An Integrated Hardware Prototype for Monitoring Gas Leaks, Fires, and Remote Control via Mobile Application

Md. Ashiqur Rahman, Humayra Ahmed, Md. Mamun Hossain
Computer Science and Engineering
Bangladesh University of Business
and Technology
Dhaka, Bangladesh

***Abstract*—Liquefied petroleum gas (LPG) is used in a wide range of applications such as home and industrial appliances, vehicles, and refrigerators. However, leakage of gas can have a dangerous and toxic effect on humans and other living organisms. In this paper, an IoT based system is employed for this purpose to monitor gas leakage, detect flames, and alert users. The MQ-5 gas sensor was used to understand the concentration level of a closed volume of gas, while the infrared flame sensor was used to detect the spread of fire in this study. The proposed system has the capacity to detect fire and gas leaks as well as take additional action to lower gas concentration by air ventilation with exhausted fan and put out fires with fire extinguisher. The suggested approach will contribute to increasing safety, lowering the mortality toll, and minimizing harm to the environment. Overall system is implemented with IOT cloud-based remote controls to prevent gas leakage by using android application in response to individual feedback or feed-forward commands. The controller used here is Arduino Uno Rev3 SMD. This study provides design approaches to both software and hardware.**

***Keywords*—Gas leakage; infrared flame detection; IoT; android; arduino UNO**

I. Introduction

When natural gas or another gaseous product escapes from a pipeline or cylinders into an area where it is not supposed to is referred to as gas leakage. These gasses are usually colorless and some are odorless, so there is no way to know if there has been a gas leakage in the environment. It may result in life threatening explosions if these leakage can not be detected [1]. Gas leaks have been a common occurrence in recent years, owing to a combination of poor equipment maintenance and a lack of public knowledge [2]. Therefore, a gas leakage detection system is needed to be introduced to detect gas leakages from domestic or industrial gas pipes or cylinders. It is essential to prevent loss of lives and properties. With the help of Wireless Sensor Networks (WSN), Radio Frequency Identification (RFID), and cloud computing, IoT device communication has become more practical than it once was[3].IoT is a system of web-enabled devices that use sensors to gather data from their environment, process it, and transmit it over the network [4]. Everything is becoming more connected to the internet, which is causing the Internet of Things to grow exponentially [5].

Nowadays a great number of people around the world are using smartphones. So it will be greatly convenient if we can use smartphones as a surveillance device in order to detect gas leakage.Therefore, we have developed a gas leakage detection system accompanied by an android application. However, this system does not only detect the gas leakage but also it can take actions against the explosions that might happen due to leakage.

Currently, the gas leak detection system is a widely used mechanism. These function nicely and substantially reduce damage. If they adopt additional safety measures in addition to looking for gas leaks, they may be more effective. Existing gas leak detection systems can find leaks, sound audible alarms, and text or contact users to alert them to a leak. However, there is no safety precaution, which means that if there is no user, any accident could occur. Our recommended system, however, has safeguards. For instance, the user can promptly take action by utilizing their Android mobile phone in the event of a gas leak, such as cutting off the gas and power supply to lessen the likelihood of an accident. Using our developed app on their phone, they can remotely operate the entire system.

Our system's main goal is to create a gas leakage detection system and take the required actions to avoid disasters caused by gas leakage.The entire system is powered by Arduino. When a gas leak, smoke, or flame is detected, the proper procedures can be performed to notify the users. The entire system can be controlled from remote location by designing an Android app using cloud database. In addition, an automatic fire extinguishing mechanism has been incorporated to provide more reliability to the system's user.

This paper presents the latest IoT and app based intelligent system and provides a substantial new research direction. Some significant contributions of this paper are outlined as follows:

- **Smart Management:** A smart system is developed using edge cutting technology to monitor and control the gas leakage and fire break out.
- **Remote Controlling:** A mobile application is developed to control the system remotely.
- **Smart Decision Making:** A decision tree algorithm is developed based on the data to help the user making intelligent decision.
- **System Integration:** This system's components and integration are both cost-effective and dependable.

The rest of the paper is segmented as follows. Section II discusses about related works. Section III provides a detailed description of the hardware that we have used to build our proposed system. Section IV provides a detailed description of our proposed system. Section V presented the whole scenarios of implementation of our proposed system and Section VI, provides a detailed view whether our system works properly or not. Section VII shows performance evaluation of our system with the existing system and Section VIII gives a detailed view of how security is provided in our IoT system. Section IX concludes the paper.

II. Related Works

Srivastava et al. [6] presented a home automation system for consumer safety in . The suggested system automatically cuts off the gas supply whenever a gas leak is identified. Customers can also keep track of their gas consumption and bring refills before the gas runs out by using the system. They did not employ LPG cylinders in practice due to budgetary and timing constraints. They used a water container and lighters to demonstrate gas leaking in the test case experiment. In [7], Keshamoni et al. built an IOT based system for monitoring gas levels, booking new cylinders, and detecting gas leaks to avoid mishaps. The device reduces gas accidents by informing users of leaks and pre-alerting them to schedule a replacement cylinder. They just alert the users that there is a leakage happening in the system but no remote controlling or monitoring is not implemented there. In [8], Varma et al. presented an IoT based system for detecting harmful gasses. The system notifies customers through personal call, SMS, and email when a gas leak is detected by the gas sensor. The system uses relays to turn off the main power supply when the gas concentration is likely to reach the Lower Explosion Limit (LEL). However if relays fail to perform, there is no alternate way to cut down the main power supply which may lead to a great accident. In [9], Siddika et al. build a microcontroller-based system for monitoring LPG gas leaks and warning users using an Arduino and a MQ-135 sensor. The device activates and sounds an alarm by buzzing the buzzer when the gas sensor detects a gas leak. It also sends a message labeled “GAS LEAKAGE" to a predefined mobile number through the GSM module. They didn’t provide any sort of automatic safety system in place.

In [10], Tamizharasan et al. proposed an IoT-based automated system for monitoring gas density in LPG cylinders. The gas sensor delivers information to the micro controller, which activates the buzzer when a gas leak is detected. They employed a load sensor to measure the weight of the LPG cylinder in this arrangement. When this weight drops to a dangerously low level, the system alerts the user and instantly orders a replacement cylinder by contacting the registered gas booking number. They just monitor the gas density level but they do not detect the leakage occurred in the cylinder. In [11], Tharad et al. proposed a method for detecting LPG leakage using an Arduino-based microcontroller. MQ2 gas sensors, an Arduino microprocessor, a GSM module, an LCD display, a temperature and humidity module, as well as a buzzer were all employed in the system. The gas concentration in the surrounding area will be displayed on the LCD display, and a buzzer will sound when leakage is found. With the aid of a stepper motor, the power source is turned off. But, if the stepper motor fails to perform its action there is no such other option in it which can protect from destruction. Dmitry et al. [12] developed an architecture using Wavelength Modulation Spectroscopy instrument to identify the presence of gas and estimate the gas concentration. The output is sent via Bluetooth protocol to the developed application running on a LG G2 D802. The application was developed to access the HITRAN database in real-time. But there isn’t any automatic action put in it that can be crucial if a user doesn’t receive the notification or take the action. Rahul et al. [13] implemented a system to detect the liquefied petroleum gas (LPG). The system used the high sensitivity sensors to detect the gas leakage as early as possible. They did not include in their system such as cut off power supply, alert system, flame detection, etc.

Anindya et al. [14] presented a new approach for detection of domestic cooking gas leakage. During the experiment the humidity and temperature maintained in a fixed value. Different concentration of LPG has been tested under coated and uncoated conditions. Then the concentration was analyzed for different situations. However, this system doesn’t do anything in response to the presence of gas in the surroundings. Noor et al. [15] proposed a gas leakage detection system using two Internet of Things (IOT) platforms. In this system, MQ-2 gas sensor is used to detect the gas leakage. Then the sensor sends the signal to microcontroller and after that microcontroller sends it to an external device such as cell phone. Blynk IoT application is used to alert the concerned person using alarm and Thingspeak IoT cloud is used to record and visualize the data. To monitor LPG leakage, Malviya et al. [16] presented an LPG gas leakage detection and indication system. This setup uses a gas sensor to detect LPG gas leaks and simultaneously sounds an alarm. After the gas leakage equals or exceeds the predetermined threshold, it also uses a Wi-Fi module to send a message to mobile phones. But they didn’t provide any suggestion how to control the leakage using mobile phone or any other device.

In order to facilitate user engagement with the suggested system, QI Sarhan et al. [17] employed an Arduino Uno microcontroller in conjunction with a number of suitable sensors, actuators, and GSM as a wireless communication channel. Users may be alerted to events like fire, gas leaks, and home invasions via SMS messages, emails with attachments, etc. In this research, MR Habib et al. [18] suggested an automatic fire alarm system with an extinguishing device that is based on Arduino for fire protection. Smoke detector and temperature sensor support the flame sensor in the proposed system, which is explained together with a thermal model of a dwelling. They didn’t use the cloud server and automated decision making approach in their system.

III. System Hardware

1) Arduino UNO (Fig. 1):

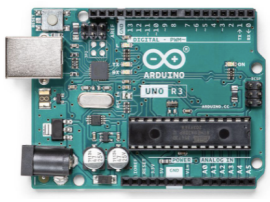

Fig. 1. Arduino UNO.

Features:

- Operating voltage : 5V
- Input voltage range : 6v to 20V
- Input/Output pins : 14
- Analog i/p pins : 6
- DC Current for each input/output pin : 40 mA
- DC Current for 3.3V Pin : 50 mA

2) Gas sensor(MQ-5) (Fig. 2):

Fig. 2. Gas Sensor (MQ-5).

Features:

- Good sensitivity to harmful gasses in a wide range.
- Long life and low cost.
- Possesses high sensitivity to ammonia, benzene, sulfide gases.
- Simple drive circuit.

3) Sim module (Sim 800L) (Fig. 3):

Fig. 3. Sim Module.

Features:

- Works between the voltage range 3.4V to 4.4V and it works in low power mode.
- Operates in 2 mode: Sleep Mode, Ideal Mode.
- Consumption of power is less than 2 mA in Sleep Mode and less than 7 mA in Ideal Mode.
- Supports micro SIM card.
- Searches its corresponding network.
- Helps to send and receive call and SMS.
- Indicates different states by using LED such as: first blinking(no network coverage or searching), slow blinking (logged in), not blinking (power problem).

4) Infrared Flame Detection Sensor (Fig. 4):
Features:

- The sensor can detect fires with wavelengths ranging from 760 to 1100 nm.
- It can detect a lighter flame from 80cm, the larger the flame the farther the sensing distance.

5) ESP Module (ESP 8266) (Fig. 5):
Features:

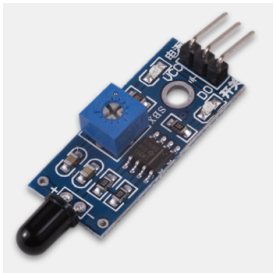

Fig. 4. Infrared Flame Detection Sensor.

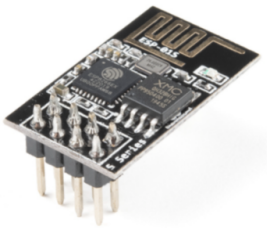

Fig. 5. ESP Module.

- Integrated with TCP/IP protocol stack.
- Build in temperature sensor.
- Power consumption - 70 mA.
- Voltage range - 3V to 3.6 V.
- We need to program our device and communicate with the ESP8266 chip by converting USB signals to serial.

IV. Proposed Methodology

Arduino UNO micro controller is the main component of our proposed system. It works as the brain of our system. As it is a low cost device, and easily programmable, we use it as the integrator of our system. It is connected with every other component shown in Fig. 7.

A. System Architecture

The product consists of an outer wooden casing in the shape of a box to carry the Arduino controller, LCD Display, GSM Module, MQ-5 gas sensor, ESP Wi-Fi module, a Buzzer, servo motor and exhaust fan. The gas sensor is placed right above the mouth of the cylinder and the pipeline. Fig. 6 shows the overall architecture of our system.

A servo motor is placed in such a way that whenever there is a signal, it will close the pipe to stop the flow of gas and with help of ESP Wi-Fi module it can stop electricity supply also. Arduino acts as the brain of control. GSM module, ESP Wi-Fi module, LCD display all are connected to Arduino controllers. An LCD display is connected which always shows how much gas is present in the air. There is a Buzzer and two exhaust fans in our system which will be helpful in case of emergency. The GSM module is connected to the Arduino UNO to send alert messages.

B. Operational Principle

- **Collecting Data from Sensor:** The sensors we have used in our system are MQ-5 gas sensor and fire sensor.

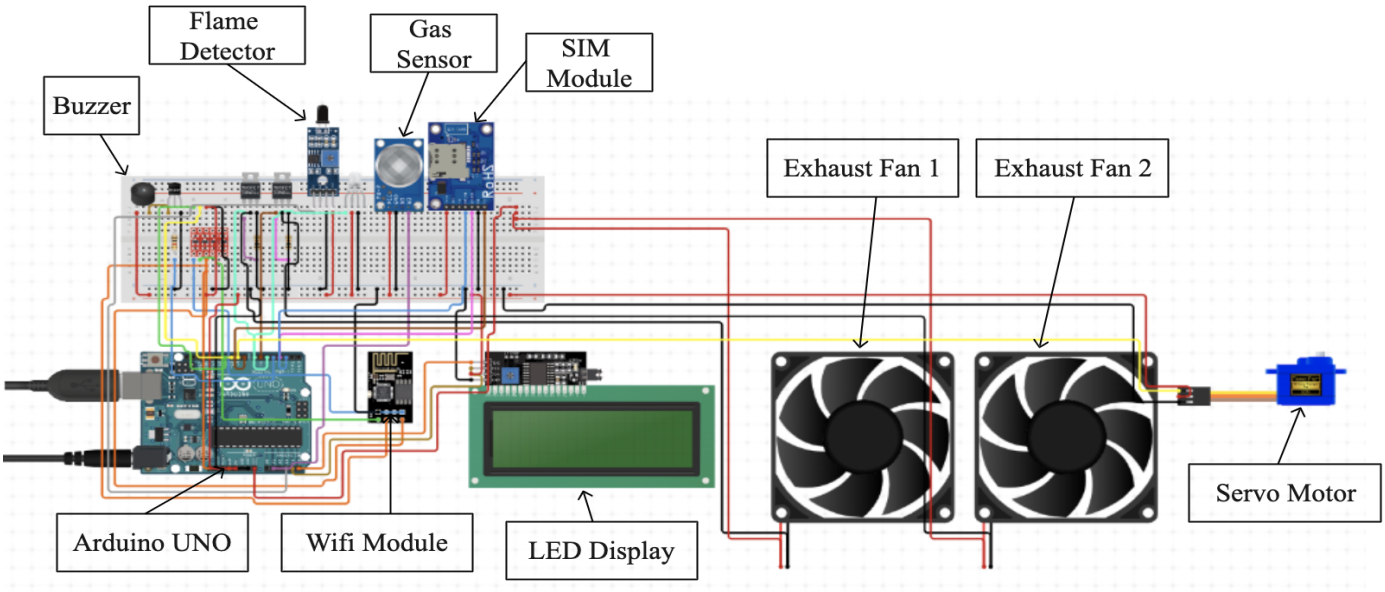

Fig. 6. System Architecture.

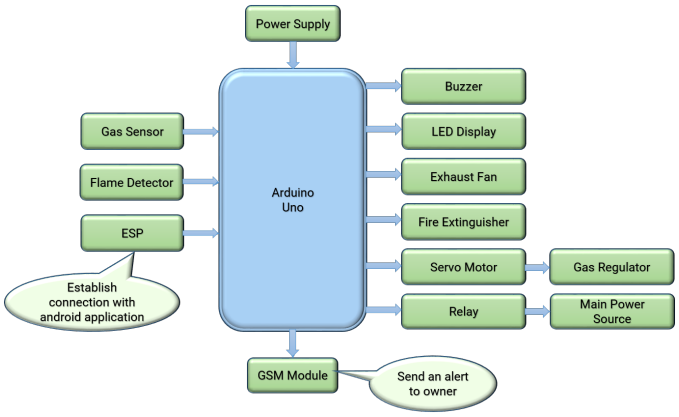

Fig. 7. Block Diagram of the Proposed System.

MQ-5 gas sensor is used to detect whether gas leakage occurs or not. It can also detect toxic gasses like ammonia gas, sulfide, benzene series steam and also trace the smoke and other gasses. The primary material of the MQ-5 gas sensor is SnO2. It possesses very low conductivity in clean air. When the gas leakage occurs, the gas concentration in that place gets higher. So when it comes into contact with SnO2 its conductivity changes. Its conductivity rises along with the level of the gas in the air. This is how the MQ-5 gas sensor works and produces a corresponding output voltage from which we can understand the level of gas in the air.

The fire breakout is detected using an infrared flame sensor. Flame detectors that use infrared (IR) or wide-band infrared (greater than 1.1 m) sense and analyze the infrared spectral band to locate predetermined patterns emitted by hot gases.

All of these sensors are connected with the Arduino UNO board and data from the sensors has been displayed on the LCD monitor. If the gas leakage occurs in the system, an alarm or buzzer rings to alert everyone within the house. And an alert message is sent to the user's phone using GSM module shown in Fig. 8.

- **Sending Data to Cloud Server:**
  All of the data that is collected from the sensor has been sent to the cloud server using the Wi-Fi module that is associated with the Arduino UNO server. For cloud service, we have used the Firebase database. The Firebase saves the data as parent child combination pair. The cloud server is basically used for remote controlling of our system.

- **Data Extraction and Mobile Application Development:**
  All of these data that is stored in the cloud has been collected and sent to the mobile application that we have been built using the MIT app inventor. By using this application, the user can control the system from anywhere. The sensor data is visible to the user through the application interface.

- **Remote Controlling:**
  A decision tree algorithm is applied in the data that is collected from the cloud server and a suggestion is visible in the interface of the mobile application. Then the user can easily take the decision of turning the gas regulator off or turning on the exhaust fan or cutting off the electric supply or turn on the fire extinguisher depending on the situation. When the user gives command in the mobile application, it immediately sends the signal to the cloud database and from that the signal is executed in the Arduino UNO board. This is how remote controlling is done in our system using mobile application.

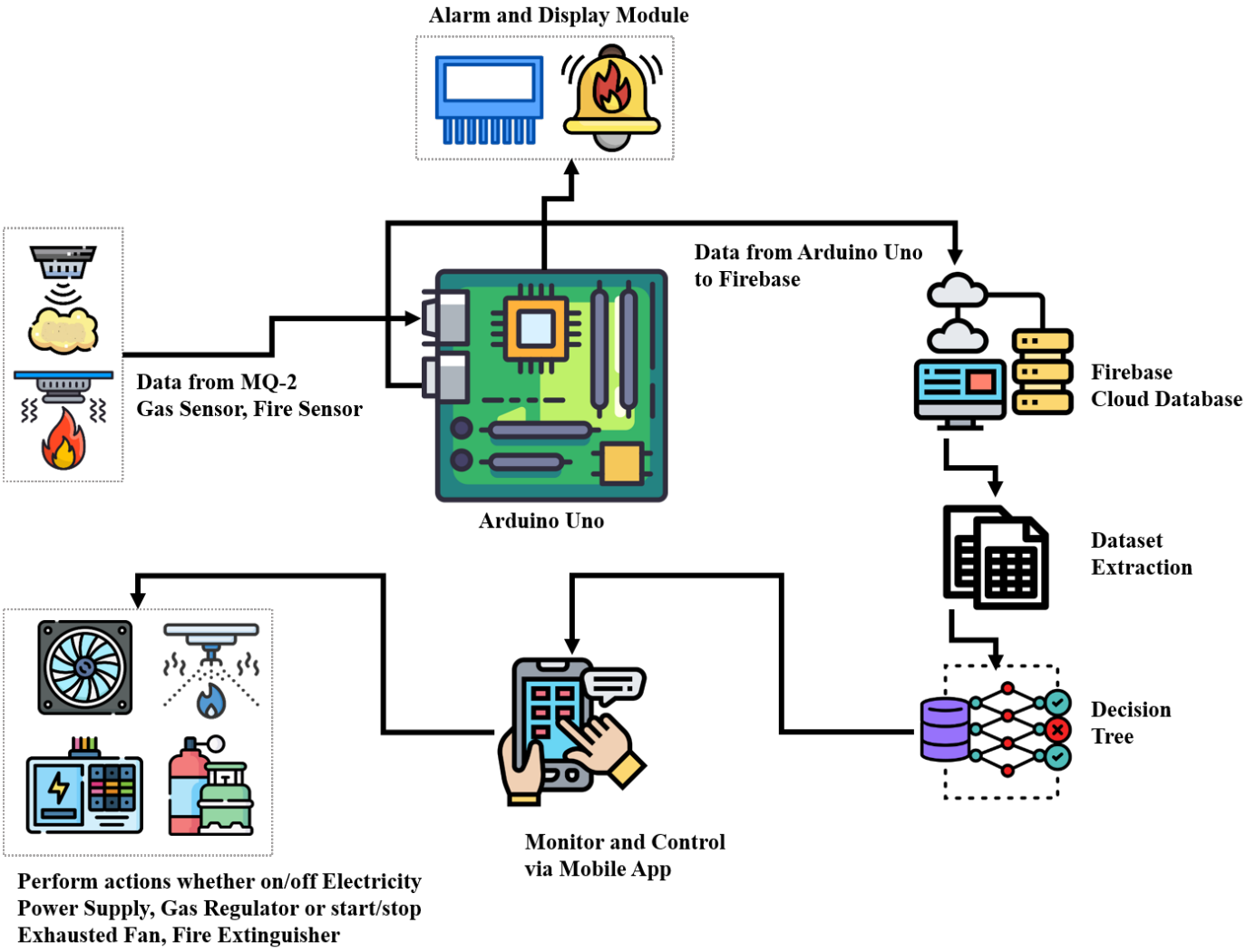

Fig. 8. Operational Flow of Detecting Gas Leakage.

V. Implementation

A. System Implementation

The below Fig. 9 represents our whole system implementation. Before implementing the overall system, we have tested every single component. In place of exhaust fans and fire extinguisher, we have used LED bulbs to minimize our implementation cost and simplification. To monetize the power supply, we have used a single LED bulb. Arduino UNO is connected with every single component of the system and acts as a brain of our system.

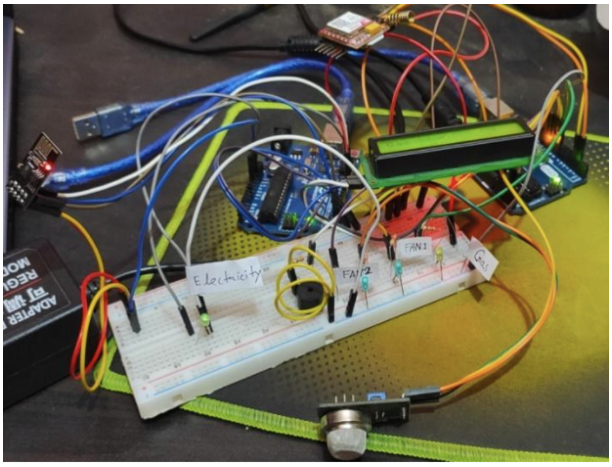

Fig. 9. System Implementation.

B. Android Mobile App Implementation

Here we have developed an android app which helps to control our leakage system from a remote distance. The user may turn the gas and electricity off and exhaust fan on in case of found leakage through apps. Fig. 10 the interface of our android app. We have implemented the decision tree algorithm 1 in the mobile application to provide suggestion about taking action to control the gas leakage.

Fig. 10. Mobile Application Interface.

VI. Test and Results

This system has been examined by taking a small amount of LPG gas near to the sensor. The MQ-5 gas sensor detects the LPG gas and then it sends a signal to the micro controller. The sensor detects gas leakage once the system is launched, if there is no gas leakage, it displays “Gas Level Normal" on the display which is shown in Fig. 11.

When gas is leaked and it crosses its limit which we set (300ppm) a signal from the micro controller goes to the display and shows “Leakage Found" which is shown in Fig. 12. Simultaneously the buzzer rings.

Then the sensor data goes to the cloud and gives a notification or alert message “Leakage Found on your kitchen" to the owner’s phone to let him know about the incident shown in Fig. 13.

After getting from leakage found message, we can stop the gas and power supply by the help of our android app.When the owner stays at home and wants to be sure of his safety, he can turn off the gas supply with his mobile through this application. And if he stays outside the home, then he can turn off both the gas supply and power supply with the help of this application. If the flame detector sensor detects the flame then it will immediately sends message to the user and the user then

Algorithm 1: Decision Tree for Gas Leakage Controlling

1. Enter the gas level
2. Enter the flame status
3. **if** $gaslevel >= 300$ && $gaslevel <= 3000$ **then**
   - **if** $flamestatus == true$ **then**
     - suggestion = 1st Exhaust Fan on & Buzzer on & Fire Extinguisher on
   - **else**
     - suggestion=1st Exhaust Fan on & Buzzer on
4. **else if** $gaslevel > 3000$ && $gaslevel <= 7000$ **then**
   - **if** $flamestatus == true$ **then**
     - suggestion = 2nd Exhaust Fan on & Gas Regulator Off & Fire Extinguisher on
   - **else**
     - suggestion=2nd Exhaust Fan on & Gas Regulator Off
5. **else if** $gaslevel > 7000$ && $gaslevel <= 10000$ **then**
   - **if** $flamestatus == true$ **then**
     - suggestion = Power Supply off & Fire Extinguisher on
   - **else**
     - suggestion=Power Supply off
6. **else**
   - suggestion = Gas Level Normal

Fig. 11. Show Gas Level Normal.

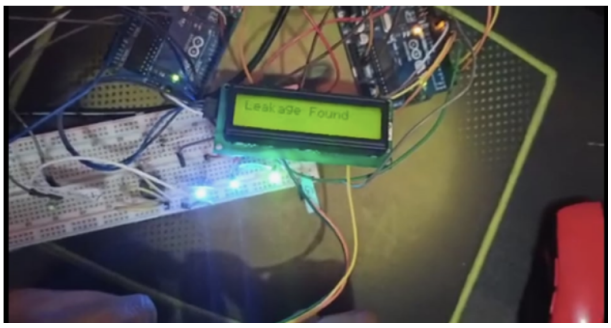

Fig. 12. Leakage Found Message Display.

TABLE I. DIFFERENCE WITH OTHER EXISTING SYSTEMS

Features	[6]	[7]	[8]	[9]	[10]	[12]	[13]	[14]	[15]	**Proposed System**
Detection of gas leakage	Y	N	Y	N	Y	Y	Y	Y	Y	Y
Detection of fire	Y	N	N	Y	N	Y	N	N	N	Y
Detection of harmful gases	N	N	Y	N	N	N	N	N	N	Y
Alert by Alarm	Y	N	Y	Y	N	N	N	N	Y	Y
Alert by SMS	N	Y	Y	N	N	N	N	N	N	Y
Alert by Personal Call	N	N	Y	N	N	N	N	N	N	N
Controlling exhaust fan	N	N	N	N	N	N	Y	N	N	Y
Controlling power supply	N	N	N	N	N	N	N	N	N	Y
Controlling gas regulator	N	N	N	N	N	N	N	N	N	Y
Controlling fire extinguisher	N	N	N	N	N	N	N	N	N	Y
Message shown in LCD display	N	N	N	Y	Y	N	N	N	N	Y

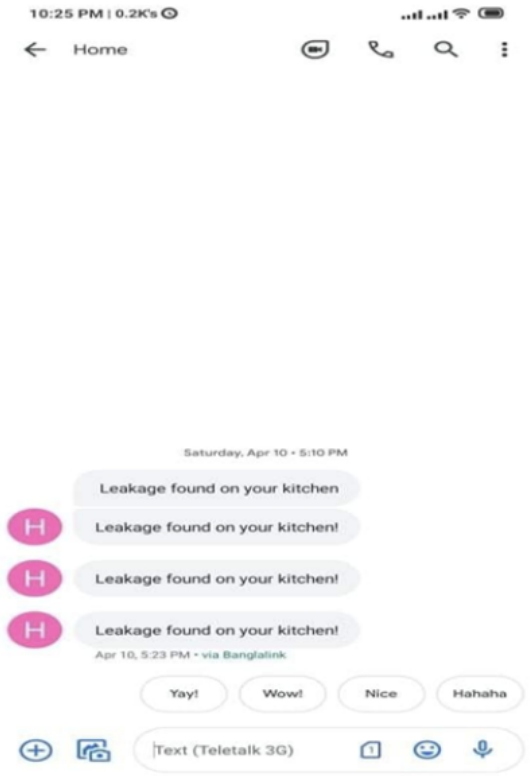

Fig. 13. Alert Message about Leakage of Gas.

using the mobile app can turn on the fire extinguisher.

VII. EVALUATION

We have evaluated our system with other existing systems in respect to the feature that they have introduced in their system. The Table I shows the difference between our proposed system and existing system.

Here, Y represents 'Yes' and N represents 'No'.

Comparing the proposed system to the other systems it can be clearly seen that from Table I, the proposed system incorporated more features in comparing with the other system. It can not only detect the gas leakage but also take necessary precautions or actions to avoid severe accidental cases happen due to gas leakage which is absent in the existing systems.

VIII. SECURITY

The majority of internet technologies and networking protocols have been created exclusively for unrestrained items, which has presented significant security concerns when integrating IoT objects into the standard Internet [19]. We must ensure security in order for the various sensors attached to our system and the data saved in the cloud database to function properly. The security measures put in place in our system to keep it secure are listed below.

- **Providing Authentication and Password:** For our smartphone application that we designed to allow remote operation of our IoT system, we have enabled authentication and strong passwords. It aids in protecting our system from brute-force attacks.
- **Monetizing and Updating System:** We have a frequent update option installed in our system and regularly monitor to detect the vulnerabilities of our system.
- **Ensuring Security of Data:** Our data is stored in the Firebase database. To protect the data, we have used their built-in authorization mechanism. In order to safeguard the data from manipulation or tampering from other sources, we have additionally deployed rule-based permission of the Firebase database for data retrieval. This makes our data secure when retrieving.

IX. CONCLUSION

In this research, we proposed a gas leakage detection approach for home safety reasons to reduce the accidental cases occur owing to gas leakage and a flame detection system is provided to manage the fire outbreak. To remotely operate the entire system, we also developed an android application. Additionally, it accomplishes some important properties that the current approaches do not. A more potent gas sensor, such as MEMS, can be used to increase system effectiveness. If a Philips micro controller is utilized, the micro controller's efficiency and memory can be improved. To generate intelligent decisions, advanced machine learning algorithms might be introduced.

ACKNOWLEDGMENTS

We would like to acknowledge the support of the Bangladesh University of Business and Technology and IoT lab for their suggestion and resource sharing.

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