New Gas Leakage Detection System using Internet of Things

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Abstract*: Liquid petroleum gas (LPG) is used for variant purposes at home such as central heating and cooking. LPG is primarily consisting of propane and butane which are highly flammable chemical compounds. Gas leakage can introduce risk of fire, which can occur inside homes, commercial premises or factories. Since the LPG does not have any odour, gas companies add an odorant such as Ethanethiol, Thiophene or Mercaptan so human can detect the leakage by the sense of smell. However, this is detection approach is not safe since sleeping person, children, low smell-sense people might not detect the leakage. Therefore, a more robust and reliable detection mechanism is required to increase safety at home. This project introduces a reliable, robust and instant-response solution for such a problem. Gas Leakage Detection System (GLDS) can detect leakage at homes, commercial premises or factories. Two highly important safety factors are considered in this system including: time and control. GLDS detects the leakage soon after it happened and sends users an immediate alarm on the incident. Moreover, by the application of the IOT (Internet of Things) people can control their home premises remotely. Consequently, in the case of users being away from home, he/she can remotely interact with the system to control the safety at home by cutting off electricity or ventilating the house*.

Keywords – *Gas detection, IOT, leakage detection*

I. INTRODUCTION

Gas leakage leads to dangerous events causing financial loss as well as casualties. The number of deaths due to the explosion of gas cylinders has been increasing in recent years. The reason for such explosion is due to old cylinders, worn out valves and lack of awareness using gas stoves [1].

Inspections by oil companies found that many liquid petrol gas (LPG) consumers do not know the safety precautions of gas cylinders. So there is no getting away from designing a remote control system to detect leakage of LPG. Thus it takes nearly 60 min [2][1] to detect when 1% of gas leak occurs. As a result, when the homeowner is out of his house, he has no idea what is happing inside, therefore, at once entering his home the disaster will happen. As a solution for the problem, a control system of gas leakage detector by wireless system needs to be developed in order to prevent a disaster to happen. By a wireless system, user can improve his safety standards, remotely control the condition of the home while he is out of his house and acts accordance with statutory requirements to protect his property from disasters.

The rest of the paper is structured as following: background of the important topics of the project in section II. Section

III presents a review of related work. Section IV shows our methodology in GLDS. Section V describes the system requirement and analysis. The system design is displayed in Section VI. Section VII presents the system implementation and testing. At the end we conclude our paper with future work and results.

II. BACKGROUND

A. Internet of Things

In 1999, Kevin Ashton introduced the concept Internet of things (IOT) in the context of supply chain management [4]. However, the term of Internet of things is changing continuously according to technology evolution, but the key aim of IOT of making a computer sense information without the person intervention remains the same. IOT is on the verge of transforming the static internet into a network of a fully interconnected objects that not only gains information from environment (sensing) and interacts with the physical world (command, control), also uses existing internet standards to provide services for information transfer, applications and communication [5]. The next revolution will be the interconnection between objects to create a smart environment.

B. Arduino microcontroller

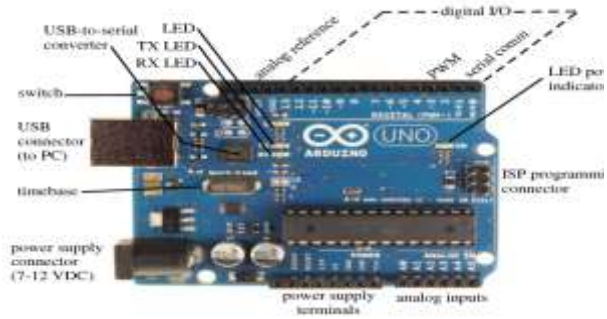

Figure 1: Arduino Microcontroller

The Arduino project was started in Italy by team of Massimo Banzi, David Cuartilles, Tom Igoe, Gianluca Martino, and David Mellis. Their aim was to build a low cost hardware and ease to use single board computer. The Arduino is an open-source, which means hardware is reasonably priced and development software is free, therefor it would be available to everyone. The Arduino board allows writing programs using C/C++ and creating interface circuits to read switches and other sensors. Figure 1 shows the Arduino microcontroller.

The significant merit of the Arduino is that the host personal computer is used to write and debug a control program, after downloading the control program to the Arduino, it will run automatically. Therefore, no longer need the PC to run the program after removing the USB cable connection to the PC.

C. Global System for Mobile (GSM)

It is a digital cellular technology used for transmitting mobile voice and data services. It has the ability to carry 64 kbps to 120 Mbps of data rates. GSM supports more than one billion mobile subscribers in more than 210 countries throughout the world. It restricts the user's mobility because of; the user should be in the range of the base station. Figure 2 shows the GSM modem.

Figure 2: GSM Modem

D. Global Positioning System (GPS)

GPS is a satellite-based navigation system consists of a network of 24 satellites located into orbit. The system provides essential information to military, civil and commercial users around the world and which is freely accessible to anyone with a GPS receiver. A GPS receiver must be locked on to the signal of at least three satellites to estimate 2D position (latitude and longitude). With four or more satellites in sight, the receiver can determine the user's 3D position (latitude, longitude and altitude) [3]. Figure 3 shows the GPS modem.

Figure 3: GPS Modem

E. Semiconductor sensors

At the heart of any gas detecting system are the sensors. The sensor detects target gases, and then converts the information into an electrical signal to the controller. Semiconductor sensors are actually the best for use with remote sensing utilities like Android software. This assertion is backed by the fact that the semiconductor sensor is the cheapest among several kinds of sensors, holds a very high potential of working efficiently with phones. The semiconductor sensor has the ability to trigger alarms with phone-integration features, immediately notifying a homeowner of gas leaks before they get to critical levels [6].

III. RELATED WORK

This section discus several applications to see what each one offers to users and what it lacks to benefit from its advantage to build an enterprise application.

A. Air Quality Egg

The Air Quality Egg (Figure 4) is a sensor system designed to allow anyone to collect very high resolution readings of NO2 and CO concentrations outside home. This system works as following:

1. Outdoor sensors sit outside home taking regular readings and send the data wirelessly to an Egg base station inside.
2. Egg base station receives the transmitted data. It then relays that data to the Internet via a wired Ethernet connection.
3. Air quality data will be sent in real-time to an open data service, which stores and provides free access to the data. The service includes embeddable graphs and generates SMS alert to

the website. Figure 5 illustrates how the SMS alerts look like.

Figure 4: Air Quality Egg System

This application is similar to the proposed project as it is taking advantage of the Internet of Things. The air quality data will be sent in real-time to xively.com, an open data service, and it provides information about the gas pollution in real time. This application differs from the proposed application as does not have an Android application, does not send SMS about the gas pollution to mobile of the homeowner. Instead, user should check the website to get it. This application is not sensitive to the liquid petroleum gas at home. This application is just a monitoring application, but the proposed application is monitoring and controlling application.

Figure 5: Air Quality Egg Website

B. Sensondrone system

Figure 6: Sensondrone System

It is a system for collecting pollution data through portable sensors positioned in many points of a specific area. A group of people should be equipped with such sensors to detect pollution. The collected data will be sent via Bluetooth to people's personal devices and managed by the data logger mobile application, then will be transferred to remote servers. This requires the sensors to be connected to the platform through smartphones and even more important, the data about the GPS position has to be sent as well as time data. Pollution data will be available in real time to everyone by downloading the mobile application Air quality. every user can also share measurements on the social networks. Figure 6 and Figure 7 show the Sensondrone system and its interface.

This application is similar to the proposed application, it can provide the real time data and information about the

Figure 7: Sensondrone Application

pollution gas, and it takes merits of the Internet of Things. It uses mobile application, and does not severely restrict the user mobility. This system is a monitoring system not monitoring and controlling system. Finally, it is expensive due to using GPS frequently.

C. WaterBot System

The WaterBot tests for water quality. One end can be dipped into a water source and then it will upload pollution data to the web via a ZigBee-installed module so that everyone who lives near that water source can stay informed Figure 8. This application is like to the proposed application, it can provide the real time data and information about the pollution. This system is a monitoring system not monitoring and controlling system. It does not use a mobile application; it is expensive due to using a personal computer.

Figure 8: WaterBot System

D. Results of the related work

A Comparison of the Air Quality Egg, Sensordrone and WaterBot systems with the Gas Leak Sensor Application is done in Table I

System	Monitor Control or both	Sensitive	IOT	Android	Cost	Real Time data	Communication Module
Air Quality Egg	Monitor	No_2, CO, temperature, humidity	Yes	No, website	Fairly	Yes	Internet
Sensondron	Monitor	Air pollution, temperature, humidity	Yes	Yes	Expensive due to using GPS for long time	Yes	GPS, Bluetooth
WaterBot	Monitor	Water pollution	Yes	No, website	Expensive due to using PC	Yes	ZigBee
Proposed System	Both	LPG	Yes	Yes	Fairly	Yes	GSM, GPS

Table I: Comparison of the three systems with the proposed one

The foresaid Table 1 shows that, all the systems share some aspects such as: implementing the internet of things concept, and providing real time information about the pollution. At any rate, there are a significant difference amongst them in accordance with the following factors:

1) Monitoring and controlling: all the similar systems are just monitoring, while the proposed system is a monitoring and controlling system, which gives the ability to put any dangerous situation instantly under the control.

2) Sensitivity: all the similar systems are sensitive to the pollution in general, while the proposed system is specialized in the Liquid petroleum gas, which is the underline cause of fires in homes.

3) Android technology: with the exception to the Sensondron system, all the similar systems do not use the Android technology, while the proposed one uses the Android to provide the end users with an emergency notification.

4) Cost: with the exception to the Air Quality Egg system, all the similar systems are expensive due to using either the GPS for long time, or the personal computer. While the proposed one is cheap in comparison with them.

IV. Methodology

The proposed project is subjected to incremental development methodology Figure 9. By using the foresaid methodology, the application is designed, implemented and tested incrementally and quickly till all the foreseen objectives of the application are accomplished. Choosing that foresaid methodology returns to several reasons:

1) It is a well way to get rapid results in a short time.

2) It is easier to test and debug during a short iteration.

3) It is more flexible and less costly to change the scope and requirements.

Figure 9: Incremental Development

A. Business Requirements:

To ensure the system works well, it has to support the following business requirements:

1) The user shall be able to receive warning message as quickly as possible.
2) The user shall be able to turn off the electricity.
3) The user shall be able to turn on the air-refreshing device.
4) The user shall be able to view information of fire station.
5) The user shall be able to view nearest fire station.
6) The user shall be able to navigate to nearest fire station.
7) The user shall be able to make call to 998.
8) The user shall be able to share his/her location.

B. Non-functional requirements:

Non-functional requirements "refer to behavioural properties that the system must have, such as performance and usability".

C. Operational requirements:

The system should be operated in android operating system.

D. Performance requirements:

1) The system should response immediately to any leakage situation.
2) The system should update the local database in real time.
3) The system should make decision within 5 seconds.
4) The Arduino response time should be fast.
5) The gas detector should be from anywhere at any time.
6) The homeowner information should be modified easily.

E. Usability requirements:

The system interface should be easy and effective. (User-friendly)

F. Availability requirements:

The system should work 24 hours 7 days a week.

G. Security requirements:

1) The communication between the Arduino and the GLDS should be secure by encryption.
2) The system should not display the homeowner personal information to anyone.

V. SYSTEM DESIGN

A. User Interface

Figure 10: Gas Leakage System (Main Page)

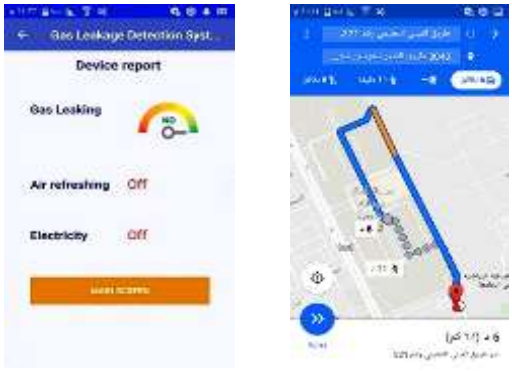

Figure 11: Gas Leakage System (Report)

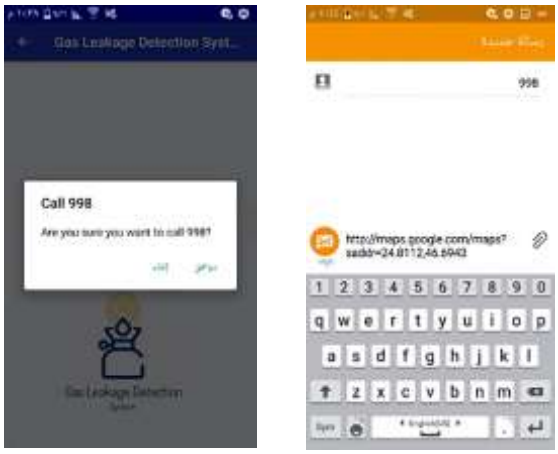

Figure 12: Gas Leakage System (Emergency call)

Figure 10, 11, 12 show the Gas leakage detection system application user interface

B. Other Alternative in Designing the Project

There are different alternatives to design this project as an application; these platforms are Android, IOS and Windows operating systems. Gas Leakage Detection System used Android platform for various reasons. Android does not have licenses; larger and growing faster than IOS and Windows platforms, and there are no costs to develop application on Android.

C. System implementation, testing and deployment

1) System implementation:

The system implementation describes the hardware and software that were used to build GLDS successfully.

2) Hardware Specifications:

The architecture mainly consists of three components, first the main detectors, which are Arduino, GSM Modem and the gas sensor, second laptops and third android mobile.

The main function of the GSM Modem is the remote communication between the user and the controller. The function of the controller is to continuously check the inputs coming from the gas sensor device and send message through the GSM network in case of emergency.

3) Arduino:

An efficient and smooth working controller is needed to continuously sense leakage of the gas. And also fast response is required when leakage found. The detection system includes Arduino duemilanove microcontroller board, which is Arduino compatible with microcontroller chip ATmega328p Figure 13. The Duemilanove is a microcontroller breakout board featuring ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 Analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button.

The Arduino Duemilanove has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers.

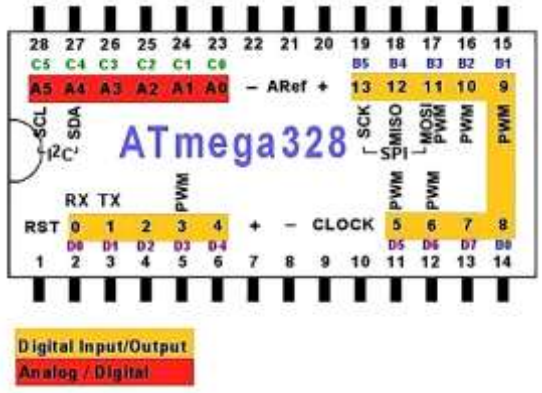

Figure 13: Arduino Chip

4) Gas Sensor:

A sensitive gas sensor is required that senses only LPG gas contents and is less sensitive to other gases like cooking fumes, cigarettes, etc.

MQ-6 gas sensor [7], [8] has high sensitivity to Propane, Butane and LPG, also response to Natural gas. This sensor is with low cost and suitable for different application.

Figure 14: Gas Sensor

5) GSM:

GSM-SMS remote measurement and control system for greenhouse is introduced in [7] based on computer connected with base station. Base station consists of a microcontroller, GSM module and sensors. The central station receives and sends messages through GSM module. Criterion value of parameters to be measured in each base station is set by central station. And this system is implemented in embedded operating system. [9] Proposes Remote Monitoring and control Systems based on GSM. GSM network is a medium for transmitting the remote signal and communication takes place between monitoring center and remote monitoring station. The central monitoring station performs real time control, alarm and data processing and also manages database. Receiving and sending of the data in the central monitoring station is achieved by using the GSM wireless communications module TC35. TC35 is invented by SIEMENS, which is a dedicated Modem.

6) Software Specifications:

This system will pass through all the software development phases which are: the plan phase, gathering the requirements, analysing, building the database, designing the interface, writing the algorithm, deployment phase, implementing the application and testing it.

7) Android Studio:

Android Studio is the official Integrated Development Environment (IDE) for Android app development, based on IntelliJ IDEA. On top of IntelliJ's powerful code editor and developer tools, Android Studio offers even more features that enhance your productivity when building Android apps.

8) Java:

Java is a programming language expressly designed for use in the distributed environment of the Internet. It was designed to have the "look and feel" of the C++ language, but it is simpler to use than C++ and enforces an object-oriented programming model. Java can be used to create complete applications that may run on a single computer or be distributed among servers and clients in a network.

9) C (Programming Language):

C ranked among the most widely used languages, is a high-level and general-purpose programming language that is ideal for developing firmware or portable applications. It has a compiler for most computer systems and influenced many popular languages – notably C++.

D. System Testing:

The important step in any project is the system testing. It contains two types of testing, the functional testing (black-box testing) and the usability testing.

1. Functional testing (Black box method):

It is based on functions and features. It contains all the activities that were done to verify a specific function. In the Black box method "The examination happens without any knowledge of the internal implementation." So, it does not analyze the code during tests.

2. Usability Test

The usability testing is about evaluating a product or service by testing it with representative users. "During a test, the users will try to complete the tasks and functions while observers watch, listen and takes notes. The goal is to identify any usability problems, collect qualitative and quantitative data and determine the participant's satisfaction with the product".

The usability testing for GLDS was done with three users to test the application. Based on the following criteria:

Verify the functions of Gas Leakage Detection System, such as:

- Leakage Detection.
- Sends a message to the user in case of gas leakage.
- User can turn off \ on the electricity.
- User can turn on \ off the air refreshing.

Verify the interface to make sure that it is good and effective. Table II shows the system result check.

ID	Criteria	Result
1.A	leakage detection	Pass
1.B	Sends a message to the user in case of gas leakage.	Pass
1.C	User can turn off \ on the electricity.	pass
1.D	User can turn on \ off the air refreshing.	Pass
2	Verify the interface to make sure that it is good and effective.	Pass

Table II: Result of Usability Test

E. Deployment diagram:

The deployment diagram is one of the structural diagrams and "it describes the physical deployment of information generated by the software program on hardware components. The information that is generated by the software is called an artifact" Figure 15.

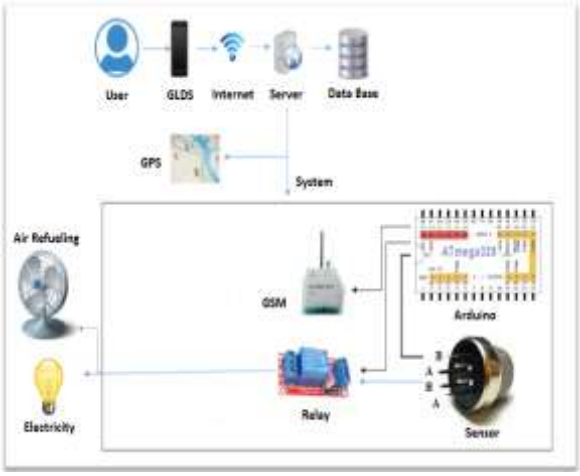

Figure 15: Deployment Diagram

VI. Result

The main reason of conducting this project is because the lack of gas leakage detection systems in many houses, also because of the increasing number of gas leakage incidents in many houses, the significant damage that caused by them, and the homeowners does not have sufficient awareness that makes them behave well in case of gas leaks. This project was conducted to help homeowners to have an easy way to avoid gas leakage incidents before they occur.

To achieve these requirements, the team has built up an Android application (Gas Leakage Detection System) that sends to the homeowner in no time a warning message in case of leakage, it gives him/her the ability to turn off/on the electricity and the air refreshing devices, it allows him/her to share the location, it navigates to nearest fire station, and it shows a list of fire station locations, as well as the ability to call 998.

VII. Future Work

For future work, these are number of suggestions that might be add to the system to upgrade it.

1. Discover other toxic gasses
2. Support Arabic language
3. Support other platforms such as IOS and windows phones.

VIII. Conclusion

This paper clarifies the basis of the project. The first section was the introduction that gives a brief description of the GLDS. Followed by the background of the important topics and some related works. Furthermore, the methodology of the project and the system requirement and analysis was described. Next, the system design and implementation was clarified. Last but least, the results and future work.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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