses IoT devices, IoT connectivity, software, and Blynk IoT platform to sense, track, monitor, and analyze LP gas leakage in real time. The system designed is structured into system hardware and software.

System Hardware

The system hardware in this study uses an Arduino nano and NodeMCU (ESP8266) as the main embedded system. It also includes a gas sensor (MQ-2), temperature and humidity sensor (DHT11), a 20kg load cell sensor (LC 20) and a load cell amplifier chip (HX711), a GSM module (SIM800L), 18650 Li-ion battery (2 Pcs), buck converter (LM2596), a capacitor (35V, 1 Pc), a buzzer, liquid crystal

Table 1. Existing studies on LPG leakage monitoring systems

S/N	Technology used	Tool used	Highlights	Citation
1	Wi-Fi	MQ-6 gas sensor, NodeMCU	Proposed an android based LPG monitoring systems which enhances instant SMS notification of gas leakage status.	[57]
2	Wi-Fi	Arduino controller, MQ-6 gas sensor, EPS32	Developed a wireless based LPG monitoring systems to enhance domestic safety.	[58]
3	ZigBee	MQ-9 gas sensor, Raspberry pi, Arduino Uno	Developed LabVIEW graphical user interface for monitoring gas leakage. In addition, the system is integrated with a self-control system to cut off gas supply once leak is detected.	[59]
4	Wi-Fi	PIR sensor, MQ-2 gas sensor, LM35, Arduino Uno	Proposed a motion-based LPG monitoring system to minimize fire and smoke in case of gas leakage.	[60]
5	RF	Lora module, MQ-2, MQ-7, MQ-135, MQ-136 sensors, Arduino controller	Implemented a wireless leak detector system to increase worker's health condition and alert gas leakage for emergency exit.	[61]
6	Cellular network (3G/4G)	MQ-6 gas sensor, IR sensor, Arduino Uno	Proposed a real-time LPG monitoring system with GSM network.	[62]
7	Bluetooth	Fire sensor, MQ-2 gas sensor, NodeMCU	Proposed an iOS smart phone application for tracking smoke and detecting LPG leakage. This system provides real time SMS update on gas leaks	[63]
8	Bluetooth	Load cell sensor, MQ-2 gas sensor, NodeMCU, EPS8266	Developed a mobile application-based detection systems to improve early detection of LPG leaks	[64]
9	Wi-Fi	Humidity sensor, temperature sensor, MQ-2 gas sensor, Raspberry Pi	Developed an intelligent LPG monitoring systems based on GPS and Internet of Things. It provides timely information of gas level status and usage	[65]
10	Wi-Fi	MQ-2, MQ-5 gas sensors, IR sensor, Arduino Uno, ESP8266	Developed an LPG alert notification-based systems to minimize fire outbreaks and burn injury in LPG environment	[66]

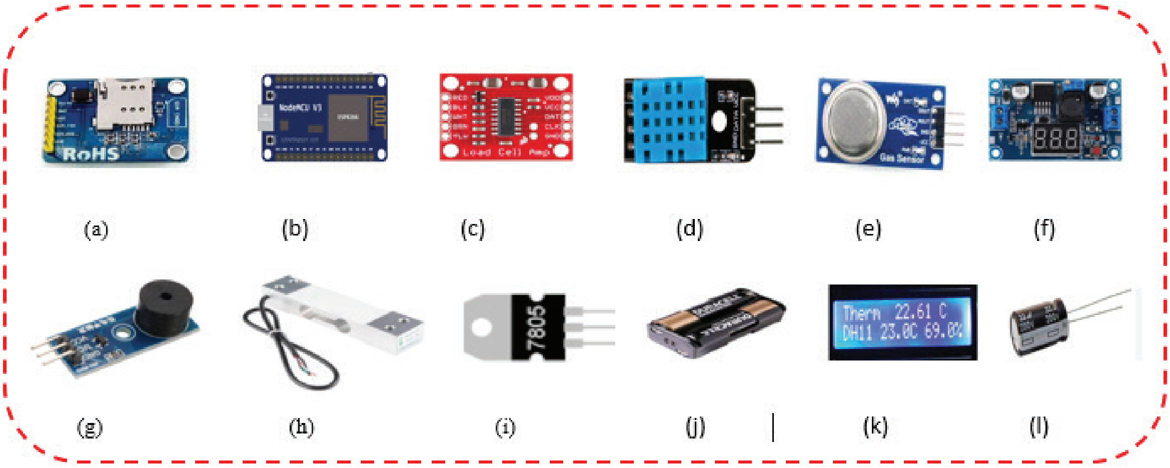

Figure 2. (a) SIM800L; (b) NodeMCU; (c) HX711; (d) DHT11; (e) MQ-2; (f) LM2596; (g) buzzer; (h) load cell sensor (LC20); (i) LM7805; (i) 18650 Li-ion battery; (k) LCD; (l) Capacitor.

display (LCD), and some jumper wires and other electronic boards needed for components assembling. Fig. 2 shows the hardware components.

IoT sensors such as the gas sensor MQ-2, humidity and temperature sensor (DHT11), and the load cell sensor (LC20) are used as sensing devices to collect physical environmental data, which is then sent into the Arduino nano. These IoT sensors are linked to the Arduino nano via various pin combinations to collect data. Furthermore, the Arduino nano provides data transmission between sensors to identify the presence of LPG gas leaks or abnormalities in temperature, humidity, and variations in LPG weight using software and firmware. The NodeMCU (EPS8266), a system-on-chip (SOC), connects the Arduino nano to the cloud server for real-time analysis of IoT sensor data. In addition, the system integrates LCD to display the LPG leakage level, humidity, temperature, and weight of LPG cylinder. A buzzer is further implemented to trigger a sound alarm to the neighborhood for prompt safety intervention or measures. IoT cloud service is applied using a bylnk IoT platform to assist the users to keep real-time data update on the gas leakage A GSM module is also included to enable users with access to

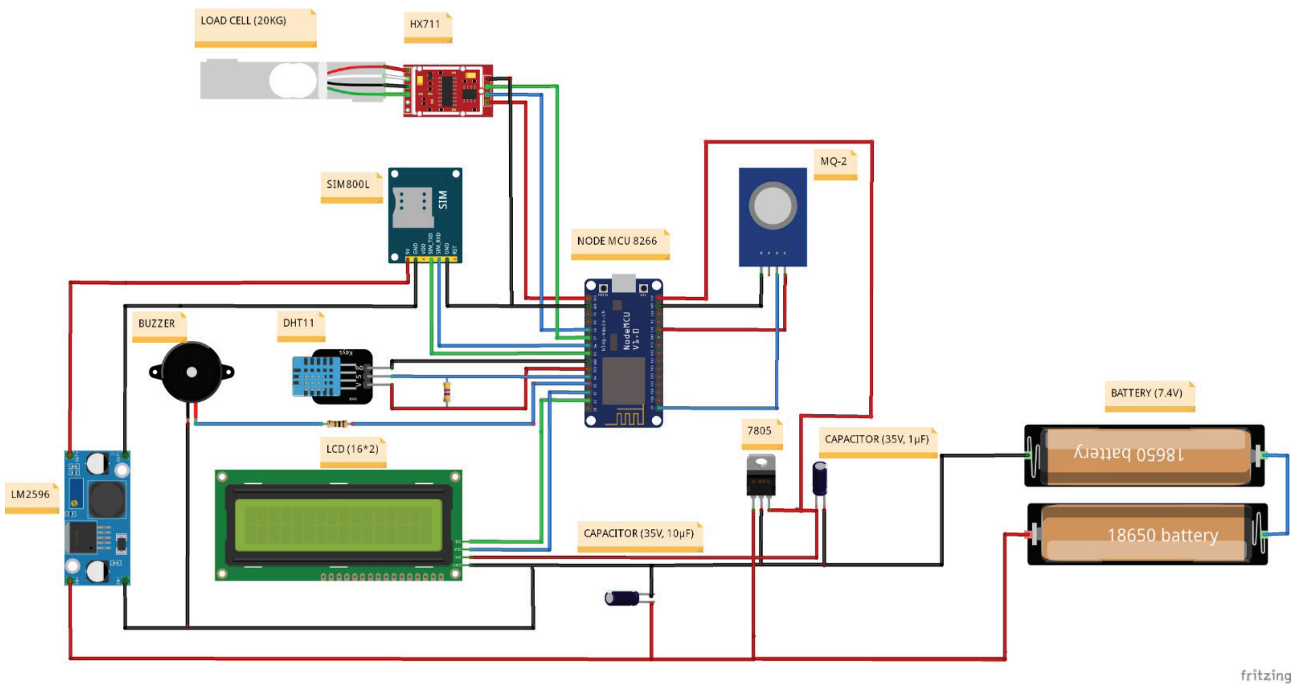

Figure 3. Proposed system hardware schematic diagram.

instant SMS updates on the liquid petroleum gas and other LPG variables. Figure 3 depicts a schematic diagram of the system hardware.

System Architecture

As shown in Figure 4, the LPG leakage model has a four-tier Internet-of-Things framework. The sensing layer detects and collects data via devices, sensors, and actuators. In this layer, the Arduino nano microcontroller interacts with sensors and actuators to detect, collect, process, and transmit data via network connectivity. The network layer employs wireless technology to build a communication gateway link between the sensing layer and the internet. The data analysis and processing of LPG leakage and other changes in LPG parameters is handled by the application layer. This layer is in charge of monitoring gas leakage levels and updating LPG data on the IoT cloud platform.

System Software

Three separate system software are required to design, code, model, and simulate the system prototype. These software applications include the following:

Arduino IDE: It is a free license software for programming and compiling Arduino series boards. It supports free use of source code, enabling the users to view, modify, and customize to meet their project demands. In addition, it is a user-friendly interface that facilitates coding, compilation, and uploading of code to Arduino boards. The proposed model is coded using Arduino IDE.

Arduino language: It is a code-based development platform for writing Arduino sketches in C or C++ and uploading them to Arduino boards. The proposed model is programmed with C++.

Arduino fritzing: This is a distributed software program designed specifically for making visual representations of

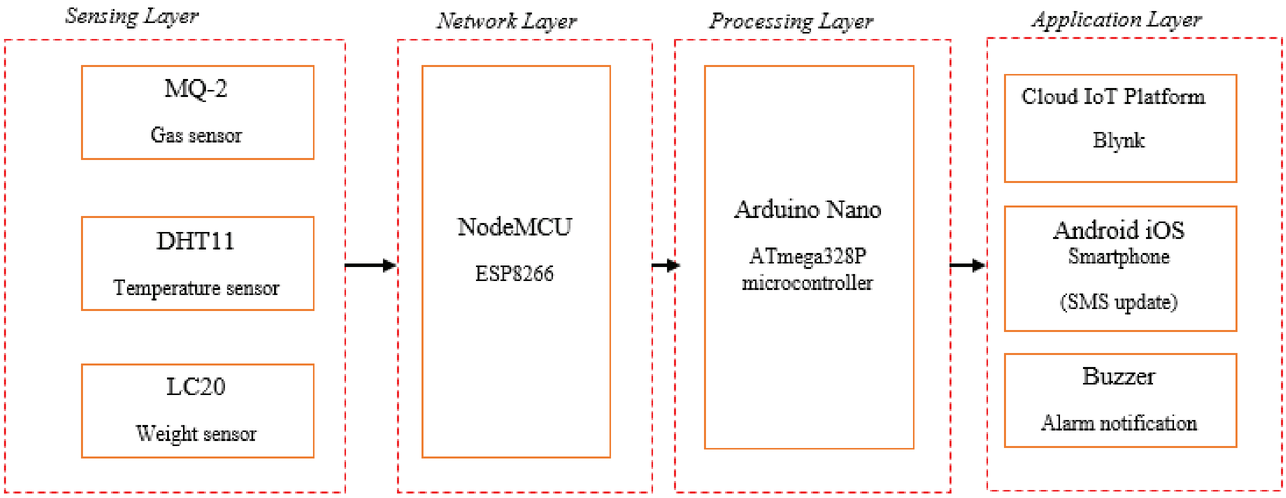

Figure 4. Proposed system architecture.

Figure 5. 3D Model of the proposed system.

Arduino circuit diagrams, and documenting electronic circuits and porotypes. It can be used to visually represent Arduino sketches and connections. It can only be used with the Arduino IDE.

Solidworks: It is a computer-aided designed (CAD) software primarily used for creating, simulating, and managing 3D model, and product designs. Solidworks offers a range of powerful and intuitive tools that enable users to design, analyze, and visualize their ideas in virtual environment. Fig. 5 depicts a 3D model of the system prototype created in Solidworks.

RESULTS AND DISCUSSION

The various hardware components and embedded systems of LPG-LM are depicted in Fig. 6. The sensor module, communication module, and the output unit are connected to the embedded system (Arduino Nano and NodeMCU). The collected data are sent to the cloud server, and accessed via bylnk IoT platform. MQ-2, DHT11, LC20, communication module, GSM800L, NodeMCU, microcontroller, Arduino Nano, output unit, LCD, and cloud storage platform were functionally tested using their pin combinations as shown in Table 2.

Table 2. Hardware components pin configuration

Hardware	Pin Configuration	Status
NodeMCU	AO, EAE, GND, Vin, D1, D2, D3, D4, D5, D6, D7	Functioning
MQ-2	AO, EAE Vin	Functioning
DHT11	GND, EAE, D4	Functioning
LC20	E+, E-, GND, D4, EAE	Functioning
HX711	GND, D7, D8, VCC,	Functioning
SIM800L	D5, D6, SIM_TXD, SIM_RXD	Functioning
LM7805	5V, Vin,	Functioning
LM2596	OUT-, OUT+,5V, GND	Functioning
Buzzer	D2, D4	Functioning
Lithium-ion battery (18650)	GND, IN	Functioning

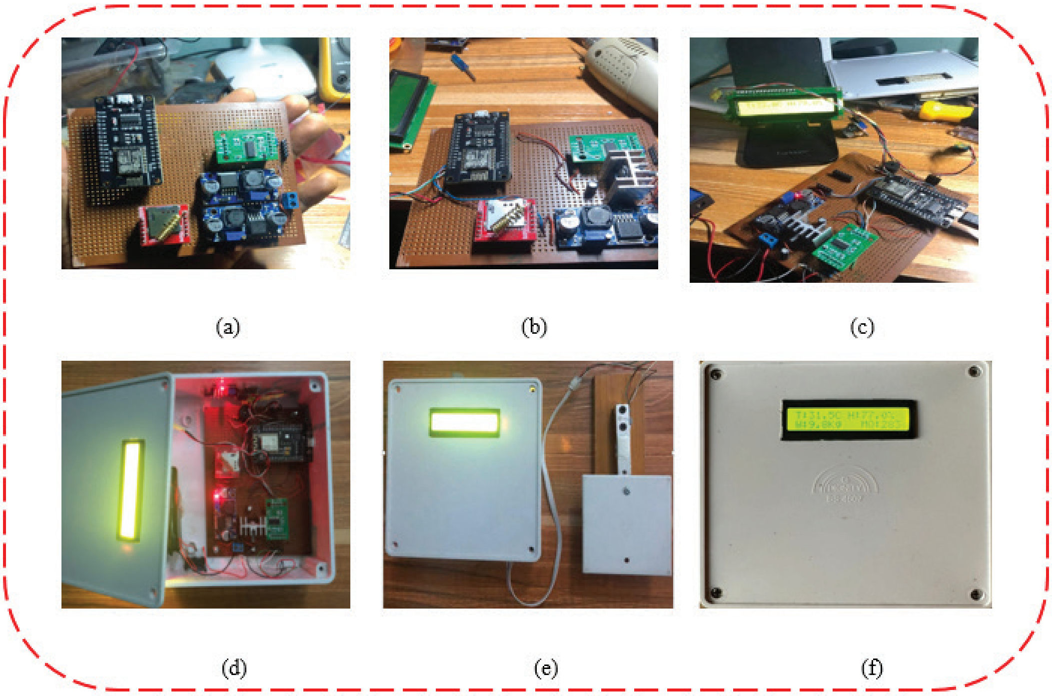

Figure 6. (a) NodeMCU and sensor set up (b) communication module set up (c) components set up (d) system testing (e) load cell with system set up (f) prototype of the LPG-LM.

The LPG-LM was experimentally set up using a 3kg liquefied petroleum gas cylinder, and instant data on LPG gas leakage, humidity, temperature, and weight are obtained in real-time via the bylnk IoT platform. For example, as illustrated in Figure 7, the LCD uses four separate letters T, H, W, MQ as indicators to, respectively, represent temperature, humidity, LPG cylinder weight, and gas leakage level.

In addition, the bylnk IoT platform uses a number of data visualization indicators to analyze and track real-time data. The gas leakage, temperature, humidity, and weight of the LPG are all displayed simultaneously in the graph depicted in Figure 8. The instant values for variables are categorized into four distinct cases A, B, C, and D, as shown in Table 3.

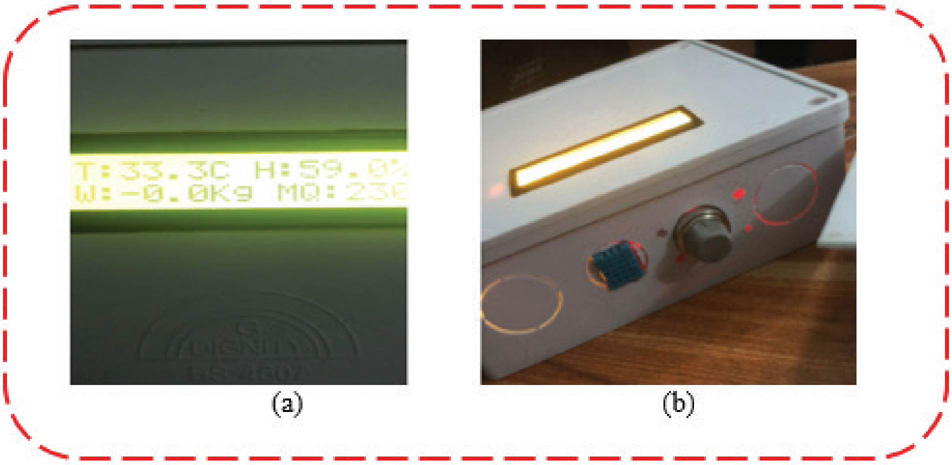

Figure 7. (a) The LPG-LM's parameters indicator ((b) System model.

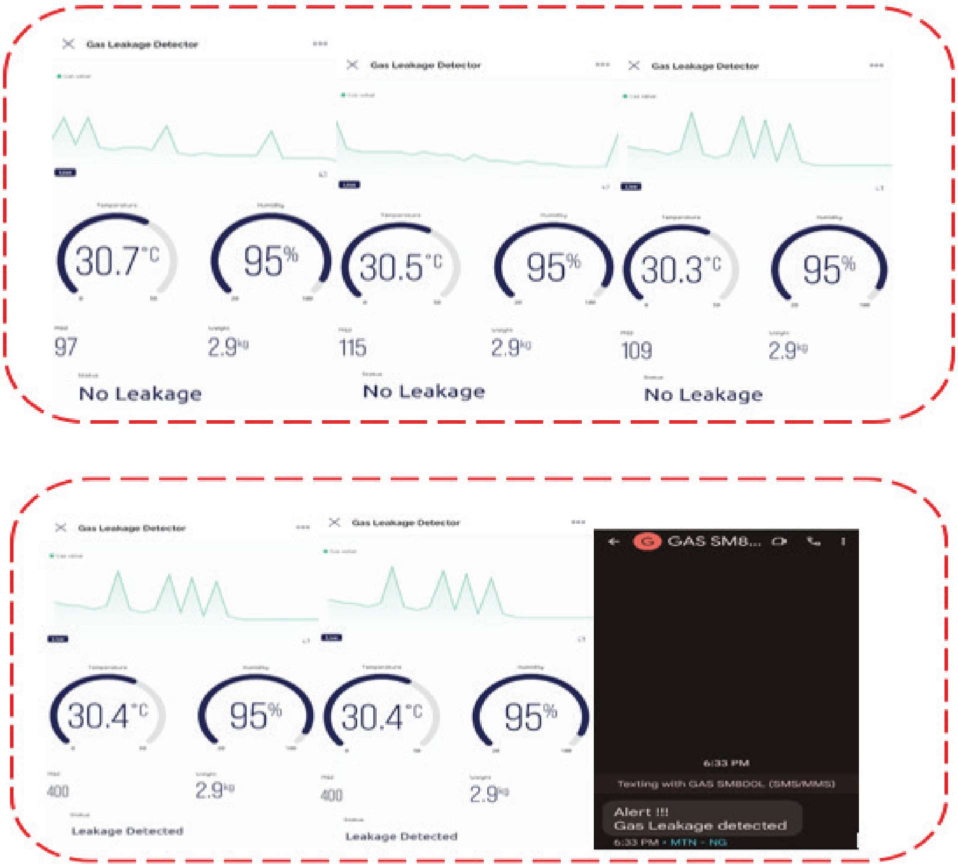

Figure 8. Detail of real-time LPG parameters in the bylnk dashboard.

Table 3. Real-time data on LPG variables

Cases	Temperature (°C)	Humidity (%)	Gas concentration (ppm)	Weight (kg)	Leakage Status
A	30.7	95	95	2.9	No
B	30.5	95	115	2.9	No
C	30.4	95	109	2.9	No
D	30.5	95	400	2.9	yes

The time duration of each case varies and depends on other environmental factors. Also, the gas sensor MQ-2 is programmed not to detect any gas leak within the range of 240 to 270 ppm and configured to display "No leakage" status via the liquid crystal display as shown in cases A, B, and C. Once the gas concentration reaches or exceeds the predefined threshold of 400 ppm (as seen in case D), the gas sensor detects the gas leakage level and send the data remotely to the bylnk platform for real-time monitoring of LPG variables. An alarm is further triggered via the buzzer to call the attention of the user.

The system is equipped with a GSM module to send instant SMS notifications update or initiates a call to the user. For instant, Figure 9, shows a real time SMS update and displays the LPG gas leakage status, temperature, humidity, weight on the bylnk IoT dashboard for remote monitoring and control. Furthermore, the temperature and humidity of the LPG cylinder must be monitored to ensure optimal operation and safety. One of the significant variables for monitoring the liquefied petroleum gas pressure inside the cylinder is the temperature. High temperatures can be dangerous, and humidity can have a considerable impact on the sensitivity and performance of the MQ-2 gas sensor. In this regard, the temperature remains normal during the testing time, ranging from 30.2 to 30.7 degrees Celsius, while the humidity remains consistent at 95%. The

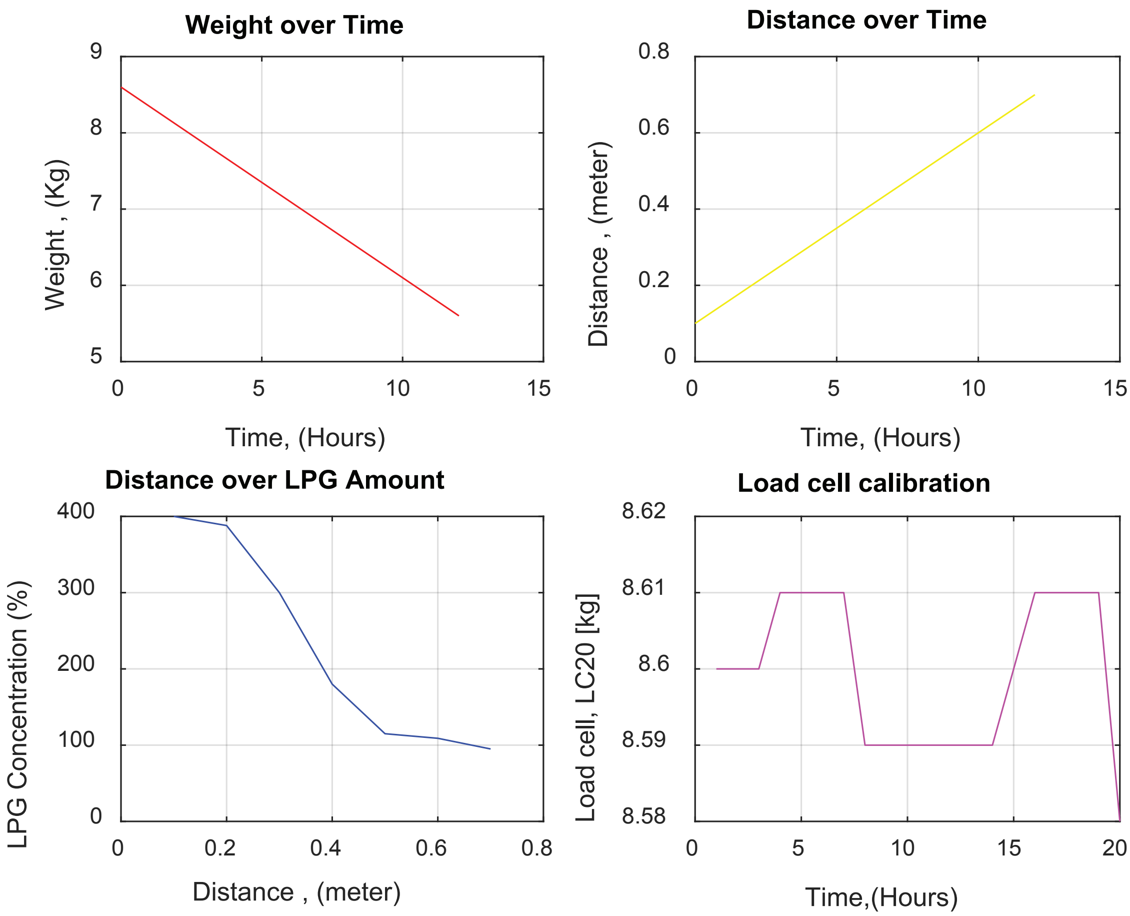

Figure 9. (a) Weight measurement (b) Impact of distance on LPG-LM (c) effect of distance on LPG concentration (d) Load cell measurement.

weight of the LPG cylinder and the gas leakage are observed for 12h- horizon with a time interval of 2hrs as shown in Fig. 9. A 3kg LPG cylinder is chosen as baseline due to its compactness and light weight. It weighs 5.6 kg when empty, and 8.6 kg when fully loaded. The goal of this experiment is to investigate the sensitivity of the LPG-LM system to gas leakage by varying its distance

The weight of the LPG decreases over time, as illustrated in Figure.9a. This implies that the LP gas usage inside the 12h-horizon changes when the gas is consumed. The weight of the LPG cylinder was measured within the 12-hour time frame to determine the sensitivity of the load cell sensor. Furthermore, the suggested system's location is changed during a 12-hour horizon to assess the device's sensitivity to position changes. It can be inferred from Fig.9b that as the distance between the 3kg LPG cylinder and the LPG-LM system increases, the time taken to activate the system increases.

The system's delayed time response is due to the fact that the experiment was done in the open air, which may have been affected by external environmental conditions such as draughts. As a result, the detectable distance of the proposed system to gas leakage sensitivity is between 0.4 and 0.5 meters. Further experiments were carried out to determine the influence of distance on gas concentration. The main goal of this experiment is to determine the sensitivity of the LPG-LM system to gas leakage distance. The LPG concentration (ppm) data was obtained using a bylnk IoT dashboard. Fig.9c demonstrates that the LP gas concentration is slightly constant over a short distance, it drops abruptly from 380% to 95% with increasing distance, and remains reasonably constant at the 12h-horizon. The load cell calibration is shown in Fig.9e. The load cell sensor is calibrated to assure an error-free and precise weight measurement.

PERFORMANCE EVALUATION

Table 4 highlights the differences in performance between the proposed system and the existing models. In general, there has been a number of previous studies on Internet of Things based LPG leakage monitoring systems. This work combines internet of Things, cloud, and GMS technologies. The synergetic combination of these

Table 4. Performance comparison of the proposed system with existing studies

No.	Paper	Network	System cost ($)	Technology	Sensitivity (ppm)	Detection zone (m)	Addition features
1	Khan et al. [67]	Wi-Fi	10.0	IoT, Thingspeak	450	0.8	SMS, data interface
2	Zaw et al. [68]	Wi-Fi	19.8	IoT, Wai	500	0.6	SMS, data interface
3	Sagar et al. [51]	Cellular (3G/4G)	13.7	GSM	1000	0.9	SMS
4	Praveen et al. [52]	GNSS	12.0	GPS	600	0.7	SMS
5	Jena et al. [69]	Wi-Fi	15.6	IoT	500	0.8	SMS
6	Abdullah et al. [46]	Cellular (3G/4G)	23.2	GSM	1000	0.9	SMS
7	**Proposed Model**	**Wi-Fi / Cellular (3G/4G)**	**7.61**	**IoT, Bylnk, GSM**	**400**	**0.4-0.5**	**SMS, call, Alarm, real-time data interface**

Table 5. Design analysis and user's ranking

Design Assessment Statement	4	3	2	1	Total	Aggregate	Mean	Interpretation
I found this system reliable, efficient, affordable and intelligent in detecting LPG leakage than existing models	42	8	0	0	50	192	3.84	Strongly Agree
The sensing module is highly sensitivity to LPG leakage	30	20	0	0	50	180	3.60	Strongly Agree
The bylnk IoT platform is easily to navigate	38	20	0	0	50	188	3.76	Strongly Agree
The gas leakage data is easily monitored and retrieve via bylnk without data loss	45	12	0	0	50	195	3.90	Strongly Agree
The developed system enhances the real time information update of LPG leakage, temperature,humidity and cylinder weight	48	2	0	0	50	198	3.96	Strongly Agree
There is no delay in instant SMS update and call	40	10	0	0	50	190	3.80	Strongly Agree

technologies enables real-time monitoring, remote access to gas leakage data as well as communication and SMS alert to users via smartphones.

In addition, a 4- point Likert scale online questionnaires was administered to 50 students within the University community hostel via google form to assess the proposed system performance. Table 5 presents the design data assessment and rank distribution of the users. The scale 4 connotes “strongly agree” and scale 1 denotes “strongly disagree” and was used as a performance metric for the proposed system. Overall, the findings of the design assessment show a high degree of acceptability and suitability of the proposed system.

System Cost

The main objective of the system cost analysis is to examine the viability of the proposed system and to provide a clear roadmap for mass production of the model for future integration in buildings, cars, and industries. Therefore, the costs of the electronic hardware components based on the difference vendor market price is presented in Table 6.

The system cost per product is estimated to be $7.61, which translates to N 6,270 in Nigerian currency using current Central Bank of Nigeria exchange rate. The proposed model is low cost, budget-friendly, and safety oriented when compared to the existing models. The integration of the proposed system with smart home system will not only enable seamless automation and control but also provide remote access of vital LPG parameters through mobile applications or web-based interfaces.

Strengths of the Proposed System

The main strength of the proposed system lies on the use of hybrid technologies of Internet of Things, IoT-cloud, and GSM to provide real-time monitoring, remote access to gas leaks and instant SMS update. In addition, the system redefines domestic gas safety through real time detection, rapid response, and remote accessibility, resulting in risk mitigation. With the Internet of Things, users can monitor LPG leakage status through mobile application. This eliminates the need for manual checks and provides convenience. Furthermore, the proposed system can detect gas leaks and send immediate alerts and email notification to the users on real-time. The system incorporated safety features such as gas leakage alarm, sensors, and real-time notification response mechanisms to provide an additional layer of safety to the users. Contrary to the previous works, the proposed system seeks to enhance safety using a fused internet of things and global system communication technology. A novel email notification, web-based dashboard mechanism, and IoT cloud platform incorporated to the system to enhance data update and data sustainability.

Future Outlook

Recent technological advancement in Artificial intelligence (AI) and Machine learning (ML) can enhance real

Table 6. Summary of bill of materials

Components	Unit	Unit cost	Total cost	Materials source link	Types of materials
NodeMCU	1	$1.50	$1.50	https://www.konga.com/product/esp8266-nodemcu-v3-ch340-lua-wifi-module-5163427	Electronics
MQ-2	1	$0.75	$0.75	https://www.konga.com/product/mq-2-combustible-gas-sensor-5582884	Electronics
DHT11	1	$0.10	$0.10	https://www.konga.com/product/dht11-temperature-and-humidity-sensor-module-6051108	Electronics
LC20	1	$1.00	$1.00	https://www.konga.com/product/arduino-20kg-digital-load-cell-weight-sensor-hx711-weighing-module-5095684	Electronics
SIM800L	1	$0.10	$0.10	https://www.konga.com/product/arduino-sim800l-gprs-gsm-module-4534877	Electronics
LM7805	1	$0.36	$0.36	https://www.jumia.com.ng/generic-10pcs-lm7805-l7805-7805-voltage-regulator-ic-5v-1.5a-204418207.html	Electronics
LM2596	1	$1.67	$1.67	https://www.konga.com/product/arduino-lm2596s-dc-dc-adjustable-step-down-power-supply-module-4860445	Electronics
18650 batteries	2	$0.99	$1.98	https://www.konga.com/product/dual-usb-18650-battery-charger-power-bank-module-with-digital-led-5695689	Electronics
Buzzer	1	$0.15	$0.15	https://www.konga.com/product/arduino-passive-buzzer-module-4599233	Electronics
		System cost	**$7.61**		

time gas leakage data trends and prediction. Such techniques can be integrated into the system model to assist in future decision making. One notable future function is the integration of advanced vision-based sensors such as cameras, GPS, other modern sensors to collect the coordinates, images, and pictures of the scene especially in mobile cars, buildings, or industrial workplaces to aid prompt safety intervention.

It is worth noting that the reliable internet connectivity is a significant issue that can affect real-time monitoring and communication capabilities of the proposed system. In this regards, redundant connectivity options can be implemented. This can include backup interment connections, cellular connectivity, and alternative communication protocols to ensure continuous monitoring and communication in case of internet outages. The MQ-2 gas sensor of the system has a limited range of distance and its only sensitives to certain gases such as methane, butane, propane, and LPG. However, MQ-6 gas can be used in combination with the MQ-2 gas to ensure domestic safety. The proposed system is limited to the cylinder weight measurement but it can be further improved to measure gas flow by incorporating high performance ultrasonic sensors, which allows users to track their gas consumption and receive timely alerts when it's time to book a refill.

Furthermore, the real-life deployment of the prototype system in places like transport, buildings, and industries will enhance real time monitoring of potential hazards, and provide timely safety measures in case of an emergence. Future enhancement of this model with various communication networks and electronic mail would enhance users and safety authority awareness on gas leakage. Further, enhancement of the model with a single sensor, capable of detecting multiple gases would not only improve system's efficiency but also save costs. A highly interesting future path of this work may be found in the energy conservative and off-grid energy system of minimizing the energy consumption of the system model. Using a renewable source such as solar or wind to power the system model would enhance system's continuous operation and efficiency, and also ensure sustainable monitoring access. In addition, the use of advanced data techniques such as data mining and machine learning can be leveraged with predictive maintenance model to identify potential issues, optimize safety and downtime in industries.

CONCLUSION

The issue of gas leakage and its potential implications with the use of liquefied petroleum gas for residential fuel necessitates the implementation of intelligent safety measures to protect against massive collateral damage and threat to individual safety. This study presented a monitoring system for tracking real-time information on LPG leakage. The system model uses 4-tier of IoT architecture to facilitate data sensing, sharing, processing, storage, and analytics. The NodeMCU serves as cloud server and also as HTTP client enabling remote data connectivity and processing. A comprehensive software suite Blynk provided intuitive interfaces for easy visualization of the LPG variables such as gas leakage, humidity, temperature, and weight. In addition, the integration of IoT enabled the user to have online access to Blynk dashboard for continuous monitoring of LP gas leak status, and other changes in LPG variables in real time.

Several experimental findings were presented to demonstrate the applicability and success of the designed system. Specifically, the instantaneous values of liquefied petroleum gas variables such as gas leakage, temperature, humidity, and weight have been carefully monitored during a 12-hour time span. The novelty of the proposed system depends not only on infused hybrid technology, but also addresses the limitation of the existing studies. For example, this work improves early detection of gas leaks by providing timely response to potential threats via real-time SMS update, alarm notification, and instant phone call, as well as improvement in real-time visualization of LPG leakage data on web interface and smart phones. Additionally, the proposed model offers a lower-cost, and more affordable than the products currently available on the market.

ACKNOWLEDGEMENTS

The lead author is grateful to the members of the research lab group for their significant contributions and prompt feedback. A special thanks also goes to the College of Engineering and Environmental Studies for providing a conducive environment to complete this project.

AUTHORSHIP CONTRIBUTIONS

A.Okubanjo:Conceptualization,Methodology,Experimentation,Writing-Original draft preparation,artworks design. I.Okakwu and A.Okandeji reviewing the manuscript critically for important context. M.Osifeko editing,and draft preparation.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

REFERENCES

[1] Afridi F, Debnath S, Somanathan E. A breath of fresh air: Raising awareness for clean fuel adoption. J Dev Econ 2021;151:102674. [CrossRef]

[2] Dalaba M, Alirigia R, Mesenbring E, Coffey E, Brown Z, Hannigan M, et al. Liquified petroleum gas (LPG) supply and demand for cooking in northern Ghana. EcoHealth 2018;15:716–728. [CrossRef]

[3] Fandiño-Del-Rio M, Goodman D, Kephart JL, Miele CH, Williams KN, Moazzami M, et al. Effects of a liquefied petroleum gas stove intervention on pollutant exposure and adult cardiopulmonary outcomes (CHAP): Study protocol for a randomized controlled trial. Trials 2017;18:1–16. [CrossRef]

[4] Demirbas A. Fuel properties of hydrogen, liquefied petroleum gas (LPG), and compressed natural gas (CNG) for transportation. Energy Sources 2002;24:601–610. [CrossRef]

[5] Al-Zuhair S, Abujayyab M, Khaleel A. Adsorption kinetics of ethyl mercaptan found in commercially available LPG in UAE. Energy Environ Eng 2016;4:7–14. [CrossRef]

[6] De Wild PJ, Nyqvist RG, De Bruijn FA, Stobbe ER. Removal of sulphur-containing odorants from fuel gases for fuel cell-based combined heat and power applications. J Power Sources 2006;159:995–1004. [CrossRef]

[7] Van Leeuwen R, Evans A, Hyseni B. Increasing the use of liquefied petroleum gas in cooking in developing countries. World Bank, Washington, DC, 2017. [CrossRef]

[8] Aishwarya K, Nirmala R, Navamathavan R. Recent advancements in liquefied petroleum gas sensors: A topical review. Sens Int 2021;2:100091. [CrossRef]

[9] Biscoff R, Akple M, Turkson R, Klomegah W. Scenario of the emerging shift from gasoline to LPG fuelled cars in Ghana: A case study in Ho Municipality, Volta Region. Energy Policy 2012;44:354–361. [CrossRef]

[10] Sierzchula W, Bakker S, Maat K, Van Wee B. Technological diversity of emerging eco-innovations: A case study of the automobile industry. J Clean Prod 2012;37:211–220. [CrossRef]

[11] Abramiuk-Lété E. LPG - The smart alternative, everywhere you need it. Liquid Gas Europe, 2023.

[12] Kivevele T, Raja T, Pirouzfar V, Waluyo B, Setiyo M. LPG-fueled vehicles: An overview of technology and market trend. Automot Exp 2020;3:6–19. [CrossRef]

[13] Bellin T, Casadei S, Rossi T, Bernetti A, De Lauretis R, Lonati G. Determination of Euro 6 LPG passenger car emission factors through laboratory and on-road tests: Effect on nation-wide emissions assessment for Italy. Atmos Environ X 2022;15:100186. [CrossRef]

[14] Khanna AA, Dubernet I, Jochem P. Do car drivers respond differently to fuel price changes? Evidence from German household data. Transp 2025;52:579–613. [CrossRef]

[15] Shigeta N, Hosseini SE. Sustainable development of the automobile industry in the United States, Europe, and Japan with special focus on the vehicles' power sources. Energies 2020;14:78. [CrossRef]

[16] Singh S, Kulshrestha MJ, Rani N, Kumar K, Sharma C, Aswal DK. An overview of vehicular emission standards. Mapan 2023;38:241–263. [CrossRef]

[17] Grzelak P, Taubert S. Consumption of gasoline in vehicles equipped with an LPG retrofit system in real driving conditions. Open Eng 2021;11:463–469. [CrossRef]

[18] Jia Q, Fu G, Xie X, Hu S, Wu Y, Li J. LPG leakage and explosion accident analysis based on a new SAA method. J Loss Prev Process Ind 2021;71:104467. [CrossRef]

[19] Ceviz MA, Kaleli A, Güner E. Controlling LPG temperature for SI engine applications. Appl Therm Eng 2015;82:298–305. [CrossRef]

[20] Sharma A, Parikh J, Singh C. Transition to LPG for cooking: A case study from two states of India. Energy Sustain Dev 2019;51:63–72. [CrossRef]

[21] Natália K. Security of pipelines in natural gas distribution network. Transp Res Procedia 2019;40:1426–1433. [CrossRef]

[22] Bariha N, Mishra IM, Srivastava VC. Hazard analysis of failure of natural gas and petroleum gas pipelines. J Loss Prev Process Ind 2016;40:217–226. [CrossRef]

[23] Polu SK, Polu SK. IoMT based smart health care monitoring system. Int J Innov Res Sci Technol 2019;5:58–64.

[24] Albesher AA. IoT in health-care: Recent advances in the development of smart cyber-physical ubiquitous environments. IJCSNS 2019;19:181–186.

[25] Yeri V, Shubhangi DC. IoT based real time health monitoring. In: 2020 Second International Conference on Inventive Research in Computing Applications; 2020. p. 980–984. [CrossRef]

[26] Shruti J, Dipali P, Rani G, Va K, Amey P, Pradip S. Smart traffic control system using green energy. In: 2018 Second International Conference on Electronics, Communication and Aerospace Technology; 2018. p. 1690–1694. [CrossRef]

[27] Kotevski N, Koceska S, Koceski S. E-health monitoring system. In: International Conference on Applied Internet and Information Technologies; 2016. p. 259–265. [CrossRef]

[28] Mohandass MP, Kaliraj I, Maareeswari R, Vimalraj R. IoT based traffic management system for emergency vehicles. In: 2023 9th International Conference on Advanced Computing and Communication Systems; 2023. p. 1755–1759. [CrossRef]

[29] Korkmaz I, Metin SK, Gurek A, Gur C, Gurakin C, Akdeniz M. A cloud based and Android supported scalable home automation system. Comput Electr Eng 2015;43:112–128. [CrossRef]

[30] Okubanjo A, Olufemi OB, Okandeji A, Daniel E. Smart bin and IoT: A sustainable future for waste management system in Nigeria. Gazi Univ J Sci 2024;37:222−235. [CrossRef]
[31] Okubanjo AA, Okandeji AA, Abolade OR, Alao OP. Development of GSM based home automation system using Arduino Uno microcontroller. FUW Trends Sci Technol J 2021;6:599−606.
[32] Okubanjo A, Okandeji A, Osifeko O, Onasote A, Olayemi M. Development of a hybrid radio frequency identification (RFID) and biometric based library management system. Gazi Univ J Sci 2022:567−584. [CrossRef]
[33] Gautam YK, Sharma K, Tyagi S, Ambedkar AK, Chaudhary M, Pal Singh B. Nanostructured metal oxide semiconductor-based sensors for greenhouse gas detection: Progress and challenges. R Soc Open Sci 2021;8:201324. [CrossRef]
[34] Xue S, Cao S, Huang Z, Yang D, Zhang G. Improving gas-sensing performance based on MOS nanomaterials: A review. Materials 2021;14:4263. [CrossRef]
[35] Gomes JB, Rodrigues JJ, Rabêlo RA, Kumar N, Kozlov S. IoT-enabled gas sensors: Technologies, applications, and opportunities. J Sens Actuator Netw 2019;8:57. [CrossRef]
[36] Khojier K, Teimoori F, Zolghadr S, Pashazanousi MB. Fast and low concentration detection of liquefied petroleum gas by Au-activated ZnO sensor. Mater Res Bull 2018;108:96−100. [CrossRef]
[37] Asri MIA, Hasan MN, Fuaad MRA, Yunos YM, Ali MSM. MEMS gas sensors: A review. IEEE Sens J 2021;21:18381−18397. [CrossRef]
[38] Mane SA, Nadargi DY, Nadargi JD, Aldossary OM, Tamboli MS, Dhulap VP. Design, development and validation of a portable gas sensor module: A facile approach for monitoring greenhouse gases. Coatings 2020;10:1148. [CrossRef]
[39] Vm A. Metal oxide gas biomarkers of diseases for medical and health applications. Biomed J Sci Technol Res 2020;29:22328−22336. [CrossRef]
[40] Jian Y, Hu W, Zhao Z, Cheng P, Haick H, Yao M, et al. Gas sensors based on chemi-resistive hybrid functional nanomaterials. Nano Micro Lett 2020;12:1−43. [CrossRef]
[41] Nasution TI, Asrosa R, Nainggolan I. Application of MQ-138 semiconductor sensor for breath acetone detection. In: J Phys Conf Ser 2018;1116:032023. [CrossRef]
[42] Nasri A, Petrissans M, Fierro V, Celzard A. Gas sensing based on organic composite materials: Review of sensor types, progresses and challenges. Mater Sci Semicond Process 2021;128:105744. [CrossRef]
[43] Simion CE. Special issue "Advanced materials for gas sensors". Materials 2021;14:6765. [CrossRef]
[44] Isaac NA, Pikaar I, Biskos G. Metal oxide semiconducting nanomaterials for air quality gas sensors: Operating principles, performance, and synthesis techniques. Microchim Acta 2022;189:196. [CrossRef]
[45] Data T. MQ-2 semiconductor sensor for combustible gas. Pololu 2016;2.
[46] Abdullah W, Ramadhani UA, Saputra EM. GSM-based LPG (liquified petroleum gas) leakage detection and alert system. In: IOP Conf Ser Earth Environ Sci 2023;1209:012027. [CrossRef]
[47] Nuga OO, Amusa KA, Olanipekun AJ. GSM-based gas leakage detection and alert system. ABUAD J Eng Res Dev 2017;1:100−104.
[48] Hussien NM, Mohialden YM, Ahmed NT, Mohammed MA, Sutikno T. A smart gas leakage monitoring system for use in hospitals. Indones J Electr Eng Comput Sci 2020;19:1048−1054. [CrossRef]
[49] Mahmood SN, Ishak AJ, Hussain ST. GSM based gas leak monitoring system. Period Eng Nat Sci 2019;7:670−678. [CrossRef]
[50] Tasnim Z, Das S, Islam R, Biswas J, Shamrat FJM, Khater A. Sensor based smart automated gas leakage detection and prevention system. In: 2022 6th International Conference on Trends in Electronics and Informatics; 2022. p. 460−466. [CrossRef]
[51] Dwibedi RK, Vanitha V, Sagar RD, PhaniSai P. Automatic gas leakage detection using IoT. In: IOP Conf Ser Mater Sci Eng 2020;981:042085. [CrossRef]
[52] Sharma VP, Raman D, Padmavathi V, Gurram GVR. IoT based gas leakage detection system using GPS. In: E3S Web Conf 2023;391:01064. [CrossRef]
[53] Rambabu M, Reddy GA, Hyndavi A, Hemalatha M. Gas detection using GPS tracking system. Int J Commun Comput Technol 2022;10:27−31. [CrossRef]
[54] Dash A, Bandopadhay S, Samal SR, Poulkov V. AI-enabled IoT framework for leakage detection and its consequence prediction during external transportation of LPG. Sensors 2023;23:6473. [CrossRef]
[55] Nooralishahi P, López F, Maldague XP. Drone-enabled multimodal platform for inspection of industrial components. IEEE Access 2022;10:41429−41443. [CrossRef]
[56] Nooralishahi P, López F, Maldague X. A drone-enabled approach for gas leak detection using optical flow analysis. Appl Sci 2021;11:1412. [CrossRef]
[57] Meidelfi D, Moodutor HA, Sukma F, Adnin S. Android based spark and gas leak detection and monitoring. J Comput Netw Archit High Perform Comput 2022;4:148−157. [CrossRef]
[58] Sriwati SA, Andani A, Umraeni SAE. Intelligent system of LPG gas leakage detection for web-based living house security. ICIC Express Lett Part B Appl 2019;10:89−96.
[59] Yan HH, Rahayu Y. Design and development of gas leakage monitoring system using Arduino and ZigBee. In: Proc Int Conf Electr Eng Comput Sci Inform; 2014. p. 207−212. [CrossRef]

[60] Priya RV, Kowsalya G. Detecting LPG leakage and automatic turn off using Arduino connected with PIR sensor. In: J Phys Conf Ser 2021;1717:012043. [CrossRef]
[61] Dinesh D, Mowshik AN, Meyyappan M, Kowtham M. Analysis of universal gas leak detector of hazardous gases using IoT. Mater Today Proc 2022;66:1044–1050. [CrossRef]
[62] Manjunathan N, Muthulingam S, Jaganathan D. IoT based gas leakage detection system. In: 2023 International Conference on Sustainable Computing and Data Communication Systems; 2023. p. 1137–1142. [CrossRef]
[63] Santiputri M, Tio M. IoT-based gas leak detection device. In: 2018 International Conference on Applied Engineering; 2018. p. 1–4. [CrossRef]
[64] Bhavithra S, Sushmitha B, Venkatesan T, Sankar P. Intelligent LPG gas leak detection and automatic gas booking alert system using PIC microcontroller. Int J Eng Sci Technol 2021;5:1–8. [CrossRef]
[65] Ogu RE, Achumba IE, Okoronkwo CD, Chukwudebe GA, Chukwuchekwa N. An IoT solution for air quality monitoring and hazard identification for smart city development. In: 2022 IEEE Nigeria 4th International Conference on Disruptive Technologies for Sustainable Development; 2022. p. 1–5. [CrossRef]
[66] Alshammari BF, Chughtai MT. IoT gas leakage detector and warning generator. Eng Technol Appl Sci Res 2020;10:6142–6146. [CrossRef]
[67] Khan MM. Sensor-based gas leakage detector system. Eng Proc 2020;2:28.
[68] Oo ZL. IoT based LPG gas level detection & gas leakage accident prevention with alert system. Balk J Electr Comput Eng 2021;9:404–409. [CrossRef]
[69] Jena B, Pradhan SK, Jha R, Goel S, Sharma R. LPG gas leakage detection system using IoT. Mater Today Proc 2023;74:795–800. [CrossRef]

APPENDIX – MODEL CODES

```
#include <iostream>

#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <DHT.h>
#include <SoftwareSerial.h>
#include "HX711.h"

//blynk

#define BLYNK_TEMPLATE_ID "TMPL5xIVUeFmT"
#define BLYNK_TEMPLATE_NAME "Gas leakage detector"
#define BLYNK_AUTH_TOKEN "DJgh5mpLQ57uv7TaoJV8gUomJczZJEha"

#define BLYNK_PRINT Serial            // Comment this out to disable prints and save space
#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>

char ssid[] = "MTN_4G_4A23DB";
char pass[] = "passpass#MTN#";

BlynkTimer timer;

// Set the LCD address to 0x27 for a 16 chars and 2 line display
LiquidCrystal_I2C lcd (0x27, 16, 2);

// DHT sensor setup
#define DHTPIN 2                      // DHT sensor data pin is connected to D4
#define DHTTYPE DHT11                 // DHT 11
DHT dht (DHTPIN, DHTTYPE);
```

```
#define gasSensor A0
#define buzzer 0
int gas_threshold = 400;
String text = "Leakage Detected";
float humidity;
float temperature;
int gas_value;
float weight;
String status;

//weight sensor
#define calibration_factor 109990.0         //This value is obtained using the SparkFun_HX711_Calibration sketch

#define LOADCELL_DOUT_PIN D7
#define LOADCELL_SCK_PIN D8

HX711 scale;

//sim800l
const String PHONE = "+2347064982193";
#define rxPin D5
#define txPin D6
SoftwareSerial sim800L (rxPin, txPin);

// This function is called every time the device is connected to the Blynk.Cloud
BLYNK_CONNECTED ()
{
 // Change Web Link Button message to "Congratulations!"
 Blynk.setProperty (V5, "offImageUrl",
                    "https://static-image.nyc3.cdn.digitaloceanspaces.com/general/fte/congrat-
ulations.png");
 Blynk.setProperty (V5, "onImageUrl",
                    "https://static-image.nyc3.cdn.digitaloceanspaces.com/general/fte/congrat-
ulations_pressed.png");
 Blynk.setProperty (V5, "url",
                    "https://docs.blynk.io/en/getting-started/what-do-i-need-to-blynk/
how-quickstart-device-was-made");
}

void
myTimerEvent ()
{
 // You can send any value at any time.
 // Please don't send more that 10 values per second.
 Blynk.virtualWrite (V1, temperature);
 Blynk.virtualWrite (V2, humidity);
 Blynk.virtualWrite (V3, gas_value);
 Blynk.virtualWrite (V4, weight);
 Blynk.virtualWrite (V6, status);
}

void
setup ()
{
 Serial.begin (9600);
```

```
 Blynk.begin (BLYNK_AUTH_TOKEN, ssid, pass);

 // Setup a function to be called every second
 timer.setInterval (1000L, myTimerEvent);

 //sim800l start
 //Begin serial communication: SIM800L
 sim800L.begin (9600);

 Serial.println (“Initializing...”);
 //Once the handshake test is successful, it will back to OK
 sim800L.println (“AT”);
 delay (1000);
 sim800L.println (“AT+CMGF=1”);
 delay (1000);
 // initialize the LCD
 lcd.init ();

 // Turn on the backlight and print a message.
 lcd.backlight ();
 //sim800l end

 // Initialize DHT sensor
 dht.begin ();
 pinMode (gasSensor, INPUT);

 // Other setup code...
 pinMode (buzzer, OUTPUT);

 //WEIGHT SENSOR
 Serial.println (“HX711 scale demo”);

 scale.begin (LOADCELL_DOUT_PIN, LOADCELL_SCK_PIN);
 scale.set_scale (calibration_factor);     //This value is obtained by using the SparkFun_HX711_Calibration sketch
 scale.tare ();                            //Assuming there is no weight on the scale at start up, reset the scale to 0
 Serial.println (“Readings:”);

 lcd.setCursor (1, 0);
 lcd.print (“IOT Gas Leakage”);
 lcd.setCursor (0, 1);
 lcd.print (“Detection system”);
 delay (2000);
}

void
loop ()
{

 while (sim800L.available ())
        {
         Serial.println (sim800L.readString ());
        }

 // Read DHT sensor data
 humidity = dht.readHumidity ();
 temperature = dht.readTemperature ();
```

```
 //weight
 weight = scale.get_units ();
 Serial.println ("weight");
 Serial.print (weight);

 status = "No Leakage";

 // Your existing code for other sensors or tasks...

 gas_value = analogRead (gasSensor);
 Serial.println (gas_value);
 if (gas_value > gas_threshold)
        {
         tone (buzzer, 1000, 500);
         Serial.println ("leakage detected");
         send_sms ();
        }

 else
        {
         noTone (buzzer);
        }

 // Display
 lcd.clear ();
 lcd.setCursor (0, 0);
 lcd.print ("T:");
 lcd.print (temperature, 1);
 lcd.print ("C H:");
 lcd.print (humidity, 1);
 lcd.print ("%");

 lcd.setCursor (0, 1);
 lcd.print ("W:");
 lcd.print (weight, 1);
 lcd.print ("Kg");

 lcd.setCursor (10, 1);
 lcd.print ("MQ:");
 lcd.print (gas_value);

 delay (1000);                              // Delay for 2 seconds between readings
 Blynk.run ();
 timer.run ();
}

void
send_sms ()
{
 lcd.clear ();
 lcd.setCursor (0, 0);
 lcd.print ("Leakage Detected");
 lcd.setCursor (1, 1);
 lcd.print ("Sending Report");
 delay (2000);
 status = "Leakage Detected";
```

```
    Serial.println ("calling....");
    sim800L.println ("ATD" + PHONE + ";");
    delay (20000);                                    //20
sec delay
    sim800L.println ("ATH");
    delay (1000);                                     / / 1
sec delay

    sim800L.print ("AT+CMGF=1\r");
    delay (1000);
    sim800L.print ("AT+CMGS=\"" + PHONE + "\"\r");
    delay (1000);
    sim800L.print (text);
    delay (100);
    sim800L.write (0x1A);                    //ascii   code
for ctrl-26 //sim800.println((char)26); //ascii code for
ctrl-26
    delay (1000);
    Serial.println ("LEAKAGE DETECTED.");

    lcd.clear ();
    lcd.setCursor (3, 1);
    lcd.print ("Report Sent");
    delay (2000);
    lcd.clear ();
   }
```