An IoT Based Interactive LPG Cylinder Monitoring System with Sensor Node Based Safety Protocol for Developing Countries

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***Abstract*— Proper implementation of internet of things (IoT) can help the people of developing countries to turn their conventional life style into a smart one. In this following research paper an IoT based smart LPG cylinder monitoring system has been approached for smoothing the cylinder uses procedure with proper safety. Robust model with custom designed PCB helps the device to be adjusted with the existing LPG cylinder system without any major changes. Mobile application with unique design and versatile functionality along with a central server connect the user with the system through IoT. Uses of different sensors establish safety through gas leakage alarm and also reduce the amount of gas wastage. Depending on the uses of LPG of the end users an automated prediction will be forecasted about the uses of LPG in the future days which ensures an astute system. Simulation based indoor experiments with a couple of outdoor experiments in practical scenarios justify the collected data and the precision of the complete designed system.**

Keywords— LPG cylinder monitoring, gas leakage detection, IoT embedded system

I. INTRODUCTION

With the dream of establishing smart cities with intelligent features internet of things (IoT) has been used worldwide for its user friendly interface. If all the controls of every daily usable instruments like light, fan, house lock, water tank etc. can be merged into one single interface with wireless command then plenty of time can be saved which is actually the primary step to turn a random city into a smart one. Many developing countries are trying to implement technologies which can confirm a trouble-free daily life-style of their citizens, but expensive components and complex user interface restrict them to realize the dream of a smart city. After a brief study of the scenario it has been found that the scope of IoT is enormous to solve the corresponding problems and help the optimistic people to dream for a better life.

In the south Asian region the uses of Liquefied Petroleum Gas (LPG) via small cylinders is the primary way for household operation like cooking. Even many restaurants as well as small industrial factories are dependent on LPG for fuel support. But there are some complications related to LPG cylinder which encounter the users a lot. There are no such mechanism available for measuring the gas amount in the cylinder in the consumer level that's why people cannot specifically know when the gas cylinder will be empty and exact when they need a new cylinder. The process of exchanging the LPG cylinder is also full of hassle as well as costly. There are not enough safety measures available for this LPG cylinder system which is the key reason for unwanted accidents. So for developing this total process a shrewd LPG cylinder monitoring system has been approached in this paper with IoT and a couple of ingenious features.

The proposed model is fully operated through IoT via a user friendly mobile application. Using a developed device the amount of gas can be measured and via a central server it can be shown in the mobile app. Different sensor has been incorporated for detecting the gas leakage and also lessening the misspend of LPG. An interactive LPG cylinder exchanging system has been introduced where user can have experience a smooth swap of cylinders without any stress. An automated generated prediction from the previous month's daily gas uses about next month's gas expenditure on a daily basis differentiate the system as a shrewd one. It will also predict the date of gas finishing. All these features within a low budget can help a developing country to make a step towards a smart city.

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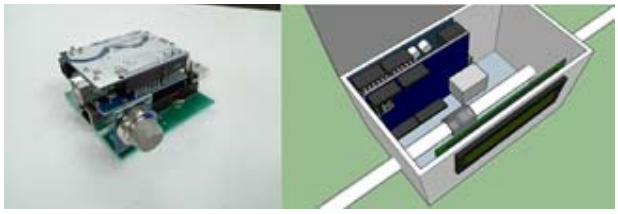

Figure. 1 LPG Monitoring Device Circuit with 3D View

II. SYSTEM ANATOMY AND OUTLINE

Measuring the amount of LPG in a cylinder using the gas pressure is the primary motive of this research. Implementation of IoT is also a goal which actually convert the system into a user friendly model. The entire system has been divided into three major subsystems. They are as follow.

A. LPG Monitoring Device

Designing a compact device for measuring the gas amount is the initial step of this research. As the device need to adjust with the existing LPG cylinders that's why a robust design with universal configuration has been chosen. The device consists of four major elements which are BMP 180 pressure sensor, microcontroller board Arduino Uno with microchip ATmega328P, Ethernet shield and sensor node. The device needs to be handy so that it can be placed with the LPG cylinder, that's why a compact PCB has been designed with plug and play facility where each and every component can be placed easily. The pressure sensor is placed into a separate 3D printed chamber so that the value can be air disturbance free. The developed device shown in Fig. 1 is connected with a central server through Ethernet.

B. Mobile Application

For defining IoT characteristics and making the system user friendly a custom designed mobile application has been developed with versatile functionality. As android operating system is voguish in contemporary time that's why android studio has been used as the platform for developing this application. An easy to use graphical user interface which is shown in Fig. 2 has been designed so that people can enjoy the system while using. Firstly user needs to log into the application using a specified user ID and a password which are unique for each device.

The application will connect the user with a central server through the internet. User can check the LPG amount in

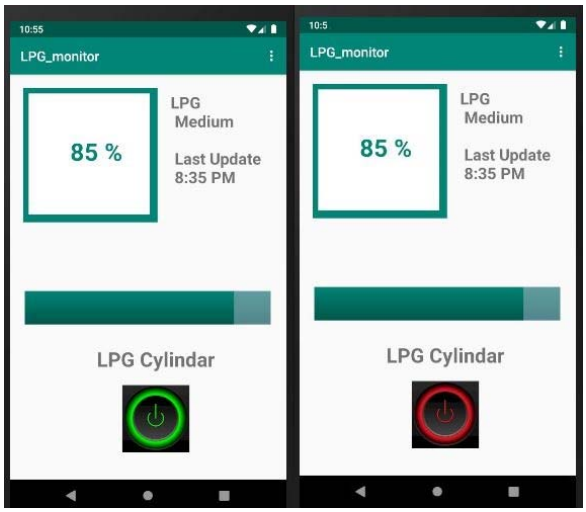

Figure. 2 Custom Designed Mobile Application User Interface

Figure. 3 Sensor Node System Setup for Safety and Wastage Reduction

percentage and also can check the present state of the LPG cylinder whether it is on or off depending on the green & red color of a button. When the LPG amount is below 10% then the mobile application automatically send a notification to the user for refilling the LPG cylinder. Also the system will automatically notify the nearest LPG cylinder dealer with the GPS coordinates of that specific house about cylinder refilling. After receiving the LPG refilling request the dealer will share the date and time of the refilling process which will be displayed in the application of the user.

C. Sensor Node

Safety measures are one of the most important sections of a research. Ensuring a safe system so that unwanted accidents can be avoided multiple sensor has been incorporated into the developed structure. Leakage of gas is the prime reason of misadventure, that's why MQ-6 gas detection sensor has been included into the system which can detect LPG. If there is any leakage of gas detected by the system an immediate notification with an alarm will appear in the mobile application as a warning so that user can take the necessary steps for preventing the situation. Also sometimes unconsciously people forgot to turn the stove off after using it which may occur wastage of LPG. For minimizing the wastage ultrasonic sonar sensor has been included into the system which will be placed parallel to the stove. If the stove is empty for 5 minutes than the ultrasonic sensor will pass a signal to the microcontroller and the LPG will automatically turned off through the custom designed motorized knob.

III. METHODOLOGY

A. Nearest LPG Dealer Shop Finding Process

When the monitoring device detects that there are only 10% LPG remaining into the cylinder than the system automatically send a cylinder refilling request to the nearest LPG dealer's shop. In this process Haversine formula has been applied for calculating the shortest path for defining the nearest shop. Conventionally Haversine formula has been used for calculating the distance between two coordinates on a sphere. From [06] the conventional equation of the popular Haversine formula is

$$\text{Haversine}\,(\theta) = sin^2\,\frac{\theta}{2} \qquad (1)$$

Using this the distance between two coordinates for radius r can be calculated through

$$d = 2r\,sin^{-1}\sqrt{sin^2(\tfrac{\alpha_2-\alpha_1}{2}) + \cos(\alpha_1)\cos(\alpha_2)sin^2(\tfrac{\beta_2-\beta_1}{2})} \qquad (2)$$

In equation (2) r is the radius of the earth and **α**, ***β*** are the latitude and longitude respectively. Based on the two equation a location-based recommendation algorithm has been developed [5]. In this algorithm input will be the user's location (latitude and longitude) and couple of LPG dealer's shop locations which can be acquired from the central server. Then an array has been initialized for storing the interspace values between user and the LPG dealer shop. For example, If the system takes 3 shop location s1, s2, s3 and a single user location U then it will calculate the interspace for user location vs each LPG dealer shop location separately using Haversine formula and store the final value in an array A. Then the system will place all the resultant values in ascending order. After that a map will be generated with all the S locations and the nearest LPG cylinder dealers location will turn Green as per user's closeness.

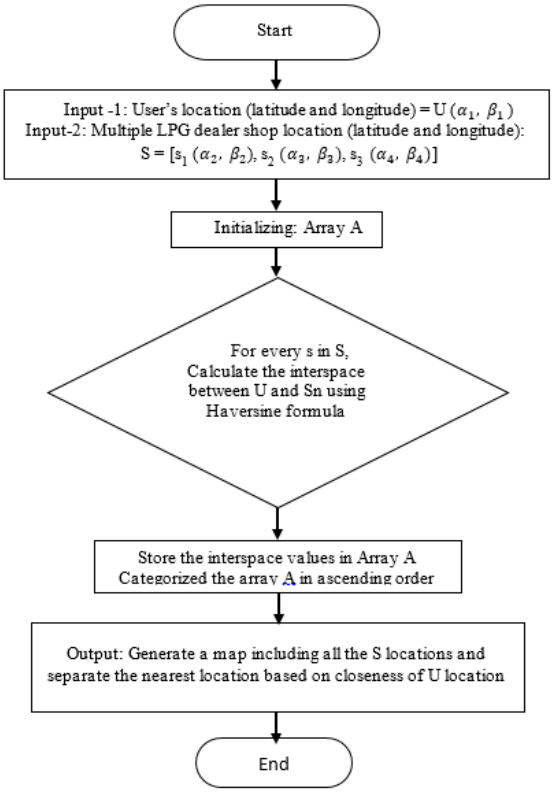

Figure. 4 Location Based Recommendation Algorithm

In this process the system will analyze the previous months daily LPG uses separately and based on that a prediction will be sent to the user that how much gas will be needed for each day and when the user will need a refill. Let's assume the system will predict about the gas consumption of month July based on the uses of month June. A dummy graph with assumed data containing per day use of LPG has been plotted for the month of June in Fig. 5. Now the plot will be divided into three sections where each section contains 10 days of month June. Separately average used amount of LPG will be calculated for each section. In this case for the dummy data set the first section contains the average of 2.92%. It means that every day nearly 2.92% of consumed during first ten days of June. Now for the first ten days of month July the user will get an automated prediction that they need around 2.72-3.12% of LPG per day. The system will predict the range with adding ±0.20 % with the average value to ensure maximum percentage of accuracy. This process will be continued for the other two sections as well. Based on the per day prediction a date will be chosen by the system when 90% of LPG will be consumed and user needs a refill.

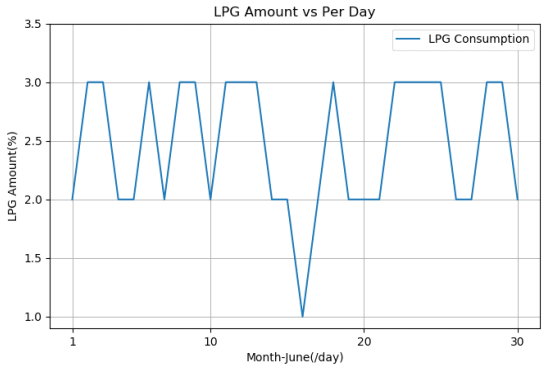

Figure. 5 Plot with Dummy Dataset for Prediction

B. *Experiment and Result Analysis*

Observing a systems behavior in practical scenario is the proper way to justify the accuracy and the reliability. In this case there are two separate experiment have been conducted for verifying the system. Firstly the measurement of LPG into a cylinder which has been tested with an actual set up. A cylinder with nearly 12Kg of LPG has been connected with a stove through the developed LPG cylinder monitoring device. When the cylinder knob is turned on the device successfully detect the pressure of the LPG and provide the pressure value in Millibars (mb). A graph LPG pressure vs time in Fig.7 has been plotted with continues data of 120 seconds. Now the pressure value will be converted into percentage so that user can understand easily about the amount of LPG. When pressure is maximum LPG amount is in the maximum state as well. With the reduction of pressure the LPG amount will also be reduced. Using the following equation the pressure of LPG has been converted into percentage.

LPG amount in percentage = (Current Pressure)/(Maximum Pressure) x 100 = 1006.75/1019.36 x 100 = 98.76%

Secondly the LPG leakage system has been tested with the detection of original LPG form the cylinder. Total 15 seconds

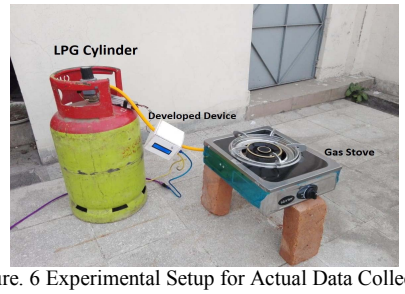

Figure. 6 Experimental Setup for Actual Data Collection

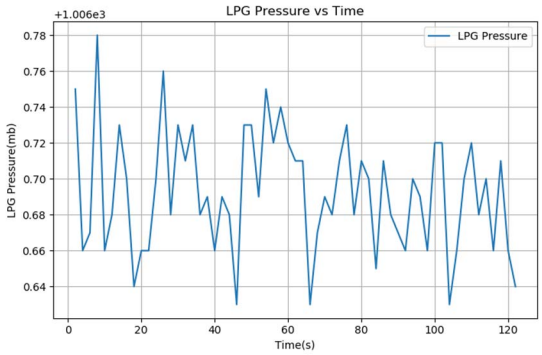

Figure. 7 LPG Pressure Vs Time Graph for Measurement

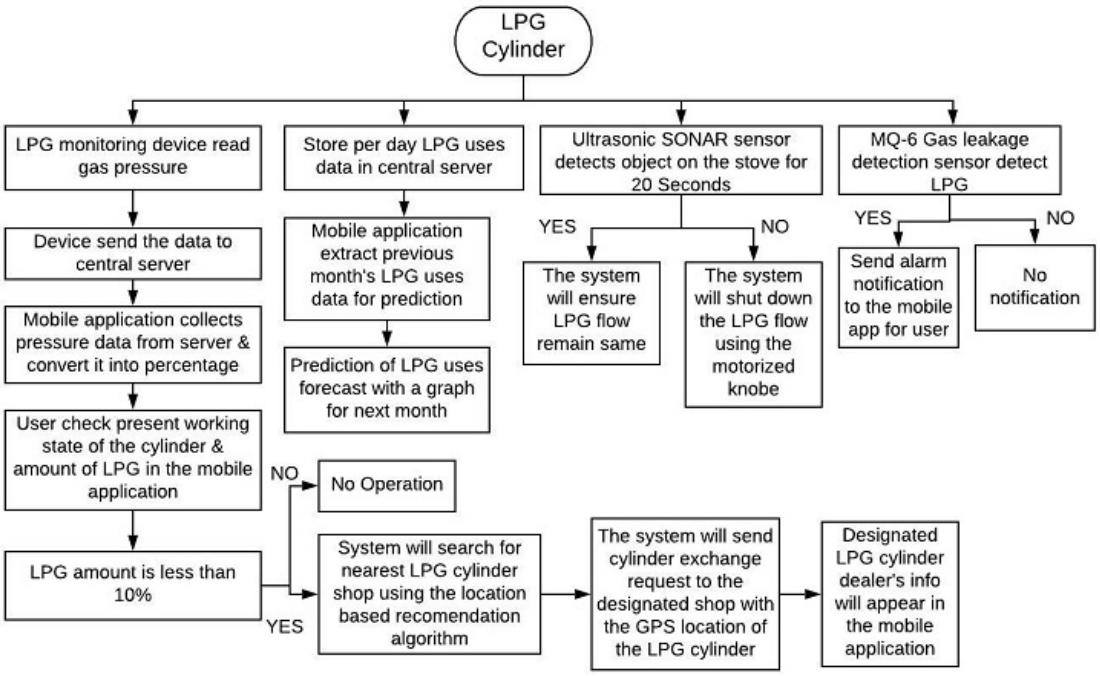

Figure. 8 Total System Block Diagram

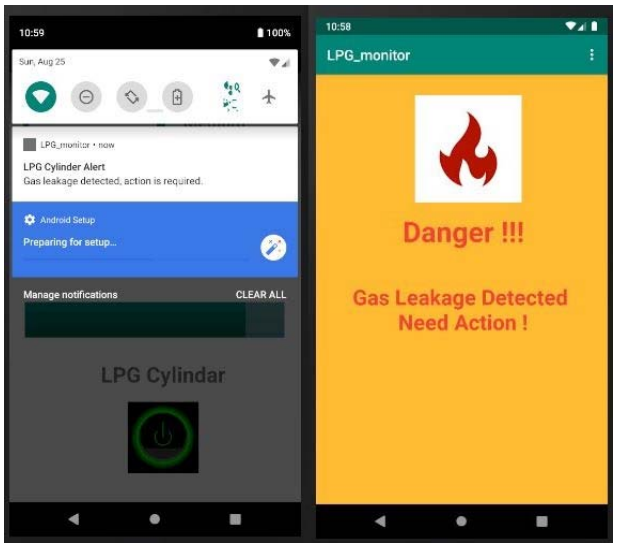

Figure. 9 LPG Leakage Detection Notification with Alarm in Mobile Application

data has been collected for the detection. Initially there was no leakage for first five seconds but after that intentionally a leakage has been created and then the value in the MQ-6 sensor was gradually increased which indicate a proper detection. After the detection of leakage the system also give the warning alarm in the mobile application successfully.

CONCLUSION

IoT is getting popular with time for digitalization of conventional systems. Implementation of smart devices with the assist of IoT helps the developing countries to introducing a tech friendly lifestyle. In this research paper a smart LPG cylinder monitoring system has been introduced and developed based on IoT. Compact design of the device helped the system to be adjusted with the present LPG cylinders. Multiple sensor node ensures a proper safety and reduced the chances of LPG wastage with maximum accuracy. The multi-functional custom designed mobile application helped the user to control the total system easily through IoT. In near future machine learning based algorithm can be applied for producing a prediction with maximum accuracy. Also more effective way of LPG measurement can be included for better performance. If all the modification can be done then the total process of using LPG cylinders will be very much convenient through this system.

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