Gas Leakage Detection and Smart Alerting and Prediction Using IoT

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Abstract

IoT is an expanding network of physical devices that are linked with different types of sensors and with the help of connectivity to the internet, they are able to exchange data. Through IoT, internet has now extended its roots to almost every possible thing present around us and is no more limited to our personal computers and mobile phones.
Safety, the elementary concern of any project, has not been left untouched by IoT. Gas Leakages in open or closed areas can prove to be dangerous and lethal. The traditional Gas Leakage Detector Systems though have great precision, fail to acknowledge a few factors in the field of alerting the people about the leakage. Therefore we have used the IoT technology to make a Gas Leakage Detector having Smart Alerting techniques involving calling, sending text message and an e-mail to the concerned authority and an ability to predict hazardous situation so that people could be made aware in advance by performing data analytics on sensor readings.

Keywords *- Internet of Things, Gas Leakage Detector, Smart Alerting Techniques, Prediction, Data Analytics.*

1 INTRODUCTION

Internet of Things aim towards making life simpler by automating every small task around us.
As much is IoT helping in automating tasks, the benefits of IoT can also be extended for enhancing the existing safety standards.

Safety has always been an important criteria while designing home, buildings, industries as well as cities. The increased concentration of certain gases in the atmosphere can prove to be extremely dangerous. These gases might be flammable at certain temperature and humidity conditions, toxic after exceeding the specified concentrations limits or even a contributing factor in the air pollution of an area leading to problems such as smog and reduced visibility which can in turn cause severe accidents and also have adverse effect on the health of people.

In order to have a control over such conditions this paper proposes a system that uses an MQ-2 sensor which is capable of detecting gases such as H2, LPG, CH4, CO, Alcohol, Smoke and Propane [1]. This system is not only capable of detecting the leakages and hence presence of excess amounts of harmful gases and alerting through audible alarms but also, with the help of IoT, alerting the concerned authority about the condition before any mishap takes place through a personal call and message using GSM module, an e-mail about the details of the area using an Ethernet Shield. The system cuts off the main power supply of the house or building when the concentration of gas is about to reach its Lower Explosion Limit (LEL) which is done with the help of relays. The Gas Leakage Detector System also sends the sensor reading to cloud so that analytics could be carried out on the readings for increasing the precision of the system.

2 RELATED WORK

Gas Detectors have been in the market for a very long time and have been vastly used. They have wide range of applications and can be found in industrial plants, refineries, pharmaceutical manufacturing, paper pulp mills, aircraft and ship-building facilities, wastewater treatment facilities, vehicles, indoor air quality testing and homes[2].
There are a lot of ways in which the Gas Detectors could be characterized. They are categorized on the basis of what type of gas they detect, what is the technology behind the making of the sensor and sometimes even the components which are used that affect their operation mechanism (semiconductors, oxidation, catalytic, photoionization, infrared, etc.)[2]. Gas Detectors are also widely characterized as fixed or portable detectors. They are characterized on the basis of which category of risk they fall in, Ex-Ox-Tox, the three categories of risk - Ex – Risk of explosion by flammable gases - Ox – Oxygen Risk of asphyxiation by oxygen displacement Risk of

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increase of flammability by oxygen enrichment - Tox – Risk of poisoning by toxic gases [3], the list of categorization goes on. As a result we cannot have a single system or a group of systems which we can call the best but instead there is a plethora of devices available for matching the varying user requirements some of which are listed below.

A. Handheld EGD01
This Handheld EGD01 delivers high-sensitivity, and is easily adjustable for detecting a wide variety of combustible gases, including methane, propane, and butane. It is used by the building inspectors [4]. As the name of the product suggests, it is a portable device and hence battery operated. It has both a sound and light alarm.

B. Amprobe GSD600 Gas Leak Detector
This is a portable gas detector for detecting gases such as methane and butane. It has a stainless steel probe. The probe allows the user to get into the hard-to-reach places. It was designed for detecting gas within closed piping system and it has an audible alarm [4].

C. Analox Sensor Technology [5]
Safety of campus in terms of gas leakage detection in laboratory environment, canteens and other areas of possible gas leakage have been ensured by using of devices such as O2NE+, SAFE-OX+, A50, etc. provided by ANALOX Sensor Technology [5] and many more such devices by various other producers are used all around the world in all the campuses.

Other devices like First Alert CO615, Kidde KN-COPP-B-LPM, KN-COEG-3 Nighthawk, PNG2000A Natural Gas Detector Pen, Safe-T-Alert 30 Series and so many more, to name only a few are available in market for the gas detection purpose.

These are a few of the mostly used devices and all of them have a very high precision. Their price range from 30$ to 180-200. These devices are mostly battery operated and are used for detecting a wide range of gases. One common thing that all these devices share is the mode of transmitting warnings which is audio (high pitched alarms) and visual (digital or LED) techniques. Our IoT based model for gas leakage detection is taking this traditional approach a notch up by adding the feature of immediately intimating the concerned authorities and also updating the sensor readings, time to time, on cloud. The detailed description is given in Section 4 of this paper.

3 SMART HOMES AND CITIES

Internet of Things is being used everywhere in order to ease our daily tasks and improve the quality of life. There are innumerable modules that could be thought of for smart homes and cities and some of them are discussed below:

A. Gas Detection Systems
This is the system which has been discussed in this paper.
The versatile nature of this system comes because of the fact that the same system with a change in the type and number of sensors can be used in different places. They can be used at homes, buildings, industries for detecting LPG, Propane, Methane or any other harmful gas leakages (discussed in this paper) and with some changes could be used in cities for detecting air pollution and performing analytics on the sensor readings to predict and prevent dangerous situations.

B. Traffic management system
In London, a traffic management system known as SCOOT maximises green light time at traffic intersections by feeding back magnetometer and inductive loop data to a supercomputer, which can orchestrate traffic lights across the city to improve traffic throughput.[6]

C. Smart Lighting
Flexible street lighting (smart lighting) [7] allows municipalities to control the brightness of street lights.

D. Voice Controlled Automation
The commercial products Google Home and Amazon Echo are being widely used for automation of home. These improve quality of living as well as consider the energy conservation factors such as switching off lights and fans automatically when the room is empty.

E. Queue Management System
This system allows the people to know about the shortest queue and also the average waiting time of a certain queue
.

An alternative use of smart city technology can be found in Santa Cruz, California, where local authorities analyse historical crime data in order to predict police requirements and maximise police presence where it is required [8]. The analytical tools generate a list of 10 places each day where property

crimes are more likely to occur, and then placing police efforts on these regions when officers are not responding to any emergency. This use is different to the manner in which European cities utilise smart city technology, possibly highlighting the breadth of the smart city concept in different parts of the world [9].

4 GAS LEAKAGE DETECTORS

Different types of equipments are used for various purposes in our day to day life and most of them have the capability of emitting some kind of gases or some compounds in the air while in use. It is very important to keep a check on the concentration levels of the gases and other compounds as some of them, when exceed the safe concentration level, are flammable under the room temperature and humidity condition.

Mixtures of dispersed combustible materials (such as gaseous or vaporized fuels, and some dusts) and air will burn only if the fuel concentration lies within well-defined lower and upper bounds determined experimentally, referred to as flammability limits or explosive limits. Combustion can range in violence from deflagration, through detonation, to explosion [10].

A traditional gas detection system checks for the concentration levels and alerts people about the leakage through audio and visual alarms.

The IoT based model of the traditional gas leakage detection system does not only alerts people by audio alarm but also attempts to alert the concerned personnel through a call and text message on their phone so that even if no one is present in the area of leakage, they are made aware of the situation.

Along with this the prototype also sends the details containing sensor reading recorded at the time when the alarm got actuated which could be used by an individual or an organisation to make decision about what type of attention is required in the area of gas leakage.

Another most significant feature of this prototype is that it can record the sensor readings and maintain a database of these readings of concentrations of gases at different timestamps. This data could be utilized for carrying out analytics on it. The analysis of the sensor readings can help in understanding the usual conditions of the area, under what conditions do the readings of sensor usually goes up and when does it actually start getting dangerous and needs attention. This will increase the precision of the system, reducing the false alarms and hence actually becoming a very reliable system within a span of a few days. Along with all these features, this system also comes with a power cut off option. In case the concentration of flammable gases is about to reach their lower explosive limit (LEL) the system trips the main switch which causes a complete power cut off of the building or office or wherever the system is installed. This will serve two purpose that is one, it will prevent any disaster due to electricity or power and two, in case the leakage is being caused by any such device whose turning off will prevent any further leakage, this purpose will be served by the power cut off feature. Description about the components used and the processing steps involved have been discussed in detail in Section 4.1 and Section 4.2 of this paper.

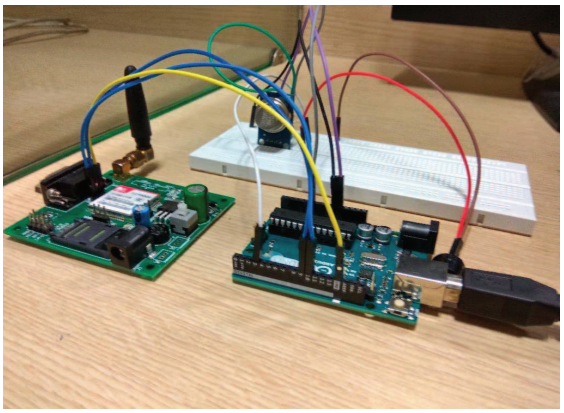

Fig. 1 Prototype

4.1 Components

Fig. 2 shows the circuit diagram of the prototype. The main components used in the making of this prototype are as follows:

1) Arduino UNO (ATMEGA328P): A microcontroller board that comes pre-programmed with a boot loader that allows to upload new code to it without the use of an external hardware programmer. The Arduino Uno can be programmed with the Arduino Software IDE [11]. The gas sensor is connected to this board for processing the sensor readings according to the program. Arduino powers the Ethernet Shield which is stacked upon it, used for connectivity to Internet. It also powers the GSM Module which is used for making a call. The Piezo Buzzer used as an audible alarm and a 5V relay used for the power cut off feature are also mounted on this board.

2) Ethernet Shield (W5100): The Arduino Ethernet Shield allows an Arduino board to connect to the internet. It is based on the (Wiznet W5500 Ethernet chip). The Wiznet W5500 provides a network (IP)

stack capable of both TCP and UDP [12]. It has an operating voltage of 5 volts which is supplied from the Arduino Board and provides a connection speed of 10/100Mb.

It helps in uploading sensor values on cloud and sending email when the sensor value crosses the threshold limits.

3) GSM Module (SIM900A): This module is connected to Arduino board which helps in making calls and sending text messages when the sensor value crosses the threshold limits.
The SIM900A delivers GSM/GPRS 900/1800MHz performance for voice, SMS, Data, and Fax in a small form factor and with low power consumption [13].
4) Gas Sensor- MQ2: The prototype of gas detector system here uses an MQ2 sensor of the MQ-x family that detects gases, specifically H_2 (Hydrogen), LPG (Liquefied Petroleum Gas), CH_4 (Methane), CO(Carbon Monoxide), Alcohol, Smoke and Propane, in the atmosphere. The sensor value only reflects the approximated trend of gas concentration in a permissible error range, it does represent the exact gas concentration. The detection of certain components in the air usually requires a more precise and costly instrument, which cannot be done with a single gas sensor [1].

5) Relay: Relay that works with 220V and has a 5V input is used in the circuit for cutting off power when required. The relay has 5 pins. One pin is connected to one of the digital pins of the Arduino Board. One is connected to bridge the 220V power supply to the relay. The other pin redirects this supply to the appliances. Rest of the two are ground connection, one for the main power supply and the other for Arduino Board.

6) Piezo Buzzer: It is used for generating audio alarm.

4.2 Processing Steps

Fig.3 shows a flowchart depicting the processing steps.
1) The MQ-2 Gas Sensor of the MQ-x family detects the concentration of gases. In order to stabilize the sensor reading it is important to pre-heat it. The best preheat time for MQ-2 sensor is 24 hours or more.

The gas sensor module consists of a steel exoskeleton under which a sensing element is housed. This sensing element is subjected to current through connecting leads. This current is known as heating current through it, the gases coming close to the sensing element get ionized and are absorbed by the sensing element. This changes the resistance of the sensing element which alters the value of the current going out of it. [14]

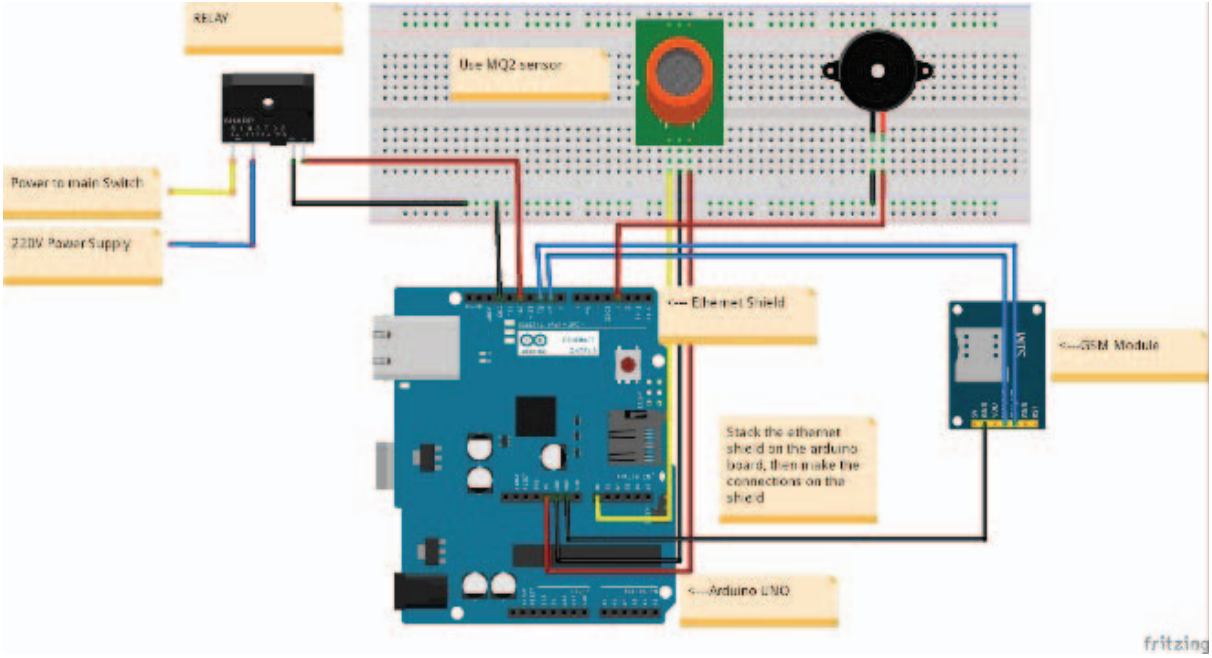

Fig. 2 Gas Leakage Detector Circuit Diagram

Steel Mesh filters out the suspended particles so that only gaseous elements are able to pass to insides of the sensor. [14]

2) Every value recorded by the sensor is checked against a threshold value. This threshold value is decided based upon the nature of the gases and also on the behaviour of the sensor.

Precisely the sensor is connected to the A0 pin of the Arduino board. The voltage read from the sensor is calculated and displayed. This value can be used as a threshold to detect any increase/decrease in gas concentration. [1]

Now when the sensor will be exposed to the gases that MQ-2 can detect then the sensor readings could be compared with the threshold value for detecting leakages.

3) The concentration of gases are recorded by the sensor and these values are updated on a cloud platform and in this case on ThingSpeak. The internet connection required for doing so is provided by stacking up the Ethernet Shield on Arduino UNO board.
There are other platforms which could be used for this, for example. Microsoft Power BI, Google Big Query and the sensor data can also be posted on Google spreadsheet.

4) The buzzer is actuated when the readings exceed the threshold value.

5) An email about the details containing the concentration levels of gases is sent to the concerned authority (Lab In charge, Technical Department). In order to send the email an internet connection is required which is provided by the Ethernet Shield.

This feature is totally modifiable depending upon the need of the user. The e-mail could be sent every hour, every 24 hours or whatever is desired. It requires only a simple manipulation of code.

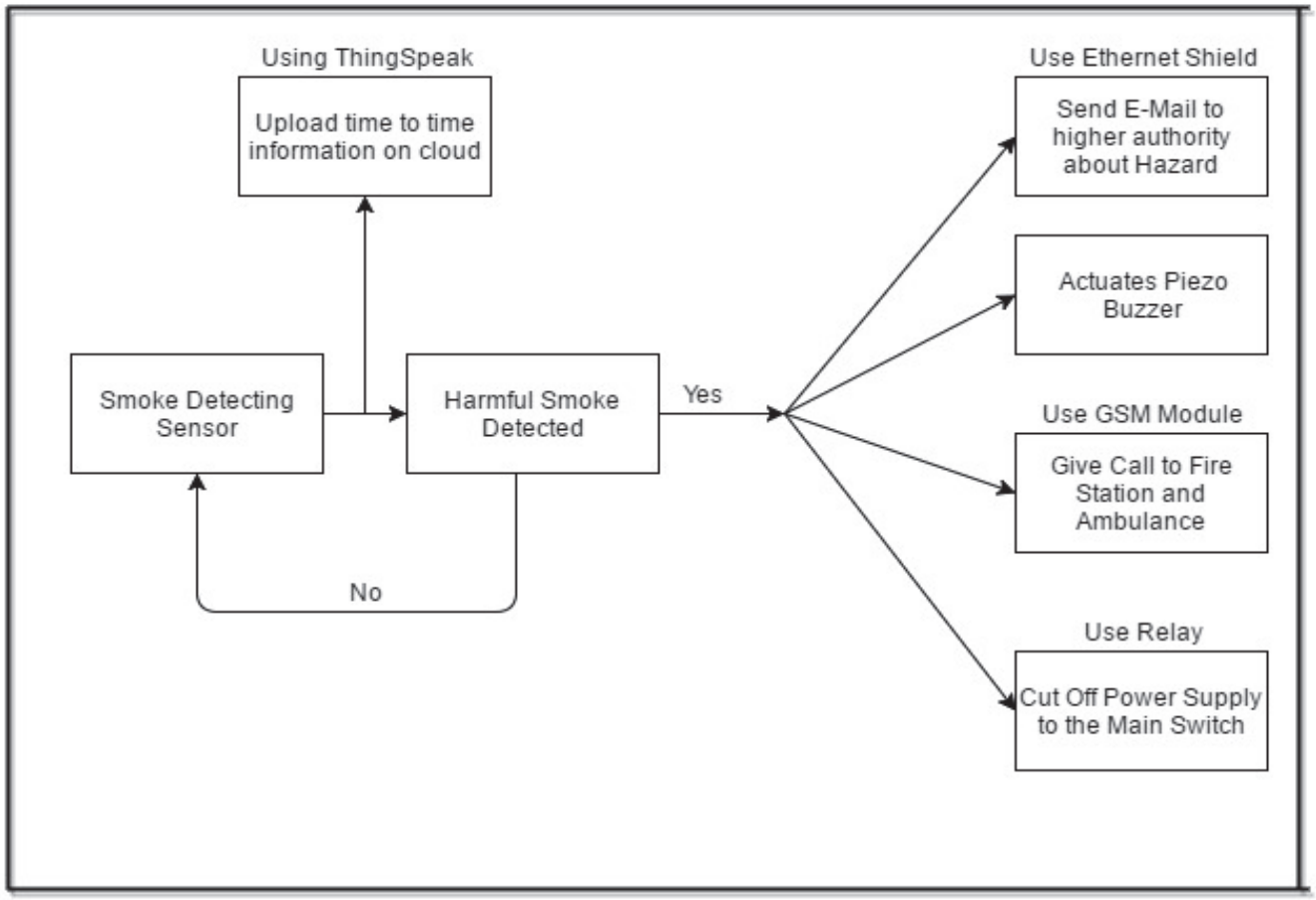

Fig. 3 Gas Leakage Detection Processing Steps

6) A call is made to the concerned authority (Lab Incharge, Fire Station, and Ambulance). GSM Module is used for making a call as well as sending text message.
Just like the email feature, this is also modifiable according to the user needs as to when and what message should be sent and who all should be the recipients.
7) If the sensor readings are about to reach the lower explosion limit (LEL), the relay cuts off the power supply to the main switch.

8) The sensor readings that were uploaded to cloud (Step 3) can be used for data analytics. The average reading of 24 hours can be calculated, every day since the day of deployment. The comparison of these average readings will help in increasing the precision of the system and help it in understanding the behaviour of the environment in which it is deployed.

4.3 Cost Estimation of Project and Comparisons

The price of the existing Gas Detection system in markets vary from around $30 to $150-$180 and more, with the one with minimum specification costing the least.
The Gas Detection system proposed in this paper has a cost estimate of $50. This system inculcates the features that are not available in any other existing gas detectors; smart alerting and prediction. With all these features and some calibration this system can prove to be as good as any high priced module and maybe even better.

5 CONCLUSION AND FUTURE WORKS

The proposed gas leakage detector is promising in the field of safety. The attempt while making this prototype has been to bring a revolution in the field of safety against the leakage of harmful and toxic gases to minimize and hence nullify any major or minor hazard being caused due to them.
Nevertheless there is always scope of improvement and some of the features that will improve the system and make it even better and reliable have been mentioned below:

A. Extended Features of System
The behaviour of the gases is dependent on the temperature and humidity of the air around. A gas at certain concentration might not be flammable at low temperature but might have explosive nature at high temperature. For this reason addition of a Temperature and Humidity Sensor will be very helpful.

B. Performing Big Data Analytics on the sensor readings
Analytics could be performed on the sensor readings. The readings from sensors could be used for forming predictions of situations where there can be a mishap. Instead of straightaway alarming when the concentrations have gone high, algorithms could be worked upon which could determine such situations prior to their occurrence. Combining the gas sensor readings with the readings from temperature and humidity sensor would increase the precision of the system. The cases of false alarms being raised will reduce down to very small percentages.

C. Dedicated Application for System
A dedicated mobile application could be made for the system. The features of the application would be:
1. Getting the details of the concentration levels of the house within a tap of a button.
2. Since it is a safety device it is important for it to be perfectly calibrated and maintained at all times. The app can make sure to send reminders about getting the system checked every once in a while.
3. The user can add or remove the recipients who will receive the information of leakage whenever they require

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