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Portable gas leak detection system using IoT and off-the shelf sensor node

Marwan Ihsan Shukur[1], Maytham Kamal Abas Al-Adilee[2]
[1]Department of Medical Instrumentation Techniques, Al Hikma University College (HIUC), Baghdad, Iraq
[2]Department of Internet Engineering and Computer Sciences, Universiti Tunku Abdul Rahman (UTAR), Selangor, Malaysia

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ABSTRACT

In companies that use toxic gases in vast amounts for a range of procedures, there are a host of high-risk concerns to address. People will not be able to track or control the emission of these gases on a routine basis until it becomes harmful. Sensors are expected to actively detect leaks and alert users to any potential hazards. Gas leakage may occur at multiple locations within a single installation. As a result, sensors are implanted as close to the suspected leak site as possible, enabling them to track leakage and relay signals to a base station that is situated far away. Many sensor values are received and analyzed using a microcontroller. The generated data is encoded in the wireless module and sent to the base through the internet of things link, where it is decoded and viewed by another microcontroller. When leaks are detected, the device sends an audio and visual alert, and since the detection period is very limited due to high-speed processing, leakage situations are brought under control with minimal or no effect. Using the new IoT technology and tracking from anywhere on the network, this project offers a cost-effective and reliable solution for mitigating leakage risk.

Corresponding Author:

Marwan Ihsan Shukur
Department of Medical Instrumentation Techniques
Al Hikma University College
Four Streets, Yarmook, Baghdad 00964, Iraq
Email: Marwan.Al-Jemeli@hiuc.edu.iq

1. INTRODUCTION

Many fatal poisoning incidents can happen in labs or offices. Those have invisible gases leakage. Some of these gases are not detectable by human basic senses as they have no smell, light smell, or the due to human smelling sense lose. This project is concerned about solving the mentioned problem and a detection entity is developed. This paper will present the development of portable gas leak detection system using IoT to reduce the gas incident in chemical industry and surroundings.

In closed air working environment, especially, laboratories, offices and schools, where poisonous gas cylinders are kept, the workers are susceptible to get poisoned if any of those gases leaks out. Many commercial detection devices been introduced to the market. This paper presentes an off the shelf based gas leakae detection sensor node with interent connection capabilites. The main objective of this project is to design and develop a gas leakage detector with an IoT dashboard. The produced apparatus has been tested for its capabilities and evaluated in terms of end-to-end delays of the message transmission from event triggered source sensor to the monitoring base-station. Message delay metric is important since the sensor node information needs to reach the bases station as soon as possible to avoid dangerous circumstances.

2. LITERATURE REVIEW

The chemical Industry transforms a limited number of natural raw materials, such as oil and gas, into thousands of chemical intermediates (via a chemical process or chemical reaction) [1]. A system for detecting gas leaking out of joint in a gas transport and/or storage system is required [2]. The system makes uses of plurality of sensors located at fixed position, as close as possible to the potential leak site(s) to provide signal indicative of the leak to data acquisition unit which can then determine the main leak direction, whereupon corrective action can be taken e.g. tightening the bolt(s) closest to a leak [3]. Moreover, the system enables one to monitor and keep track changes in the leakage rate [4].

This system can also help to prevent the gas leakage that might happen inside the chemical factories and outdoor areas near such factories. The air quality index should be the reference to the public to keep alert the air quality index at their place is under range 0-100 [5]. Monitoring outdoor areas close to chemical production compaines is of high importance to avoid polluting the close by villages and towns or wild life habitate [6], [7]. IoT technology can help in environmental monitoring by transmitting sensor node(s) data and automatically alert the field force officer whom will take immediate action depending on the service level agreement (SLA) [8].

The researchers in [9] have developed a gas leak detection system by sampling gas(s) components and measure its concentration from one gas to another [10]. Developed gas leak tracking method based on the gas utilization and operating state in a controled environment by using electronic embedded system. A Fourier transform infrared spectrophotometer [11] is used to analyze the components of sampled gases. If the analysed gases contain at least one type of specific gas equal to or greater than a predetermined amount, a controller sends a signal to an operation display monitor signalling leakage of the type of specific gas [12]. As a result, regardless of the source of leaking gas, identification by type of gas can be achieved with high accuracy.

A microcontroller is basically a single-chip device at a low cost [13], [14]. The word "single-chip" refers to a computer device that is housed inside a sliver of silicon encapsulated within the plastic housing of an integrated circuit [15]. Micro-controllers are usually equiped with components similar to those that are found in a computer system [16]. components such as processing module, memory, Input/outputs and analogue-to-digital conversion (and vise versa) modules [11], [17].

In [18] suggested using an integrated circuit and MQ-9 to detect harmful gases. They used an integrated architecture, which involves standard input and output devices such as switches, relays, solenoids, light emitting diodes (LEDs), small or custom liquid crystal display (LCD) screens, radiofrequency devices, and sensors for data such as temperature, humidity, and light intensity, among others. Embedded systems are normally devoid of a keyboard, panel, disks, scanners, or other identifiable I/O equipment seen on a personal computer, as well as human interface devices. The number and type of alarms, as well as the type of fire alarm device, that an owner prefers for home protection would be determined by the owner's property protection priorities, the property's valuation, and the insurance company's specifications [19].

Heat control can be used in all fields that are not considered high value in general [20], [21]. One of the most common failures in fire alarm system implementation is to provide only partial building security when requiring high efficiency from installed systems of some type [21]-[23]. The gas detector warning device is configured to ensure that a gas incident is intelligently observed, quickly alerted, and interactively controlled [24], according to the theory of operation suggested in this article. It is based on a timer that takes feedback from the MQ-9 gas sensor and triggers a buzzer and a series of leds that sound an alarm in the event of gas [13], [25]. According to the datasheet, the MQ9 sensor specializes in gas detector equipment for carbon monoxide and CH_4, liquid petroleum gas (LPG) family, and every other related industry or vehicle assemblage [26].

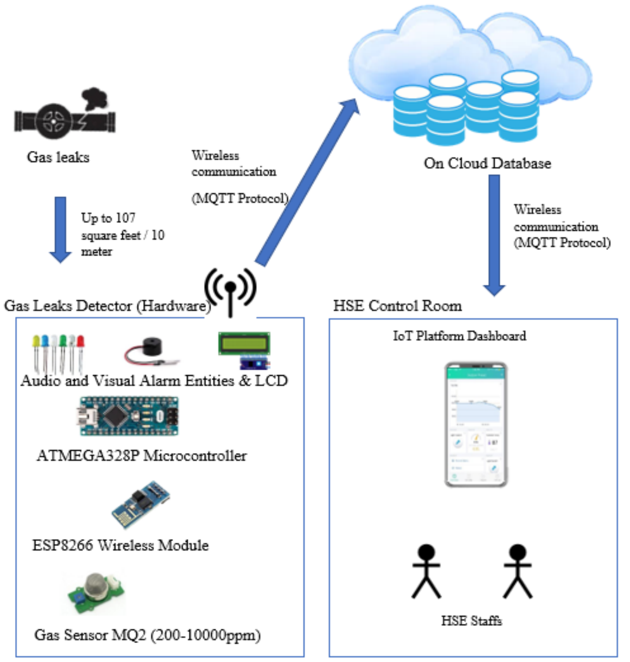
MQ 9 is the sensor that was utilized in this paper. Its advantages include strong CO/combustible gas sensitivity, high sensitivity to methane, propane, and CO, long life and low cost, and a quick drive circuit. The enveloped MQ-9 has six pins: four for fetching signals and two for supplying heating current. The sensor can operate with voltages ranging from 5 to 12 volts AC or DC [27]. For this plant, a 5V supply voltage was used. When the sensor is switched on, the output is usually HIGH, but when gas is detected, it becomes LOW. Table 1 illustrate the list of gas leakage detectection sensors and what gases each sensor detects.

3. PORTABLE GAS LEAKAGE SYSTEM

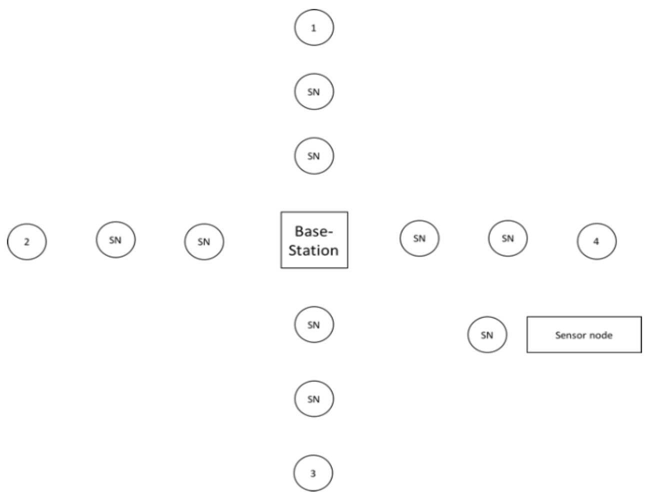
The proposed apparatus opertion in terms of connectivity and main components is detalied in Figure 1(a). The system has been tested for its capabilites of gas detection and data delivery. The next step was to replicate the system into several sensors (12 in total) to create a star network to test the end-to-end delays of the network when transmitting data to the monitoring base-station. Figure 1(b) illustrates the network layout for the sensor network created for th purposes of testing data delivery delays. The distance between each adjacent node is 30 meters and the area of deployement was (200x200) square meters. The transmission range for each node was set to 40 meters with 80 meters of reception sensitivity.

Table 1. List of gas detection sensors

Gas Sensor	Types of Gases
MQ-2	Combustible Gas, Smoke
MQ-3	Alcohol Vapor
MQ-4	Methane, CNG Gas
MQ-5	LPG, Natural-Gas, Town-Gas
MQ-6	LPG, butane gas
MQ-7	Carbon-Monoxide
MQ-8	Hydrogen Gas
MQ-9	Carbon Monoxide, Coal Gas, Liquefied Gas
MQ-131	Ozone
MQ-135	CO, Ammonia, Benzene, Alcohol and smoke
MQ-136	Hydrogen-Sulphide
MQ-137	Ammonia-Gas
MQ-138	Benzene, Toluene, Alcohol, Acetone, Propane, Formaldehyde gas, Hydrogen
MQ-214	Methane, and Natural-gas
MQ-216	Natural-gas and Coal-gas



(a)



(b)

Figure 1. Sensor node operation and design; (a) sensor node connection and (b) sensor network layout for end-to-end message delays evaluation

3.1. System algorithm

Figure 2 illustrates the process flow of the portable gas leakage detection system from the power on until rebooting the system. By using a simple rate comparator, which detects the leakage concentation of the leaked gas, the system will provide leakage indication by specific beep and colored light indication and send the concentration level to monitroting base-station thorugh the internet. If gas concentration does not exeed the threshold value, the system will display a safe status message on the propsed device display and also send this information IoT platform dashboard.

3.2. Schematic diagram

The schematic diagram is illustrated Figure 3(a). The figure shows the connection of the gas leakage detection system for each entity that connected with the microcontroller. There a buzzer, switch, LCD, sensor, battery, Wi-Fi Module and also LED. The node is connected to an access point through the Wi-Fi module to provide aceesss to the internet.

3.3. LED pin connection

In the LED Pin connection is shown in the Figure 3(b). The figure illustrate the 3 colours of LED which are red, yellow and green. The LEDs are connected to resistor before it is connected to the ATMEGA328P Nano microcontroller. Each color indicates the gas leakage state detected by the sensor, where green represents a no leakage or safe state, yellow is for catious state and red is for danger state.

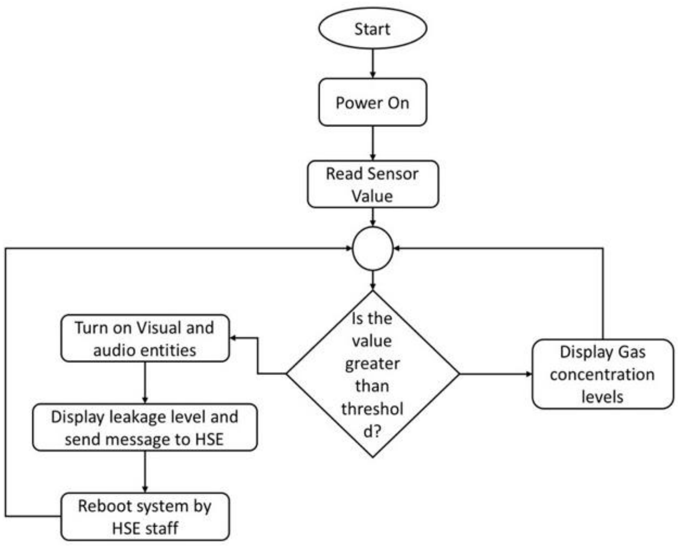
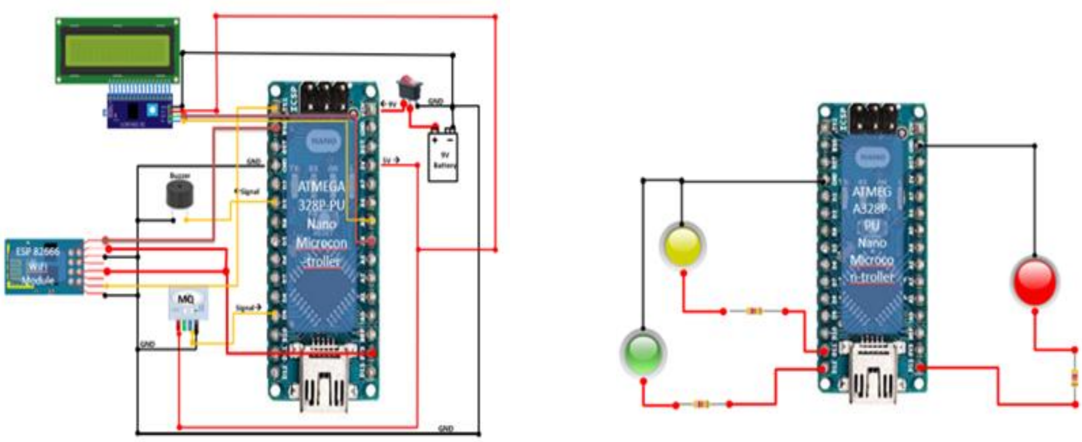


Figure 2. The proposed system operation flowchart



(a) (b)

Figure 3. Sensor node schematic; (a) sensor modules layout and (b) LED pin connection

4. RESULTS AND DISCUSSION

4.1. Prototype testing and schematic diagram

A prototype of the gas leak detection system has been designed and developed and perfomance measurments are detailed in the coming sections. As illustrated in Figure 4, the system may sense the concentration of gas (liquid petroleum gas) in the air and warn the consumer by audio and light entities. In addition, the established system will present a helpful guidance for the user on the current gas concentration status and monitor the leakage using an IoT dashboard, as shown in Figure 5. Figure 5(a) represents the leakage level for a dangerous state, Figure 5(b) represents a precaution state and figure 5(c) is for the safe state. Table 2 illustrates the indicator for the LED, Buzzer (sound), LCD and the gas concentration value for each of the categories.

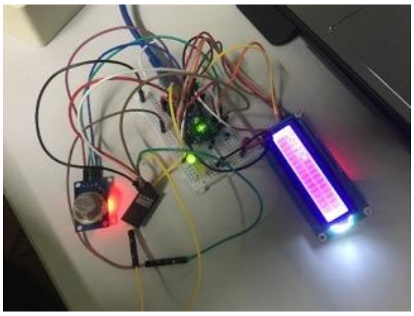
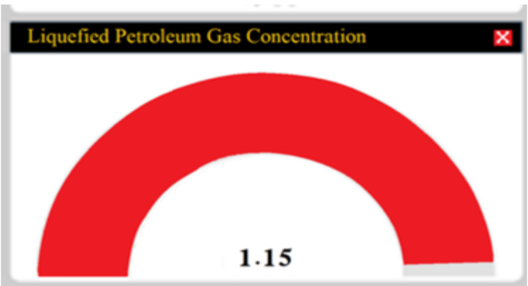
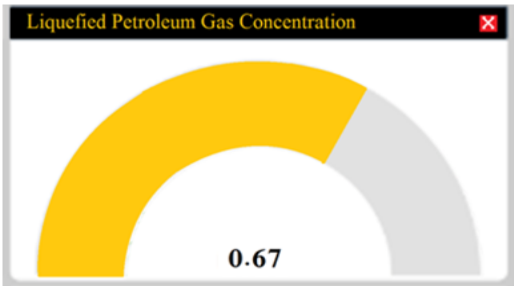


Figure 4. Gas-leakage hardware assembly



(a)



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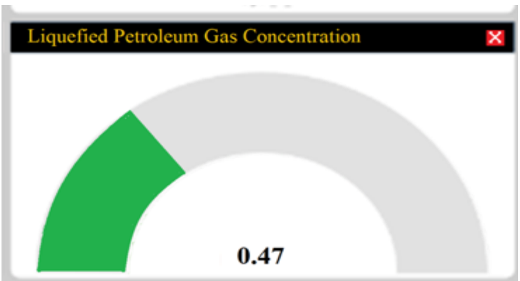


(c)

Figure 5. IoT dashboard; (a) dangerous gauge, (b) precaution gauge, (c) safe gauge

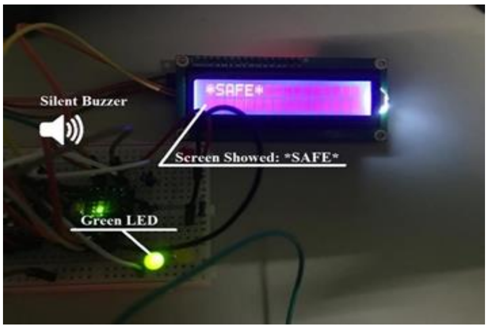
Table 2. Gas leakage system indication table

Indikator type	Dangerous levels	Precaustion levels	Safe levels
LED	RED Light	Yellow	Green
LCD	“Dangerous”	“Precaution”	“Safe”
Gas Concentration	<1000 PPM	500-1000 PPM	>500 PPM

Figure 6(a), 6(b) and 6(c) and Figure 7 illustrate the operation steps of the proposed portable gas leakage detection system for all the indication levels. Since the air content is less than 500 ppm and there is no warning sound for this state, the LCD Screen displayed the SAFE condition status as shown in

Figure 6(a). A lighter was used to test the gas sensor, as seen in Figure 6(b). Liquefied petroleum gas is a safe and easy-to-handle gas that can be used in lighters and other household products including air fresheners. LPG has been used for research purposes.

Since the air concentration is greater than 500 ppm and less than 1000 ppm, the LCD panel reflected the PRECAUTION state status. Under this state, the alerting sound can be heard. As illustrated in Figure 7, since the air concentration is greater than 1000 ppm, the LCD panel displayed a Hazardous State. During this state, the alerting with the rapid tone can be heard.



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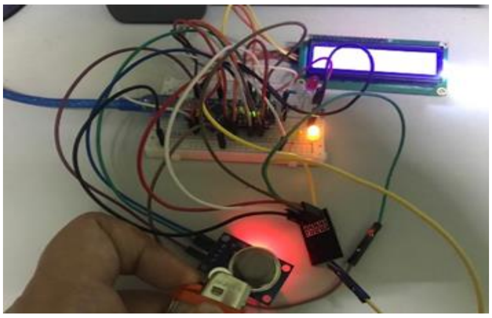

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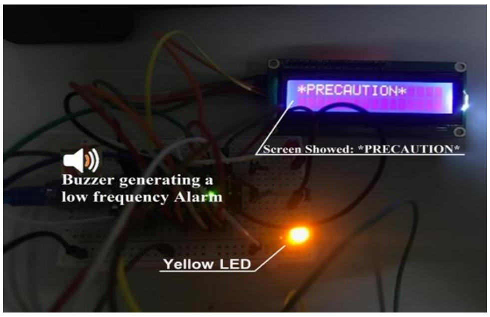

(c)

Figure 6. Detection system layout; (a) the device LCD safty indicator, (b) liquified gas (lighter-gas) used for the system testing perposes, (c) precaution condition indication

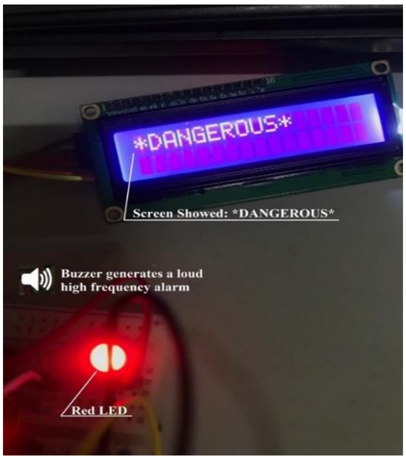

Figure 7. Dangerous condition indication

4.2. Data end-to-end delay analysis

To evaluate the message delays from soucer node of gas leak detection to destination (base station), four sensor nodes were chosen as source of leak destection data. The source nodes are the nodes that lays the farthest from the base station. Two testing scenarios were developed: the first scenario was when the data is sent from source to base station in single hop fashion and the second scenario is when the nodes send their information in a multi-hop fashion.

Each data transmission process has been repeated for 31 times to achieve 95% confidence interval for the data collected. Each node was equiped with a Wi-Fi module that operates at 2.4 Ghz signal frequency that implements 802.11/n protocol suite. Both scenarios were repeated by switching the Wi-Fi modules with ZigBee compatible wireless modules that runs the 802.15.4 package protocols since such modules are targeted towards IoT applications. Figure 8 and Figure 9 presentes the results for both scenarios.

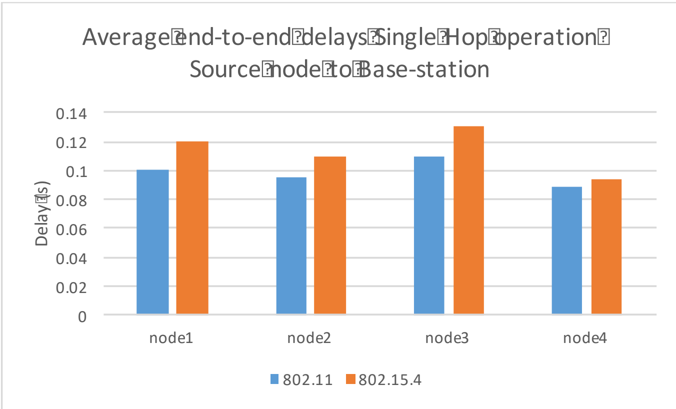

Figure 8. The average data end-to-end delays from source node to destination in single hop operation

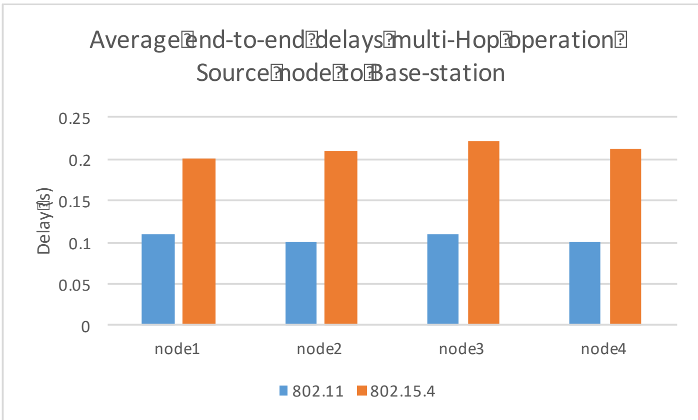

Figure 9. Average end-to-end delays of data from source nodes to destination node in multi-hop operation

From the results presented above, the 802.11 protocol operation provides better end-to-end delays in multi-hop operation whilst 802.15.4 protocols delays were doubled. This is because the duty-cycle of 802.11 protocol were longer (the Tx/Rx module stayes active for longer periods) almost double the period of 802.15.4 duty-cycle. Whilst in single-hop operation the protocols were close to each other in terms of data delays.

IEEE 802.11 protocol is targeted towards house hold wireless operation were wireless nodes energy consumption is rather neglegable. While IEEE 802.15.4 protocol is targeted towards applications were energy preservation is required and the distance of data delivery is higher than that of IEEE 802.11. Therefore, the duty-cycle is shorter in IEEE 802.15.4 to preserve node energy.

5. CONCLUSIONS

This paper presented a low-cost portable gas leaks detection system using IoT to reduce the gas poisoning in both smart-home and industrial environment. The system was composed of off the shelf hardware that can be reached by different and composed for different appliations. Carbon cloud imaging (GCI) technology is being used to track leakage in gas pipelines. The specific sequence implemented by this technology has advantages for gas operations and pipeline system layout, which are very difficult in ensuring safe and efficient natural gas distribution to their clients without risking harm to the public, customers, staff, or the environment. This system can be used along the entire pipeline path and is used in combination with gas point detectors to provide maximum detection coverage. The technique has a larger range of uses in the oil and gas industry, with the aim of improving protection and reducing the number of accidents.

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BIOGRAPHIES OF AUTHORS

Marwan Al-Jemeli received the B.Sc. degree in computer engineering from the University of Baghdad, College of Engineering, Baghdad, Iraq, in 2005, and the M.Sc. degree in electrical and electronic engineering from Universiti Teknologi Petronas, Perak, Malaysia, in 2010. He received his Phd. Degree in electrical and electronics engineering from university Teknology PETRONAS. Since 2017 he is with Al Hikma University College, Department of Medical instrumentation techniques. His current research interests include computer networks, wireless network, wireless sensor networks, routing, medium access control, location estimation, and mobility in wireless networks.

Ts. Dr. Maythem Kamal Abbas Al-Adilee was born in Baghdad, Iraq, in 1984. He got his BSc in Control and Computer Systems Engineering from University of Technology in Baghdad, Iraq in 2005. Subsequently, he completed his Higher Diploma in IT in Bickenhall College of Computing (Middlesex University partner) in London, United Kingdom in 2008. Consequently, he completed his Master’s degree in IT from Universiti Teknologi PETRONAS, Malaysia in 2009. In 2014, he was granted his PhD in Electrical and Electronic Engineering from the same university. Currently, Dr. Maythem works as an assistant professor at the University of Tunku Abdulrahman (UTAR) and an active researcher in Centre for Artificial Intelligence and Computing Applications (CAICA).