Detecting Gas Leaks: A Case Study in IoT Technologies

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Abstract — This paper presents a case study in the creation and utilization of an Internet of Things (IoT) device. An Arduino-based gas leak detector is utilized for the demonstration of IoT technologies and their advantages. The gas leak detection device focuses on detection of Liquified Petroleum gas. Upon detection of a leak, the device can communicate over the internet using cellular networks, thus helping to alleviate Wi-Fi and ethernet failure issues such as loss of power in a natural disaster. Because of the device's resilience, it can help ensure the user is notified of the emergency as soon as possible. This automated gas leak monitoring system is reliable and will not be put out of action in a disaster or emergency situation.

Keywords — Arduino, GSM Module, Internet of Things, MQ-2 Gas Detector.

I. INTRODUCTION

Liquified Petroleum (LP) gas is used as fuel in different heating appliances, cooking equipment, and vehicles in the modern world. Despite of its variety of uses the LP gas is highly explosive and toxic to breathe. It is also colorless, tasteless, and naturally odorless, although in many applications Ethyl Mercaptan is used as odorant (similar to rotten eggs). In the event of a LP gas leak, all building occupants must be immediately notified and evacuated; the leakage could result in severe injuries or even death. Additionally, the building can catch on fire and be destroyed. Occupants can be notified about a building gas leak by conventional methods as well as Internet of Things (IoT). This paper will explore the creation and usage of such a gas detection IoT device, and the benefits and effectiveness of this device.

Traditionally, gas leak detectors can alert occupants using visual or auditory means, but this assumes they are inside the building. As alluded to earlier, sometimes bitterants are added to aid occupants in knowing when a gas leak is occurring, but this assumes occupants can smell within the olfactory range of the leak. Occupants will need to rely on such an emergency information concerning the leak being passed to them by third parties if they are not within range of the detector's alarm, or within visual range of the detector's alert.

One way to solve these issues is to create a gas detector using the IoT device. The IoT is a collection of millions of objects that communicate over the internet in order to accomplish physical tasks in the real world. Consider the example of an IoT light switch, it will be able to operate

autonomously and alert the operator when it is on/off over the internet using a variety of protocols. Other devices have been adapted to the Internet of Things such as street lights [1], agricultural systems [2], smart dustbin [3], wildlife trackers [4], home automation [5], [6] and nursing home architecture [7]. The disadvantage of this method is that it requires internet connectivity. Without internet connectivity, the devices are rendered far less useful. A wired connection to the internet would be reliable but it will fail if the cable is damaged by the gas leak or circumstances associated with the gas leak. Additionally, both Wi-Fi and ethernet will fail if the power is cut by a disaster.

In order to help alleviate this problem, a gas leak detector can communicate over the internet using cellular networks. These networks have a wide coverage across most countries and can easily be accessed by a device with a working Subscriber Identification Module (SIM) card. This will allow the device to send a text message to a specified number to instantly alert high-level personnel of the gas leak, as well as any relevant information concerning the leak. Interfacing with a cellular network can be accomplished by connecting a Global System for Mobile Communications (GSM) module to the mainboard. It allows devices to interface with the 2G cellular network. When a SIM card is inserted into the module, the device can be programmed to connect to the internet and perform a variety of tasks including text messaging, email, and more.

This paper presents a case study in the creation and utilization of an IoT device and an exploration of how this allows it to behave in a manner superior to a device without such capabilities. Both the software and hardware of the IoT gas detector device will be discussed, and comparisons between the different methods of alerting the user will be made. Finally, conclusions are presented, and future development plans are discussed.

II. RELATED WORK

There are a wide variety of methods that have been used by IoT devices to alert users of a gas leak [8], [9]. Several different ways of connecting IoT gas detectors to the internet have been used. For example, there are detectors that utilize Bluetooth [10] and Wi-Fi [11] to achieve a connection. The goal is to ensure to the greatest extent possible that the user will be notified of the leak as soon as it occurs. But these methods have shortcomings.

A Bluetooth system is severely limited by distance. It is

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known as a key component in many personal area networks (PAN), which has an extremely limited range [12]. For the user to be alerted of a gas leak, they would have to keep their phone and themselves within about 30 feet of the device to maintain a Bluetooth connection. At that range, a simple alarm will usually suffice in alerting the user.

A Wi-Fi system would be less affected by distance; it has a further range compared to Bluetooth. Wi-Fi coverage of the building can ensure the device has access to the internet. On the other hand, the device is vulnerable to power outages. If the power is cut by a natural disaster or the internet connection is lost, the gas leak detector will be unable to connect to the internet and alert the user.

Notifying a user through an Email [13] will require the IoT device to be connected to the internet. It has the same disadvantages as Wi-Fi does. If any network outages or equipment damage, they will possibly cause the IoT device to lose internet access and be unable to contact the user during an emergency. Also, Email method may take some time before the user realizes what is happening. Not everyone checks their email often and no one can be expected to open an email while driving or performing similar activities.

Our gas leak detector can communicate over the internet using cellular networks. This project helps alleviate Wi-Fi and ethernet failure problems if the power is cut by a disaster.

III. IMPLEMENTATION

A. Software Approach, Libraries, and Methods

This automated gas leak monitoring system is coded in the Arduino IDE. There are two different libraries used in developing the application. The LiquidCrystal library for the Arduino contains methods that support the utilization of the LCD screen and display gas readings and levels. The SoftwareSerial library for the Arduino allows the application to use digital serial pins to communicate with hardware and utilize the GSM module.

A setup function to initialize the automated gas leak monitoring system is shown in Fig. 1. It initializes the LCD, sets the baud to 9600 for both the GSM module and Arduino serial data transmission. Then, the LCD screen displays that the gas detector is ready.

```
void setup() {
  lcd.init(); // initiating the LCD
  lcd.backlight();
  paoSerial.begin(9600); // GSM baud
  Serial.begin(9600); // Arduino baud
  delay(100);
  pinMode(buzzer, OUTPUT);
  lcd.setCursor(2, 2);
  lcd.print("DETECTOR READY");
}
```

Fig. 1. Initializing the Automated Gas Leak Monitoring System.

The gas detector constantly checks the level of gas in the area of the sensor. If the gas level is calculated to be more than or equal to 10, it triggers a sequence of leak detection events in the software and hardware shown in Fig. 2. It calls the SendMessage function, which uses the GSM module to send the Short Message Service (SMS) message. And it prints to the LCD screen an emergency has been detected.

```
if (gasvalue >= 10) { // the gas limit
  SendMessage();
  lcd.setCursor(3, 2);
  lcd.print("Leak Detected!");
  lcd.setCursor(3, 0);
  lcd.print("EMERGENCY!!");
}
```

Fig. 2. Response to a Gas Leak.

When a gas leak is detected, the LED light has its voltage switched from low to high repeatedly, which makes it flash shown in the Fig 3.

```
// turn the LED on (HIGH is the voltage level)
digitalWrite(buzzer, HIGH);
// wait for half a second
delay(500);
// turn the LED off by making the voltage LOW
digitalWrite(buzzer, LOW);
delay(500);
```

Fig. 3. LED Light Flash for a Gas Leak.

In Fig. 4, the SendMessage function is called if a gas leak is detected. It sends the SMS text message to a specified number. The communication with the GSM module is performed using software serial pins through the library. It begins to set the GSM module to text mode. There are delays placed between each of these GSM lines to ensure instructions have time to execute properly. After the text mode, the GSM module is told the mobile number that it should connect to. Then, the content of the SMS message is specified. Lastly, a CTRL-Z character is sent to denote the end of the SMS message.

```
void SendMessage() {
  // GSM text mode
  paoSerial.println("AT+CMGF=1");
  delay(1000);
  // x is phone number being used
  paoSerial.println("AT+CMGS=\"+91xxxxxxxxxx\"");
  delay(1000);
  // message will be sent
  paoSerial.println("EMERGENCY! Gas Leak Detected!");
  delay(100);
  paoSerial.println((char)26); // ctrl+z
  delay(1000);
}
```

Fig. 4. Sending the SMS Text Message for a Gas Leak.

B. Hardware Approach, Modules, and Schematics

The circuit diagram for the automated gas leak monitoring system is shown in Fig. 5. The IoT gas detector hardware includes the Arduino board, LCD screen, gas detector, and GSM module.

The primary component of the gas detector is an Arduino [14] Uno R3 board shown in Fig. 6. It executes the source code, coordinates communication between the different modules, and powers the components. A simple LED light is connected to the Arduino and wired/programmed to be activated when gas is detected. A small buzzer is also set up to emit noise upon the detection of a gas leak.

Fig. 5. Circuit Diagram for the Gas Detector

Fig. 6. An Arduino Uno R3

The MQ-2 gas detector is shown in Fig. 7. This component can be used to detect a variety of gases including smoke, methane, alcohol, propane, hydrogen, and LP gas. The MQ-2 gas detector contains an element which conductivity changes when exposed to gas. Normally, oxygen binds to the surface of the element, but in the presence of gas these oxygen molecules are replaced which allows electricity to flow through. The outer mesh ensures only fluids can touch the element. By the element's conductivity changing gradually based on the gas level, the device can detect the presence of gas as well as the general volume of gas.

Fig. 7. A MQ-2 Gas Detector

In Fig. 8, the SIM900A GSM module is used to connect with the 2G cellular network. A standard SIM card is inserted into the GSM module in order to utilize cellular networks. This GSM module can operate on the 850 MHz or 1900 MHz bands depending on the different countries.

In the United States, the equipment operates on the 850 MHz frequency. Physical connection to the Arduino is achieved using Pulse Width Modulation (PWM) enabled pins. The PWM technique is used for getting analog results with digital means. It allows the GSM and Arduino to communicate with digital Rx/Tx pins.

Fig. 8. A GSM Module

IV. EVALUATION

This gas detector performed well in testing. The user would have been aware of a gas leak within seconds of it occurring shown in Fig. 9. As long as the device is plugged into an operating USB power source, it will be a reliable gas detector. The addition of the GSM module allows the detector to operate in conditions when a Bluetooth or Wi-Fi detector would be unable to.

Fig. 9. A Gas Leak Message for Emergency on a Mobile Phone

This gas detector is also highly adaptable to different conditions and circumstances around the globe. The GSM module can simply be switched to a different frequency in another country. It will be still able to communicate on any other cellular network.

This device functions well without internet capability. It is a cheap, effective, and highly adaptable IoT device that will be able to save lives and property in an emergency situation.

V. CONCLUSION AND FUTURE WORK

This automated gas leak monitoring system helps alleviate

Wi-Fi and ethernet failure issues if the power is cut by a disaster or emergency situation. The use of cellular networks with SMS messages ensures that the user is informed of the emergency situation as soon as a gas leak is detected. This automated gas leak monitoring system is reliable and will not be put out of action in a disaster due to loss of Wi-Fi or internet. Future development of this device will possibly include networking multiple detectors together and mapping them out, which can ensure that an entire building or series of buildings is monitored for gas leaks.

Computer Architecture, Programming Languages, and Expert Systems.

Kuo-pao Yang is a full professor in the Computer Science department at Southeastern Louisiana University. He received his B.S. degree in Computer Science at Tamkang University, Taipei, Taiwan, R.O.C. in 1991. He earned his M.S. degree in Computer Science from Illinois Institute of Technology in 1994. He received his Ph.D. degree in Computer Science at Illinois Institute of Technology in 2003. His research interests include

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