International Journal of Application or Innovation in Engineering & Management (IJAIEM)
Web Site: www.ijaiem.org Email: editor@ijaiem.org
Volume 6, Issue 6, June 2017 **ISSN 2319 - 4847**

Design and Development of IoT Based Residential Automation Security System with Bluetooth Technology

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ABSTRACT

Internet of things is a new emerging technology and is an established set of specifications for wireless personal area networking which means digital radio connections between computers and related devices. The objective of the paper is to design a smart residential security system using wireless IoT protocol which deals about home automation applications by making use of the wireless IoT protocol. The XBee OEM radio frequency modules were engineered to operate within the IoT protocol and provide reliable delivery of data between devices. In this research design and development IoT based residential security system with bluetooth technology was carried out. The developed security system can detect and inform theft, leaking of raw gas, fire and measure the room temperature through which we can easily control the residential security system. The characteristics of the IEEE 802.15.4 standard with the maturing IoT specification has been applied in defining the wireless profiles for low data rate monitoring and controlling the applications. The capabilities of both resulted in the availability of a technology, tailored specifically for the low power, cost and complexity applications in the industrial and residential application for today and for the future.

Keywords: Bluetooth, IoT, Residential, Security System, Sensor

1. INTRODUCTION

Majority residential owners simply do not have sufficient funds to pay for a professionally installed security system. The use of residential alert system in Internet of things (IoT) is affordable and easy to install. IoT is targeted at radio frequency applications which require a low data rate and secure networking and deals on general purpose self-organizing mesh network that can be used for household appliances as well as for industrial purposes to control embedded sensing, medical data collection, building automation and home automation. With its unique emphasis on reliability, low cost, long battery life and easy deployment IoT paves the way for intelligent sensors to provide greater control of lighting, heating, cooling, water and filtration, appliances use and security systems from anywhere in and around the home as well as anywhere in the world using cloud storage data [1], [2]. IoT connection can always be made from pair of master and slave devices. The system monitors certain unexpected parameters like gas leakage and fire during the absence of family members in the house. Through the access of website one can get all the information on what is happening in the home from any other place and incase any problem occurs it could be solved by an authorized person [3], [4]. A microcontroller is considered for this purpose since it is affordable to the general public and is also reliable as it operates without any failure. As the world grapples with increasing power demands that exceeds supply these additional controls play an instrumental role in dramatically improving energy efficiency as well as the concerns that surrounds greenhouse gas emissions. XBee and XBee-Pro are the radio frequency (RF) modules which are used as IoT devices in the transmitter and receiver sections [5], [6]. The objective of the paper is to design a smart residential security system using wireless IoT protocol dealing with home automation applications.

2. LITERATURE SURVEY

The residential automation security system with Wi-Fi technology consists of three major modules. The web server presents system core which controls and monitors users' residential and hardware interface module [7], [8]. Wi-Fi shield printed circuit board (PCB), three input PCB alarms and three output PCB actuators provides suitable interface

to sensors and actuator of the residential automation security system. As compared to the commercially available residential automation security systems this security system is better from the point of view on scalability and flexibility. The user may utilize the same technology to login to the server web based application. If server is connected to the internet, remote users can access server web based application through the internet using compatible web browser. The application has been developed based on the android system [9], [10]. An interface card has been developed to assure communication between the remote user, server, raspberry Picard and the home appliances. The application has been installed on an android smartphone, a web server and a raspberry pi card to control the shutter of windows. Android application on a smartphone issues a command to raspberry Picard. An interface card has been realized to update signals between the actuator sensors and the raspberry Picard. Design and implementation of a residential gateway to collect metadata from home appliances and send to the cloud-based data server to store on hadoop distributed file system (HDFS), process them using map reduce and to provide a monitoring function to remote user [11]. It has been implemented with raspberry Picard through reading the subject of e-mail and the algorithm. Raspberry Picard proved as a powerful, economic and efficient platform for implementing the smart home automation security system [12]. Application developed using the android platform controlled and monitored from a remote location using the smart home application and an arduino ethernet based micro web-server [13]. The sensors and actuators are directly interfaced to the main controller. Proposed design offers are the control of energy management systems such as lightings, heating, air conditioning, security, fire detection and intrusion detection with siren and email notifications. Arduino board is the controller used to control the appliances by using global system for mobile communications (GSM) technology. It uses certain peripheral drivers and relays to achieve this interfacing. The application on smartphone generates short message service (SMS) messages based on the user commands and sends it to the GSM modem attached to the Arduino and controls the home appliances [14]. The system has drawbacks of cost and reliability of SMS. This paper is based on review of available security system assembled with microcontroller home automation, which is linking of appliances, monitoring and controlling them through an intelligent network.

3. BLUETOOTH

Bluetooth is a wireless technology standard for exchanging data over short distances (using short-wavelength UHF radio waves in the ISM band from 2.4 to 2.485 GHz) from fixed and mobile devices, and building personal area networks (PANs). Bluetooth is managed by the bluetooth special interest group (SIG), which has more than 30,000 member companies in the areas of telecommunication, computing, networking, and consumer electronics. The bluetooth SIG oversees development of the specification, manages the qualification program, and protects the trademarks. A network patents apply to the technology, which are licensed to individual qualifying devices. A master BR/EDR (Basic Rate/ Enhanced Data Rate) Bluetooth device can communicate with a maximum of seven devices in a piconet. The devices can switch roles, by agreement, and the slave can become the master. The bluetooth core specification provides for the connection of two or more pioneers to form a scatternet, in which certain devices simultaneously play the master role in one piconet and the slave role in another. At any given time, data can be transferred between the master and one other device. The master chooses which slave device to address; typically, it switches rapidly from one device to another in a round-robin fashion. Since it is the master that chooses which slave to address, whereas a slave is supposed to listen in each receive slot, being a master is a lighter burden than being a slave. Being a master of seven slaves is possible; being a slave of more than one master is possible. The specification is vague as to required behavior in scatternet. Bluetooth is a standard wire-replacement communications protocol primarily designed for low-power consumption, with a short range based on low-cost transceiver microchips in each device. Because the devices use a radio communications system, they do not have to be in visual line of sight of each other; however, a quasi optical wireless path must be viable. Range is power-class-dependent, but effective ranges vary in practice. This version of the bluetooth core specification is the introduction of an EDR for faster data transfer. The bit rate of EDR is 3 Mbit/s, although the maximum data transfer rate is 2.1 Mbit/s. Bluetooth took a massive leap forward to deliver advanced beacon and location-based capabilities in home, enterprise and industrial environments. Bluetooth 5 quadruples the range, doubles the speed and boosts broadcast messaging capacity by 800%-the key to enabling robust, reliable IoT connections that make full-home and building and outdoor use cases a reality.

3.1 Working of IoT

IoT basically uses digital radios to allow devices to communicate with one another. Every IoT network must contain a network coordinator. It is a device that sets up the network to be aware of all the nodes within its network and manages both the information about each node as well as the information that is being transmitted /received within the network. Other full function devices (FFD's) may be found in network and these devices support all of the 802.15.4 functions. They can serve as network coordinators, network routers, or as devices that interact with the physical world. The final device found in these networks is the reduced function device (RFD), which usually serves only as a device that interacts with the physical world. IoT is designed for wireless controls and sensors. It could be built into just about

anything you have around your home or office, including lights, switches, doors and appliances. These devices can then interact without wires, and you can control them all from a remote control or even from our android mobile phone and allows wireless two-way communications between lights and switches, thermostats and furnaces, hotel-room air-conditioners and the front desk and central command posts. It travels across greater distances and handles many sensors that can be linked to perform different tasks. The schematic representation of IoT function is shown in figure 1.

Figure 1 Schematic diagram of IoT function

3.2 IoT protocol

IOT protocol was engineered by the IOT alliance, a non-profit consortium of leading semiconductor manufacturers, technology providers, original equipment manufacturers (OEM) and end-users worldwide. The IOT protocol carries all the benefits of the 802.15.4 protocol with added networking functionality. The 802.15.4 specification was developed at the institute of electrical and electronics engineers (IEEE). The specification is a packet-based radio protocol that meets the needs of low-cost, battery-operated devices. The protocol allows devices to intercommunicate and be powered by batteries that last years instead of hours. The IoT protocol functions are shown in figure 2.

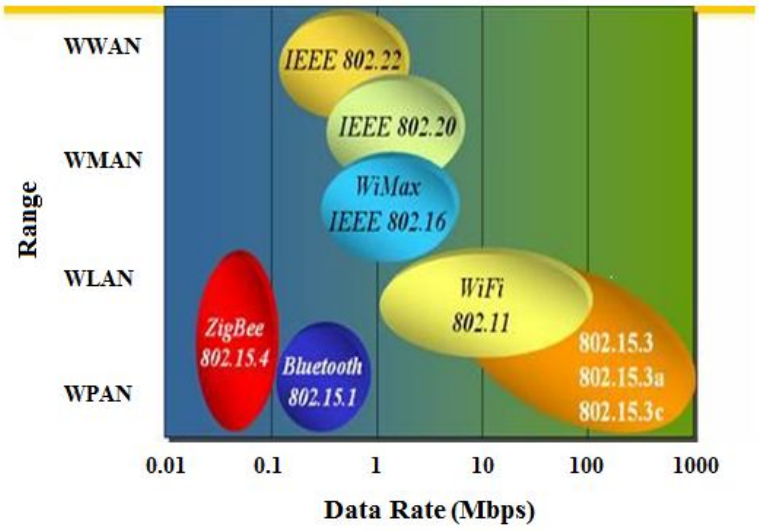

Figure 2 IoT protocol

IOT can be implemented in mesh networks larger than is possible with bluetooth. IOT compliant wireless devices are expected to transmit 10-75 meters, depending on the RF environment and the power output consumption required for a given application, and will operate in the unlicensed RF worldwide. The data rate is 250kbps at 2.4GHz, 40kbps at 915MHz and 20kbps at 868MHz. IEEE and IOT Alliance have been working closely to specify the entire protocol stack. IEEE 802.15.4 focuses on the specification of the lower two layers of the protocol. On the other hand, IOT alliance aims to provide the upper layers of the protocol stack for interoperable data networking, security services and a range of wireless home and building control solutions, provide interoperability compliance testing, marketing of the standard, advanced engineering for the evolution of the standard. A lot of research is currently underway to harness the power of bluetooth technology in the healthcare domain. With the help of bluetooth, health conscious individuals will have access to wireless devices to record information pertaining to body temperature, pressure count and metabolism.

The Bluetooth enabled devices will first collect vital information with the patients and then share it with a doctor via a mobile phone or personal computer. Compatible mobile phones will be better equipped with new dual-mode chips that support both traditional Bluetooth technology and other low-energy applications. The low energy communicates with lightweight health sensors, while the traditional Bluetooth specification continues to operate with existing bluetooth-enabled products such as hands-free headsets which enable mobile manufacturers to add dual-mode capabilities without significant increase in product pricing.

3.3 IoT works

IoT basically uses digital radios to allow devices to communicate with one another. A typical IoT network consists of several types of devices. A network coordinator is a device that sets up the network, is aware of all the nodes within its network, and manages both the information about each node as well as the information that is being transmitted / received within the network. Every IoT network must contain a network coordinator. Other full function devices may be found in the network, and these devices support all of the 802.15.4 functions. They can serve as network coordinators, network routers, or as devices that interact with the physical world. The final device found in these networks is the reduced function device which usually only serve as devices that interact with the physical world. An example of an IOT network is shown in figure 3, which introduces the concept of the IOT network topology. Several topologies are supported by IOT, including star, mesh, and cluster tree. Star and mesh networking are both shown in the figure above. As can be seen, star topology is most useful when several end devices are located close together so that they can communicate with a single router node. That node can then be a part of a larger mesh network that ultimately communicates with the network coordinator. Mesh networking allows for redundancy in node links, so that if one node goes down, devices can find an alternative path to communicate with one another.

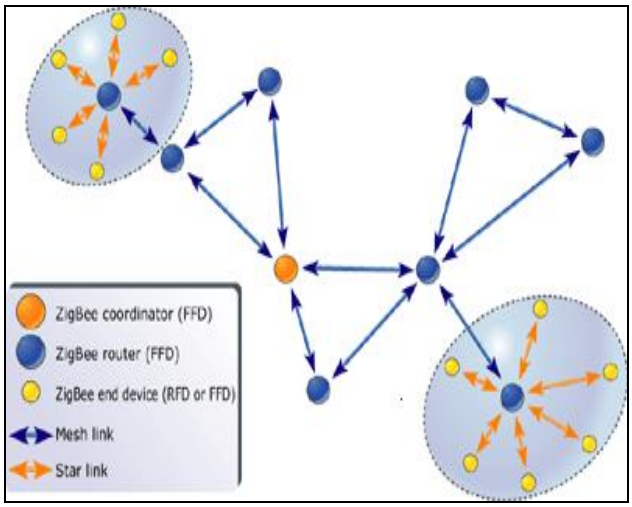

Figure 3 IoT work

3.4 Working principle of proposed design

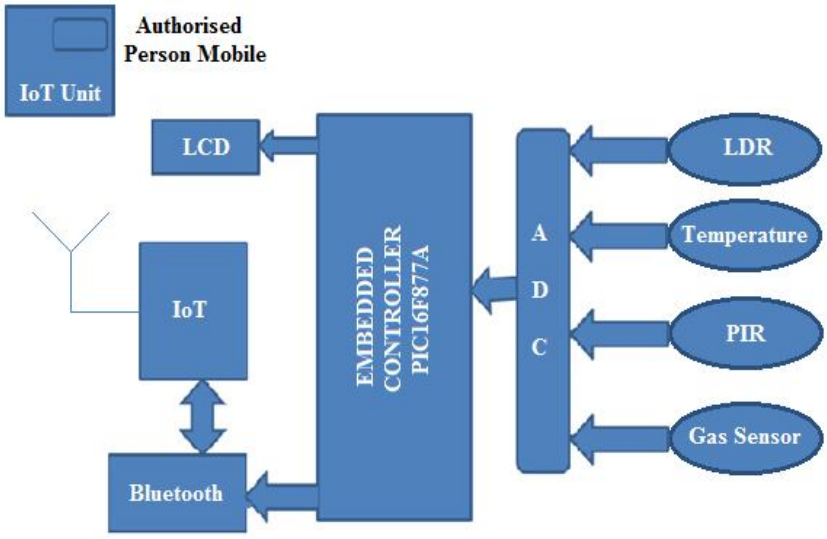

Figure 4 Working of the proposed design

XBee and XBee-Pro are the RF Modules which are used as IoT devices in the transmitter and receiver sections. The microcontroller used in this project is PIC16F877A. It takes input from the external sources and roots them to the appropriate devices as programmed in it. The LCD used here is PCD8544 which is a low power CMOS controller/device. It is used to display the name of the appliance which is being currently controlled. Each and every key in the keypad is designed for a particular function. A device can be controlled by pressing the corresponding key. Power supply unit is used to provide a constant 5Volts, 1.5A supply to different integrated circuits. This is a standard circuit using external 12V DC adopter and fixed 3-pin voltage regulator. The working principle of proposed design is shown in figure 4.

3.4.1 PIR sensor

A passive infrared radial (PIR) sensor controls the switching on/off of the lighting load when it detects a moving target. The built in sensor turns on/off the connected lighting load when it detects motion in the coverage area. It has different working principle during the day time and the night time. During the day, the built in photocell sensor saves electricity by deactivating the lighting load connected to the sensor. During the night the connected lighting load is turned on by adjusting the luminosity knob (LUX). Instead of infrared or laser transmitters and receivers, PIR sensors are used in this circuit which is shown in figure 5. The sensor is basically a piezoelectric device. When the device is exposed to infrared radiation, it generates an electric charge. The device is made of crystalline material. According to the change in the amount of infrared striking the element, there will be a change in the voltages generated, which is measured by an on-board amplifier. The infrared light explained here refers to the light radiating from all objects in its field of view. The reason for not having a transmitter and receiver is that the device does not emit one, but only accepts the energy emitted from objects above absolute zero in the form of radiations. Thus the temperature will be different for a human working past a sensor, and that of a wall right in front of it. Thus the word 'passive' is used in PIR to explain that it does not emit a radiation and receive it, but instead accepts the incoming infrared radiation passively.

Figure 5 PIR sensor

3.4.2 Gas sensor

Sensor is a technology device that detects/senses a signal, physical condition and chemical compounds. Sensors are mostly electrical or electronic. Gas sensor is a subclass of chemical sensor which is shown in figure 6. Gas sensor measures the concentration of gas in its vicinity and interacts with a gas to measure its concentration. Each gas has a unique breakdown voltage i.e. the electric field at which it is ionized. Sensor identifies gases by measuring these voltages. The concentration of the gas can be determined by measuring the current discharge in the device.

Electrochemical Gas Sensors: Chemical reactants (electrolytes or gels) two terminals (an anode and a cathode) Anode is responsible for oxidization process and cathode is responsible for reduction process. As a result, current is created. Positive ions flow to the cathode and the negative ions flow to the anode.

Carbon Monoxide Gas Sensor: It can either be battery-operated or AC powered. Mostly the sensor will not sound an alarm at lower concentrations. The alarm will sound within a few minutes at 400 ppm. So the function is specific to concentration-time. Figure shows simple carbon monoxide sensor. Infrared radiation which is not being absorbed by CO_2 produces heat so the temperature will increase. The infrared detector measures the temperature. A voltage is produced due to the temperature increase in the infrared sensor. We can read amplified voltage into the data logger.

Figure 6 Gas sensor

3.4.3 Temperature sensor

A temperature is an objective comparative measurement of hot or cold. A temperature sensor is a device that provides for temperature measurement through an electrical signal and is shown in figure 7. A thermocouple is made from two dissimilar metals that generate electrical voltage in direct proportion to changes in temperature and is used to measure how much temperature is available.

Figure 7 Temperature sensor

4. XBee™/XBee-PRO™ RF MODULES

The XBee and XBee-PRO OEM RF modules were engineered to meet IEEE 802.15.4 standards and support the unique needs of low-cost and low-power wireless sensor networks which are shown in figure 8. The modules require minimal power and provide reliable delivery of data between devices. The modules operate within the ISM 2.4 GHz frequency band and are pin-for-pin compatible with each other.

Figure 8 XBee™/XBee-PRO™ RF module

5. EVALUATION OF KEIL SOFTWARE

The Keil µVision2 IDE combines project management a rich-featured editor with interactive error correction, option setup, makes facility, and on-line help. We used µVision2 to create our source files and organize them into a project that defines our target application. µVision2 automatically compiles, assembles, and links our embedded application and provides a single focal point for our development efforts. Compilers are programs used to convert a high level language to object code. Desktop compilers produce an output object code for the underlying microprocessor, but not for other microprocessors. The programs written in one of the HLL like 'C' will compile the code to run on the system for a particular processor like x86 which can be used for underlying microprocessor in the computer. For example compilers for Dos platform is different from the compilers for UNIX platform. So if one wants to define a compiler then compiler is a program that translates source code into object code. The compiler derives its name from the way it works, looking at the entire piece of source code and collecting and reorganizing the instruction. There is a bit of little difference between compiler and an interpreter. Interpreter just interprets whole program at a time while compiler analyzes and execute each line of source code in succession, without looking at the entire program. The advantage of interpreters is that they can execute a program immediately, while programs produced by compilers run much faster than the same programs executed by an interpreter. However compilers require some time before an executable program emerges. Now

as compilers translate source code into object code, which is unique for each type of computer, many compilers are available for the same language.

6. LIGHT DEPENDENT RESISTORS SENSOR

Accurate and quantifiable measurement of light is essential in creating desired outcomes in practical day to day applications as well as unique applications. From measuring the amount of light in a work space surface, to ensuring emergency exits have proper illumination, light measurement and analysis is an important step in ensuring efficiency and safety. To perform these measurements, technicians often make use of lux meters which are specialized devices that measure the intensity of light falling on a surface or lux. Luminous intensity is a measure of the wavelength-weighted power emitted by a light source in a particular direction per unit solid angle, based on the luminosity function, a standardized model of the sensitivity of the human eye. The SI unit of luminous intensity is the candela (cd), an SI base unit. The lux (symbol: lx) is the SI unit of luminance and luminous admittance, measuring luminous flux per unit area. It is equal to one lumen per square meter. In photometry, this is used as a measure of the intensity, as perceived by the human eye, of light that hits or passes through a surface. It is analogous to the radiometric unit, watts per square meter, but with the power at each wavelength weighted according to the luminosity function, a standardized model of human visual brightness perception. The light dependent resistors (LDR) sensor used in this project is shown in figure 9. A completely analog based electronic circuit has been proposed which will do the job of measuring intensity of light and the output value can be obtained in the form of LED bar graph. A twelve 5mm diameter LDR has been used as the 12 input sensors for detecting light. Twelve different 741 Op-Amps in a voltage divider configuration with non-inverting inputs connected to LDR and a fixed or variable adjustable resistor in a voltage divider configuration has been used. The inverting inputs are connected to a 2K voltage divider circuit. Thus, the resistor on each Op-Amp non-inverting input in the twelve different levels in percentage can be adjusted. The resistance value of all 12 LDR's has been set as same/fixed. The resistance values of the 2KΩ resistors have been maintained uniformly by using 1% tolerance ¼ watt metal film resistors for the inverting inputs of Op-Amps. A voltage divider of 800 Ω is to 50 KΩ at the output of all twelve 741 Op-Amps has been used, so that the uniformity is maintained on the output of all 12 Op-Amps. The output of each Op-Amp has been connected to twelve different 3mm 20mA Cree LED in a bar graph level display formation or combination of 12 different individual LED's can be used to act as a graph when placed with each other. The circuit is powered by a common 9 volt battery that is cheaply available in the market too. This design can be modified and its resolution can be increased, as per our needs, by increasing the number of 741 Op-Amp IC's. Any other type of comparator can also be used for this job and therefore this circuit is not limited to only 741 Op-Amp.

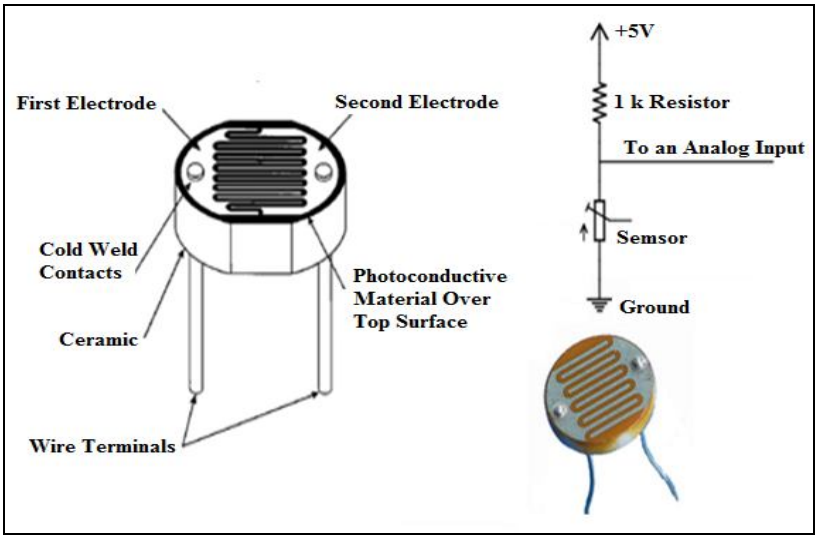

Figure 9 LDR sensor

The area and cost factor of the proposed design can further be reduced by making use of multi-input, multi-output comparator IC's. As the 741 Op Amps are having very high input impedance, the current usage for this design has been reduced to a large extent. The resolution capability of the proposed design can also be increased as per the needs, thus saving unnecessary costs and hardware. Further, different configuration of readymade IC's for comparators can also be used to fabricate this design. By this, area of the hardware can be modified and reduced by using those IC's which house multiple number of comparators on a single die. The working principle of this circuit is based on the individual principle of a single 741 Op-Amp comparator or any general purpose comparator with a voltage divider configuration on both inputs. The inverting input of the 741 Op-Amp is connected to the voltage divider of 2 KΩ

resistors. As input voltage of 9 volts has been provided to the whole circuit, the voltage at the inverting input of 741 Op-Amp will be 4.5 volts. The non-inverting input of the 741 Op-Amp has been connected to the LDR and a variable resistor or a fixed value resistor in a voltage divider configuration as shown in figure 10.

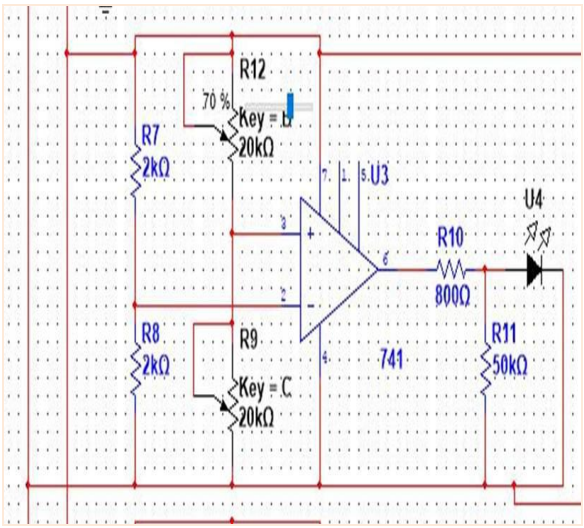

Figure 10 Circuit diagram of LDR sensor

Now when the light falls on the LDR, the voltage across the LDR varies according to the value of the variable resistor which is pre-set by us. Thus if the voltage across the variable resistor is more than the voltage at the inverting input of the Op-Amp, the output goes high and LED starts glowing. We can now pre-set the 12 different variable resistors at a difference of 5% to each other. Thus a resolution of 12 different steps for a particular input light intensity has been obtained. For higher resolution, more 741 Op-Amp comparators and LDR's are needed, as every Op-Amp will need its own LDR as a light sensor. Further, the comparison of proposed analog comparator based design with a current digital DSP based design in terms of price and resolution shows that the trend goes in favor of proposed analog comparator based design as the price differences are quite high. As observed from the graph, at a low resolution, the price of analog comparator based design is lower than the digital DSP based design by a margin of 900 INR. As the resolution increases, the margin of price difference between the proposed design and current digital design still remains high. At average resolution, the price of digital based LUX meter is 2600 INR while for the same resolution, proposed design costs only 1500 INR. At high resolution, cost of the proposed design is 2500 INR only while for the same resolution, the cost of DSP based digital LUX meter is 5000 INR i.e. double than that of the proposed design.

7. RESULT AND DISCUSSION

IoT devices can work in many ways like sensors to actuators and can work in single function devices to complex devices along with the help of wireless. In this research a single function mode that includes one sensor and wireless device was chosen. This device is a small box which contains a CPU, energy source, communication capabilities and sensors. In order to design a residential security system, we can use a large diversity of sensors. Each sensor serves a different function and some of them compensate each other. In this study LDR sensor has been used to sense the availability of light at home and if the light is glowing unnecessarily it would get a switched off automatically, temperature sensor senses the room temperature and if the temperature goes below or above the predefined value then it gives the information to the occupier contact number by SMS. Also PIR and Gas Sensor were used for this research. Wi-Fi scanner can make use of the MAC address of the occupier's smart phone in order to identify him. A more secure approach would be to have the smart phone connected to the network and authenticate for service, for which an icloud storage on internet has to be created for getting a unique user ID and password to control and monitor the home appliances from anywhere outside the home.

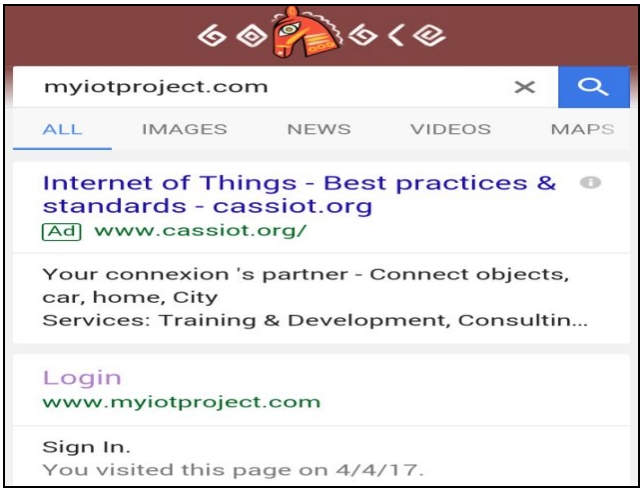

Figure 11 Web page

Figure 12 Log in page

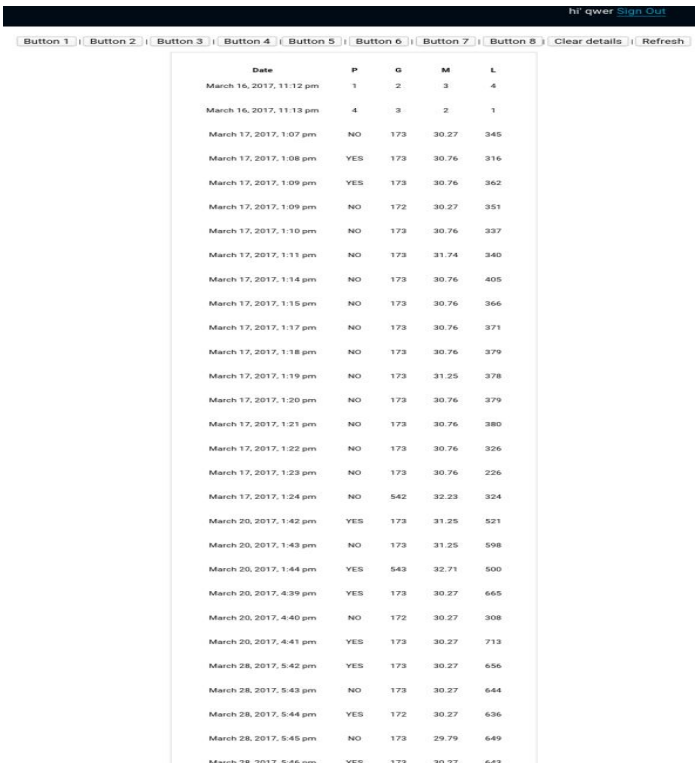

Figure 13 Output result

8. CONCLUSIONS

The big thing of a more connected world is IoT, which enables in controlling and monitoring electronics, mechanical, automobiles and other physical devices connected with internet. Design and development of a smart residential security

system using wireless IoT protocol was done, in this study by linking of appliances for monitoring and controlling them through an intelligent network.

- The characteristic of the IEEE 802.15.4 standard with the maturing IoT specification defines the wireless profiles for low data rate monitoring and controlling of the applications.
- The capabilities of both results in the availability of a technology modified specifically for the low power, low cost and low complexity applications in residential and industrial services that can be put to use presently as well as in the emerging future.
- From the study it also observed that the cost of the digital based LUX meter is 100% more than the analog proposed design.
- If the application strictly needs to communicate in a point-to-point or point-to-multipoint fashion IoT would be able to handle all the communications between our devices and would be simpler to implement.
- Finally, it could be concluded that based on our proposed design, flexible management of residential appliances in a house is possible using the IoT remote very well from outside the residence also.

9. FUTURE SCOPE

Using this new design of framework, the security system could be further extended to include various other choices which could include wireless sensor networks for monitoring and controlling different equipments available in a remote place from a remote server.

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