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Research Paper

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Protection of Industrial and Residential areas by Wireless Gas Leakage Detector using IoT and WSN

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***Abstract*—** One of the foremost predicament with industrial sector, residential premises and gas powered (CNG) vehicles like bus, cars is gas leakage. To detect the gas leakage and to cease it by human endeavour is an inconvenient problem. Hence, a Wireless Sensor Network (WSN) system-automatic gas leakage detector is essential for apprising the premises and termination of the leakage. We coalesce the concepts of Internet of Things (IoT) and Wireless Sensor Network (WSN) for the autonomous wireless gas detection. The propounded project is endeavoured to achieve the gas leakage detection by developing a prototype that constantly monitors the gas leakage with the help of the electronic Gas sensing unit having high sensitivity for detecting LPG leak, Butane leak, Methane leak or any such petroleum based gases. The embedded system is controlled by the controller, an electronic prototyping platform/board based on Atmega AVR Microcontroller Atmega328P. In the advent of gas leakage, the user is sent text message alerts via the WSN communication standard IEEE 802.15.4. The user gets notified through the Wi-Fi Module which establishes a wireless Internet connectivity between the networks in the system. Also, the system has a vigilant sound alarm which produces high pitch beeping upon gas leak and stops the alarm once gas leak is under control. A LCD is provided to display the status, properties, run time and functions of the system.

***Keywords*—** Atmega328 Microcontroller, Gas leakage detector, IEEE 802.15.4, IoT, Wi-Fi Module, WSN

I. INTRODUCTION

Liquefied Petroleum Gas (LPG) comprises of an amalgamation of chemicals like propane and butane which is highly flammable chemical. It is an odourless gas due to which Ethanethoil (Ethyl Mercaptan) is added as powerful odorant, so that leakage can be effortlessly detected. Gas leakage leads to various accidents resulting into both financial loss as well as human injuries. On 23rd October 2016, the blowout of a wellhead containing 186 billion standard cubic feet of natural gas appeared to be the worst accidental discharge of greenhouse gases in U.S. history. Such life threatening domestic and industrial threats are found to occur frequently. The challenges in gas leakage detection, gives rise to such an intelligent embedded system.

The Ethernet i.e. wired communication protocol has led back and the WSNs are emerging to revolutionize the information and technology sector [1]. WSNs are contemplated to be a next step forward to build information and communication system which improves efficiency and reliability in terms of infrastructure of embedded systems. With the progression in development of various intelligent sensors, the WSNs can become a key for the IoT Technology. WSN is an auto organizing, multi-hop networks of wireless sensor nodes utilized to supervise and control physical manifestations. The distinctive structure proposed is that, the WSN can be described as a network of end nodes about which wireless communication protocol is established for information gathering via the sensor locations [2].

The main objective of the project is to autonomously and wirelessly detect noxious LPG gas leakage and alert the people about the concentration of LPG gas in the environment.

The paper is structured as follows- Section II contains the related research work of gas leak detector using advanced and recent trends of technology. Section III consists of the architecture and methodology for the hardware as well as software of the project. Section IV describes the experimental results and analysis of parameters. Section V concludes research work with future directions.

II. RELATED WORK

Miscellaneous systems were designed previously to detect gas leakages for domestic and industrial purposes [3].

One of the designs used a wireless communication module consisting of Transmitter and Receiver to establish connectivity [4]. The proposed wireless home gas leakage system consists of two major modules: the gas leakage detection and transmission module and the receiver module.

Nowadays, the ARM architecture has been in use as a controller in embedded applications [5]. The wireless as well as wired communication protocols are utilized nowadays for connectivity between networks or systems [6].

Design of a low budget home security system can detect the theft, fire, leakage of gas or smoke and send an auto-generated email remotely to intimate the owner [7]. The main controller of the system is the Intel Edison Board with a number of sensors LM35 sensor, MQ2 sensor, PIR sensor, IoT Analytics Cloud Platform and Wi-Fi module.

Gas leakage detection and monitoring through wireless sensor networks is considered to be more economical for industrial gas leakage. Hence to avoid damages and ensure safety of gas industry, gas leakage detection and monitoring system based on low power microcontroller and Xbee was developed [8].

III. METHODOLOGY

The Figure 1 shows the basic block diagram of the embedded system. A characteristic WSN system designed and developed can be made to function effectively to detect and monitor the gas leakages in the industrial sectors and residential areas.

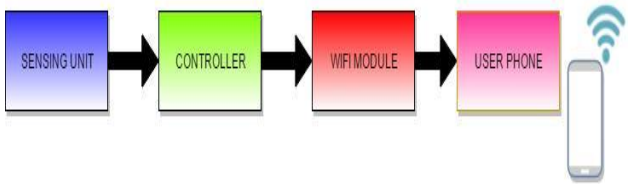

Figure 1: *Block Diagram of the WSN System*

A WSN system that describes the deployment of sensor nodes and successive calibration of the sensor output as a function of the system input (supply voltage). The sensor node attains early gas detection using a semiconductor gas sensor, an Arduino Uno Rev3 microcontroller, ESP8266-01 Wi-Fi Module, LCD module and Alarm system. The node receives leaked gas signal from the leakage area and communicate it to the network coordinator wirelessly through the Wi-Fi Protocol. When such an emergency is detected, the network coordinator alerts the user by sending SMS through the Wi-Fi Module. Also the Alarm system goes on and the buzzer rings an alert whereas the LCD module displays the status of the system. The reliability and productivity of the system are the key concerns and influence the design and development choices for the system in terms of the hardware and software design tools.

The main controller of the embedded system is the Arduino Uno Rev3, which controls, transmits and receives signals for the complete operation of the system. When there is a gas leak (like LPG, LNG Natural gas, iso-butane, propane Town gas) of the concentration 200 ppm to 10,000 ppm, in the vicinity of the system, the MQ 5 gas sensor detects it. The sensor has a sensitive lament made of SnO2. In the presence of clean air, this lament tends to have lower electrical conductivity. When a combustible gas such as LPG is introduced, the conductivity of lament rises. The amount of change in conductance/resistance can be used to indicate the equivalent gas concentration. Thus, the MQ 5 gas sensor sends signal to the Arduino through the AO/DO pin. After receiving this instruction, the Arduino sends message signal to the Alarm System and the LCD module, indicating gas leakage in the area. The Wi-Fi Module provides internet connectivity and immediately sends warning text message to the user through wireless internet communication standard IEEE 802.15.4. After the concentration of gas in the air is reduced the Alarm system goes OFF.

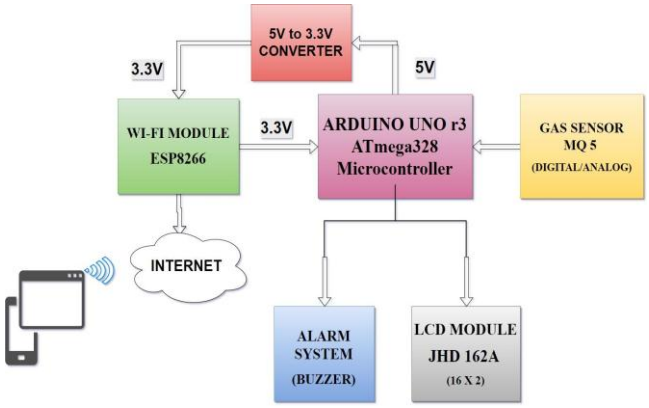

Figure 2: *Block Diagram of the System Architecture*

A. HARDWARE

1. Arduino Uno Rev3

The proposed system uses the Arduino Uno Rev3, a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a USB connection, a power jack, an ICSP header and a reset button. It has a Flash Memory of

32 KB, out of which 0.5 KB is used by the boot loader. It is featured with SRAM of 2 KB and EEPROM of 1 KB. The microcontroller has a Clock Speed of 16 MHz crystal oscillator.

2. MQ 5 Gas sensor

In the advent of gas leak, the MQ 5 gas sensor senses the leak and sends an electrical signal to the Arduino Uno r3. The gas sensor module MQ 5 has an analog out (A0) and a digital out (D0). The analog out can be used to detect Gas leakage and to measure volume of gas leakage (by doing proper calculation of the sensor output inside program) in specific units (in ppm). The digital out can be used to detect gas leakage and hence trigger an alert system (a sound alarm system and SMS activation). The digital out gives only two possible outputs High and Low. Hence, it is more suitable for detection of gas leak than to measure volume of gas present in the air. MQ5 sensor has preheating requirement, the sensor is powered on (from the Arduino Uno r3) for 15 minutes before applying gas to it.

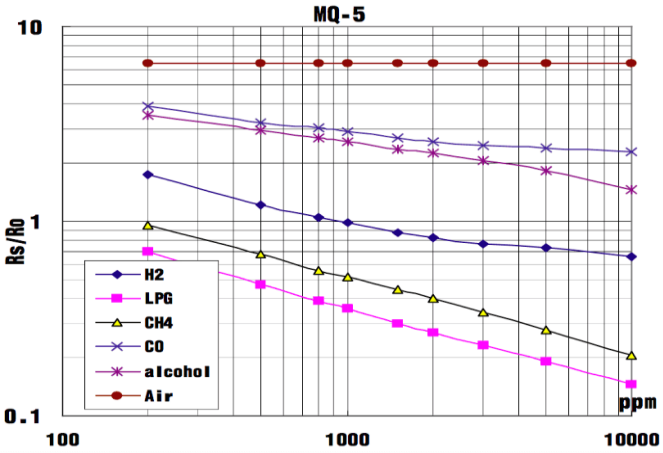

Figure 3: *Typical Sensitivity characteristics of the MQ-5*

Figure 3, shows the typical sensitivity characteristics of the MQ-5 for several gases with Temperature: 20℃, Humidity: 65%, O_2 concentration: 21%, R_L=20kΩ, R_o (Sensor resistance) at 1000ppm of H_2 in the clean air. R_s (Sensor resistance) at various concentrations of gases.

3. ESP8266-01 Wi-Fi Module

The ESP8266-01 Wi-Fi Module is a communication protocol which establishes a wireless Internet connectivity between the Arduino and the user device. The ESP8266-01 Wi-Fi Module sends an alert text message to the user's phone, in the event of gas leak detected by the MQ 5 sensor. The ESP8266-01 Wi-Fi Module is a self contained system-on-a-chip (SOC) with integrated TCP/IP protocol stack that can give any microcontroller access to your Wi-Fi network. The ESP8266-01 is a Transceiver and has capabilities for 2.4 GHz Wi-Fi with IEEE 802.11 b/g/n, supporting WPA/WPA2. It employs a 32-bit RISC running at 80 MHz. It has a 64 KB boot ROM, 64 KB instruction RAM and 96 KB data RAM. External flash memory can be accessed through SPI.

4. LCD module JHD162A (16x2)

A liquid-crystal display (LCD) JHD162A is a flat-panel display. The JHD162A has 16 pins and can be operated in 4-bit mode (using only 4 data lines) or 8-bit mode (using all 8 data lines). Here, we are interfacing LCD module and Arduino in the 4-bit mode. This means only four of the digital input lines (DB4 to DB7) of the LCD are used. This method is very simple, requires less connections and one can almost utilize the full potential of the LCD module. A potentiometer of 10K ohm is used to vary the contrast of the LCD.

5. Alarm System

Here we have developed an Arduino based LPG gas detector alarm. If gas leakage occurs, this system detects it and alerts the user by buzzing the buzzer connected with the circuit.

B. SOFTWARE

In the occurrence of Gas leakage, the MQ5 gas sensor will sense the rise in the concentration of toxicity of noxious gas in the air (i.e. gas concentration value ≥ threshold value) and send a signal to the Arduino Uno's analog pin. The Arduino upon receiving this will set the buzzer pin 8 and LCD pins 2 to 5 high (i.e. 1). The Buzzer will start beeping continuously and the LCD displays the message "ALERT!! GAS LEAKAGE!!"

The ESP8266-01 Wi-Fi Module will send an alert message to the registered user immediately once the buzzer pin is set high. The ESP8266-01 Module's GPIO 2 pin is set high by connecting it to the buzzer. Once the gas concentration goes back to normal (i.e. gas concentration value < threshold value), the MQ 5 again sends the respective message signal to the Arduino Uno and hence Arduino sets the Buzzer and LCD pins low (i.e. 0). The Buzzer will stop beeping and the LCD will display "NO GAS LEAK". Similarly, the ESP8266-01 GPIO 2 pin gets low and the message will not be sent. The MQ 5 will keep checking for the concentration of toxic gas in the air and once the concentration gets high it, reverts an immediate signal to the Arduino Uno with the information of the concentration in the air (in ppm).

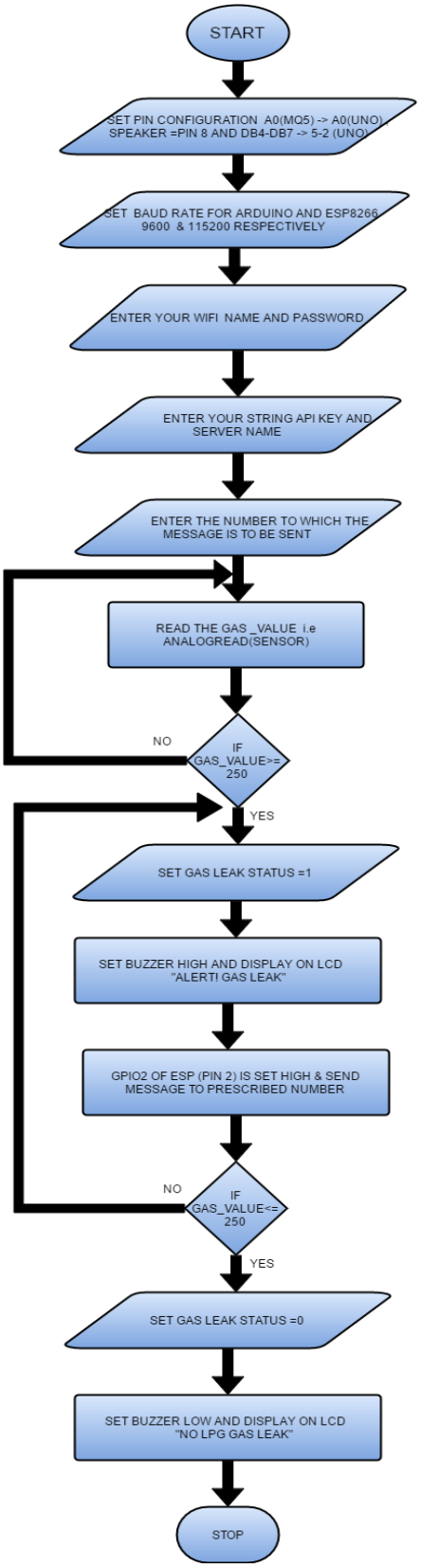

Figure 4: *Flowchart for the system*

IV. EXPERIMENTAL RESULTS AND ANALYSIS

The MQ 5 gas sensor has a detecting concentration scope of 200-10000ppm of LPG, LNG Natural gas, iso-butane and propane Town gases. Here, we are designing an embedded system which detects low concentration of toxicity in air [9].

Table 1. Sensitivity Characteristics of MQ 5 Gas sensor

Sr No.	Symbol	Parameter name	Technical parameter
1	Rs	Sensing Resistance	10KΩ - 60KΩ (5000ppm methane)
2	α (5000ppm/1000ppm CH_4)	Concentration slope rate	≤ 0.6
3	Standard detecting condition	Temp: 20°C±2°C Vc:5V±0.1 Humidity: 65%±5% Vh: 5V±0.1	
4	Preheat time	Over 24 hour	

Table 2. Parameter Evaluation

Gas Concentration	MQ 5 Gas Sensor	Sound Alarm (Buzzer)	LCD	ESP8266-01
Low(No Gas leak detected)	0 (≤ threshold value)	0	0	0
High (Gas leak detected)	1 (≥ threshold value)	1 (Buzzer rings)	1 (Displays Alert message)	1 (Sends message)

The MQ 5 gas sensor has a temperature sensitivity of 20℃±2℃. The MQ5 Gas sensor has a sensing resistance having 10K Ω to 60K Ω. The gas values detected represent the amount of toxic gas in the air. The unit of gas concentration is ppm.ie. parts per million.

The Table 2 indicates the internal threshold and digital values set for each component in the embedded system. The occurrence of noxious gas in environment sets the MQ 5 Gas sensor high (for analog pin: ≥ threshold value). Thus, the controller ATmega328 in Arduino sets the ESP8266-01, the LCD and the Alarm System (buzzer) high i.e. 1. When the air is clean, all the components are set to 0, since the MQ 5 sensor value is < threshold value.

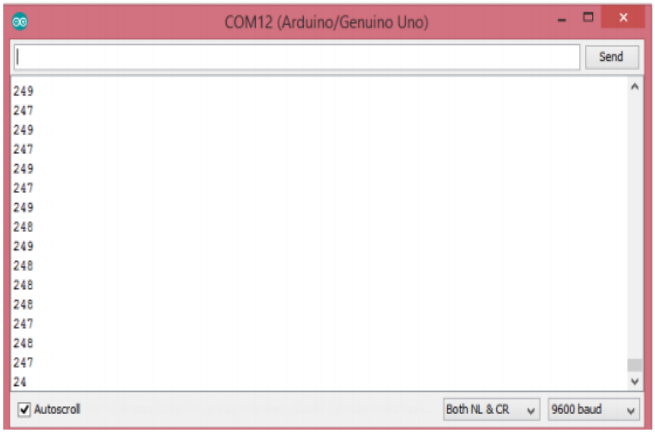

Figure 5. *Gas Concentration (in ppm)*

The MQ5 detects and displays the amount of gas concentration in the vicinity of the system. The values are expressed in ppm i.e. parts per million.

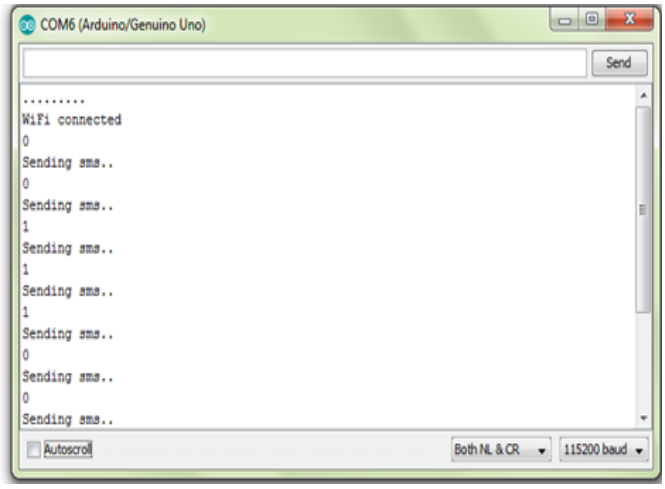

Figure 6. *ESP8266-01 sending text messages*

The figure.6 shows the output on the serial monitor of Arduino IDE.

1. After the code is uploaded, the ESP8266-01 module establishes Wi-Fi connectivity using the User name and Wi-Fi password mentioned in the code. It displays the status by displaying "Wi-Fi connected".
2. The serial monitor displays a series of 0 indicating there is no gas leak in the vicinity of the system.
3. When the gas leak is detected the value is set to 1 and the "sending message" is seen on the serial monitor. At this instance, the ESP8266-01 sends alert text SMS to the registered user.
4. Once the concentration of gas in air is back to normal the serial monitor displays "0" again.

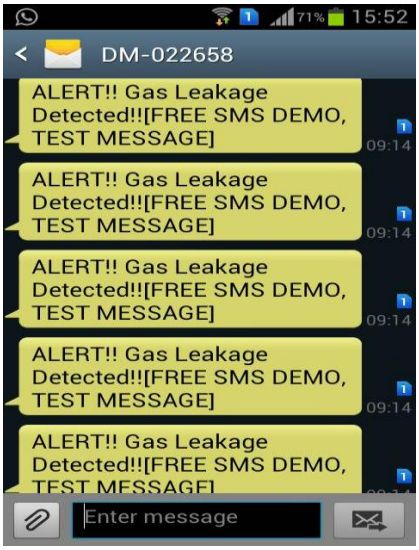

Figure 7. *Received Text Message*

The ESP8266-01 sends the text message via the IEEE 802.15.4 using the WPAN provided in the residential and industrial areas. As shown in figure 6 and 7, for each corresponding value of 1 followed by "Sending sms" a SMS is received by the user. This continues until the value is 0 again.

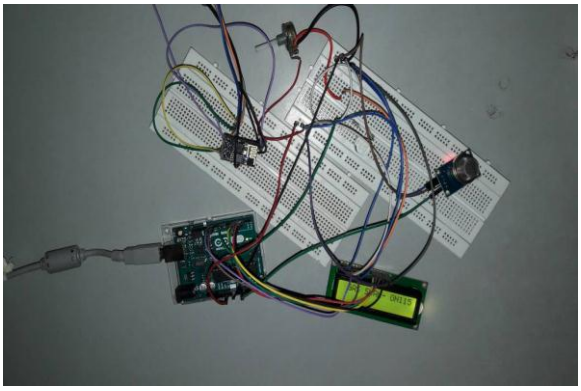

Figure 8. *Gas Leakage Detector*

V. CONCLUSION and Future Scope

Gas leakage is a very sensitive case, ceasing it has become the need of the hour. In this system, we have described a new approach for gas leakage detection system at a low concentration. Such systems are utilized for protection of industrial and domestic areas where gas leakage detection is quiet necessary. For an immediate response from the user or consumer, we have an alerting system to make the user aware of the disaster. The system has the accurate wireless communication between the user and the system at the

accident area. The message sent via the ESP8266-01 Module can be sent to any User.

The whole system requires a proper stable Wi-Fi connectivity, which makes it efficient to work with. There can be a delay in receiving of text messages if there is a poor internet service or network provider. The sensing unit requires a pre-heating time. The system can detect harmful gases up to 10000 ppm. This limits its scope of gas leak detection in highly toxic areas with gas concentration higher than 10000 ppm. Also, the areas with poor Wi-Fi connection might have the ESP8266-01 module to work inefficiently.

The outputs obtained are stable and accurate. The low power consumption, accurate results and efficient stability makes this embedded system quiet competent for use in the domestic as well as industrial areas. In future further modification of the system can be done by mounting the gas leakage detector on any Unmanned Vehicle like Unmanned Aerial Vehicle (UAV), Unmanned Ground Vehicle (UGV) or Unmanned Surface Vehicle (USV).

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