2021 3rd International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA) | 978-1-6654-4058-5/20/$31.00 ©2021 IEEE | DOI: 10.1109/HORA52670.2021.9461276

IOT Based Low-Cost Smart Home Automation System

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***Abstract*—Internet of Things (IOT) based smart homes make life simpler and more comfortable. Different potential applications of smart homes including remotely control lights, security and safety systems. Home appliances like air conditioning, washing machines and refrigerators are controlling through mobile phones, tablets and Personal Digital Assistants (PDA's). A user friendly and adaptive interface for smart homes is required because a user-friendly interface can allow more effective control to users for home appliances. Smart home automation systems that are available for commercial purposes are still very expensive and un-affordable for people. However now-a-days, the availability of micro controller; like Arduino makes it possible for implementation of low cost IOT based smart home system. In this paper, a cost effective and user-friendly IOT based smart home model is presented with implementation by using Arduino micro controller and different sensors. It focuses that the system is reliable, affordable and fulfill the needs of home user.**

***Index Terms*—IoT; user friendly smart home system; low cost smart home model;**

I. Introduction

The Internet of things opens the doors for home appliances, wearable devices and software's to share data and communicate with each other. The IOT is collection of large number of interconnected devices, objects and services with the ability to connect, share and communicate with each other. IOT is used and implemented in different domains like health care, agriculture, smart homes, smart cities, transportation, energy production and distribution [1] [2] [3]. In modern world, we concerned with automation, where most processes; such as industrial automation, homes and other business sectors, are being automated. Home automation systems are developed in mechanization processes where the machinery equipment requires human efforts to operate different loads in homes. It involves the automatic control of home appliances via desktops, laptops, smartphones or tablets using various technologies and controllers. Smart homes make life simpler and more comfortable. Home appliances like air conditioning, washing machines, refrigerators and lights are controlled remotely. When you are at work or enjoy holidays, smart home give you alerts about what happening and security system provide assistance/help in case of any emergency [4]. Three types of home automation system are discussed here:

- Power Line Home Automation System (HAS)
- Wired Home Automation System (HAS)
- Wireless Home Automation System (HAS)

In power line HAS, no additional cables are required for transferring of data. For transferring of data, the existing power lines are used,However, this type of home automation is inexpensive, but involves a significant complexity and includes additional circuits and equipment for converters. In wired HAS, cat5 or cat6 cable is used to transfer and communicate the information. The wired system can be easily used in new homes but it can also be used in existing homes. HAS using hardwiring is a good choice because wiring is reliable and we can easily join all system together. But it is quite old system and difficult for existing home because laying a cable from zero point may affects the appearances of our home. Wireless HAS is most advanced form of home automation system available in these days. It is basically expansion of wired HAS. In wireless HAS we use wireless technologies like Zigbee, WiFi, GSM, Bluetooth etc. Different sensors are attached with microcontroller, through which the lights, fans, home appliances can control remotely with the help of android based application which was install on our cell phones. The safety and security systems for smart homes are also part of the system. The adoption rate of the IoT devices throughout the world is increasing rapidly [30]. In our research, following techniques and technologies are used in IOT smart home automation system:

Following technologies used in IOT

- Low cost and low power sensor technology

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- Connectivity
- Cloud computing

In low cost and low power sensor technology, different sensors can be used. Currently, sensors are available in different varieties at very low cost. These sensors consume very low power with efficient energy consumption due to which IOT adoption rate is increasing day by day. In this study, connectivity is performed with the help of WiFi, Bluetooth and services of internet. The sensors are easily connected to cloud and other things to transfer data efficiently. The cloud is used to provide the infrastructure for IOT. Sensors and devices used in IOT generates huge amount of data, traffic but have very little storage and processing capacity or power. Therefore, services of the cloud are used for data storage, connectivity and processing. The Artificial Intelligence (AI) used in IOT makes it possible that we can control our home remotely with voice commands. Natural Language Processing (NLP) is used in IOT with the advancement in neural network such as PDA Cortana, Siri and Alexa (amazon Alexa) make our homes attractive, accessible and feasible.

A. Smart Home Applications

Different potential smart home applications can be used in the following domains or categories [5-6].

- Remotely controlled home appliances: like (air conditioning, washing machines, refrigerators and lighting) remotely controlled
- Safety: Fire detection, gas leakage detection
- Security: Intruder detection.

1) Remotely Control Home Appliances: Home appliances like lights, fans, bulbs, air conditioners, washing machines and refrigerators are control remotely with the help of mobile phones. For the said purpose android base application is install on cell phone and user can switch on and off home appliances [31].

2) Safety: For safety purposes, the fire detection and gas leakage detection systems can be install in home. These systems detect fire and gas leakage and intimate user timely and help in avoiding accidents [32].

3) Security: Intruder detection system can be installed to detect the unwanted movement in our homes and to intimate us timely in case of emergency. Smart home operations are usually control through the mobile devices like smart phones, PDA's, tablets etc. The role of Human Computer Interaction (HCI) is very important in designing the user-interface for smart home operations [7] [8]. The HCI provide the guidelines to design the system according to user's mental model. It also plays an important role to enrich the interaction of user and system, usability and security [9]. A user friendly interface allows users to control the home appliance more effectively as compared to complex one[10-11]. If the system is complex then numbers of interactive smart home items or products like lighting, heating, fans, washing machines, Microwave ovens, video recorders, etc. big Data requires more security in any area of interest from smart home to smart health[12]. In a domestic environment it is need to remember and understand that users are mostly in relaxed mode and they don't want to waste their time in reading user manuals and try to understand products that are complex in operations. Smart home system can be used by literate and illiterate users, elderly and children's can also be user of the system. Smart home system may be easy for literate users but it may be quite difficult to understand for children's, illiterate and elderly users. Poorly designed interface creates frustrations and leads to increase the chance of making errors due to which user satisfaction is not fulfilled which creates negative impact about the system and leads to rejection of the whole system [11]. There is a need to develop a system which is cost effective and adaptable by the users. Now-a-days the availability of microcontroller like Arduino makes it possible for implementation of low cost IOT based smart home system.

II. Related Work

In [18] the study, illustrates the smart home architecture that focus how to control home appliance remotely paper also describes that with the help of intelligent terminals we can detect smoke, fire, gas leakage and successfully implement the security features in our home. In [19] the research suggested the smart home system. The whole system was design with the help of Raspberry Pi microprocessor and uses the services provided by the amazon (Alexa). The system has the ability of capturing the voice commands and processes them. The purposed system helps in designing and implementation of smart home model. Davidovic et al. [20] illustrate a smart home system. The system is built by using different sensors, which are connected with Raspberry Pi Microcontroller. The Bluetooth module is used for communication. To control the devices remotely a user friendly android based interface was also used or developed. In [21] prototype for designing a smart home control system is presented. The presented system includes Hardware design and software design for smart homes. Hardware implementation consists of sensors, relays, software implementation includes interface for users that can be mobile app or website. Further, the study in [22] focuses on the security of smart home. Initially describe the smart home setup, different technologies used in smart homes and different benefits of smart homes. Then discuss issues relating to Smart Home protection, security, and threats of smart home environment like Fire protection, access control, authentication, etc. In [23] the study, states a resilience framework that helps the IOT app developers to provide services in dynamic Fog IOT environment. The framework restricts spread of failure and the helps to avoid the whole application from restart when failure arises. The framework also recovers applicative and infrastructure entities by re-configuring, restoring the application to its consistent state. IOT based smart home system [24] is introduced by the author. Proposed system is related to home security and well-organized energy management is also the part of the system. The basic concept is that home appliances control remotely through mobile phones; Wi-Fi is used for connection.The other studies [13] [14] are presented a user friendly smart home system. With the help of microcontroller,

sensors, acuraters, Bluetooth and WiFi module a user friendly smart home environment is design and implemented more effectively and efficiently. Furthermore, author [15] presented a smart home architecture that was based on IOT. User can control their smart home by interacting the different IOT devices through their smart phones, tablets and pcs. Moreover, a smart home threat model is also presents that focus on there is internal and external adversaries. Internal adversaries are inside the smart home environment and external adversaries are trying to interact via internet. In addition, smart home cyber flaws like eavesdropping, DOS, software exploitation are also discussed. Another research presented a review [16] of numerous usability measurement models by Azham Hussain et al. The author describes the pros and cons of various models which was helpful in measuring the usability of mobile applications. Ranjana Sharma et al. [17] describe how smart application of living can fulfill the need of elderly people. Cognitive problems are examined that are faced by elderly peoples and how their daily life is affected by these problems. Role of HCI in smart living for elderly peoples is also discussed in [25] author design and implement SH system to monitor power-consumption in the real time. Intel Galileo board is used for the said purpose. Additionally, a study is described in [26], the survey related to IOT technologies used in smart cities. Radio frequency identification and wireless sensor network is also discussed. RFID is used for labeling and tagging the devices, a unique identification no is assign to each device. WSN collect data from physical locations with the help of sensors. Likewise, the architecture [27] used for smart home is presented which was based on cloud platform. The home appliances are control from anywhere and also use services of the cloud to provide home data, which can be used by various service provider and applications. Raspberry PI was used as gateway to control home appliances.

III. Problem Statement

Smart home automation systems that are available for commercial purposes are still very expensive and unaffordable for families of middle and lower middle class. There is a need to develop a system which is cost effective and adaptable by the users.

IV. Proposed System and Methodology

Now-a-days the availability of microcontroller like Arduino makes it possible for implementation of low cost IOT based smart home system. With the help of Arduino microcontroller, sensors, acuraters, Bluetooth and Wi-Fi module a low cost user-friendly smart home environment will be designed and implemented more effectively and efficiently. In this paper, a cost effective and user-friendly IOT base smart home model will be presented with implementation that will be reliable, affordable and fulfill the needs of home users. The model will be based on Arduino microcontroller, HC05 Bluetooth module, Esp8266 WiFi module, different sensors like (flame sensor, motion sensor) and relay. The project includes[31-32]:

- Remotely control Lights, Fans and appliance
- Security system
- Safety System

A. Remotely Control Fans, Lights and appliances

With the help of this smart home model the user will be able to control home lights, fans and other appliances remotely through their mobiles phones. Arduino Micro controller, ESP8266 WiFi module, HC05 Bluetooth module, 4 channel relay and third party mobile app will be used for the said purpose.

B. Security System

The presented security system will detect the suspicious, unwanted movement and intimates us timely in case of emergency. For the said purpose motion sensor and buzzer will be used with Arduino micro controller.

C. Safety System

For safety purposes a fire intimation system will be use, which detects fire in home and send alert to our mobile phones which will enhance safety. Esp8266 WiFi Module, flame sensor, services of internet and Blynk app will be use for the said purpose. Blynk app will be install in our cell phones which will be configured by using the auth code in our sketch. Blynk app will receive alerts in our cell phones in case of emergency.

V. Experimentation

The following experiments are done to build a smart home model

A. Safety System (Fire Intimation System)

Fire intimation system is the basic need of smart home. It enhances safety and brigs satisfaction in our life. The systems detect the flame/ fire and intimate us by sending message/ alert to our smart phones with the help of internet.

Blynk app is install in our cell phones which is configured by using the auth code in our sketch. Blynk app will receive alerts in our cell phones in case of emergency. Following items are required for the said purpose

- NodeMCU ESP8266
- Flame Sensor
- Jumper Wires
- Power Adapter or USB cable
- Blynk App and Smart Phone
- Internet Connection

1) NodeMCU ESP8266: ESP 8266 WiFi is used to control the complete operations of the system. The sketch / Program is uploaded to ESP 8266 Wi-Fi module through Arduino IDE. It is important that we must select the board Node MCU in Arduino IDE before uploading the sketch.

2) Flame Sensor: Flame sensor is used to detect the flame or fire in the house. It has 3 and sometime 4 pins.

- Pin 1 is VCC Pin and is used to supply voltage (3.3V to 5.3V)
- Pin 2 is (GND) Ground Pin
- Pin 3 is an analog output
- Pin 4 is a digital out

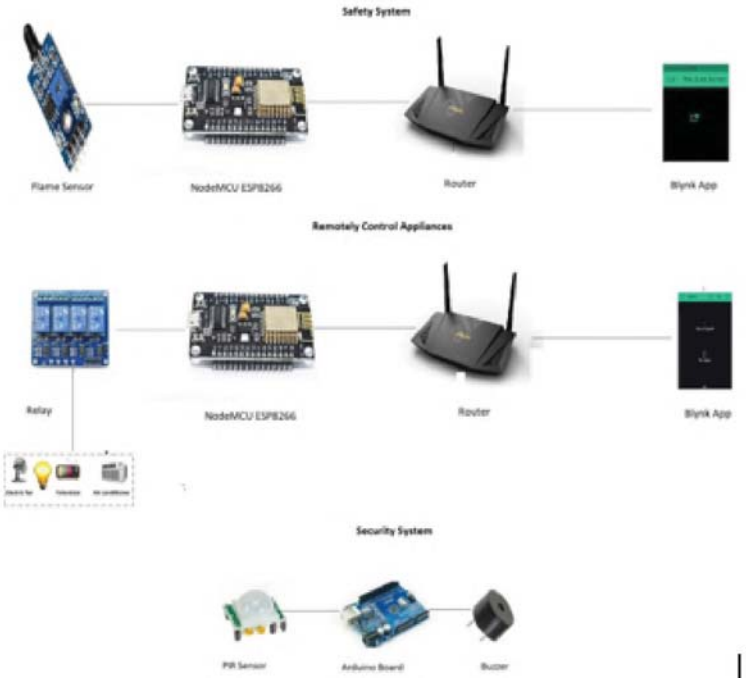

Fig. 1. Purposed System.

3) Jumper Wires: Jumper wires are used to make connection

4) Blynk : Blynk is very widely used in IOT application. With the help of Blynk we can build complex IOT projects very easily. Blynk support Arduino, Rasberry PI and other same type of micro-controllers. Blynk app can be easily download form play store and it is free of cost. Blynk include

5) Blynk App: We can make App for different projects easily. There is no need to write code Blynk Server It is responsible for communication between mobile device and Hardware. We can use the services of Blynk-Cloud or use local private blynk-server. It is open-source and blynk cloud manages/ handle huge no of devices easily

6) Setup Blynk app for project: After download blynk app from play store, open or turn on the app and login with your email or Facebook account. After login create new project and give project name as Fire Alert system and chose device as NodeMCU and connection type as Wi-Fi and click on create

When you click on create an auth Token is sent to you email address. This auth token is used in sketch

Click on + button and select Notification

TABLE I
FLAME SENSOR CONFIGURATION

Circuit Flame Sensor	***NodeMCU***
D0	D1
GND	GND
VCC	5V

Flame sensor is connected to NODE MCU ESP8266 Wi-Fi Module which was programmed in such a way that when flame sensor detects fire/flame it will trigger the NODE MCU ESP8266 module and NODE MCU send alert to Blynk App like (Fire in House). Node MCU is connected to internet through gateway / router. Blynk App is used to receive alerts. Sketch / Program that was uploaded to NODE MCU ESP 8266 WIFi Module contains

- Auth Code : auth code is send through email when we create project in Blynk
- SSID: SSID is our WiFi name
- Password: give password of WiFi

B. Remotely Control Fans, Lights and Appliances

Using ESP8266 and Blynk With the help of NodeMcu ESP8266 Wi-Fi Module and service of the Blank app we can also remotely control Lights, fans and appliance from anywhere. For the said purpose following equipment is needed

- NodeMCU ESP8266
- Relay
- Jumper Wires
- Blynk App

1) NodeMCU ESP8266: ESP 8266 WiFi is used to control the complete operations of the system. The sketch / Program is uploaded to ESP 8266 WiFi module through Arduino IDE. It is important that we must select the board Node MCU in Arduino IDE before uploading the sketch.

2) Relay : Relay is used to turn on/off the fans, lights and appliance in our home

3) Jumper Wires: Jumper wires are use to make connections

4) Blynk : Blynk is very widely used in IOT application. With the help of Blynk we can build complex IOT projects very easily. Blynk support Arduino, Rasberry PI and other same type of microcontrollers. Blynk app can be easily download form play store and it is free of cost. Relay is connected to

TABLE II
DIGITAL CIRCUIT

NodeMcu ESP8266	*Relay*
GND	GND
3v	VCC
D1	IN1
D2	IN2
D3	IN3
D4	IN4

NodeMcu ESP8266 which was connected to Router. NodeMcu ESP8266 was programmed in such a way that when user presses ON/OFF button in Blynk app it will trigger the relay and in response of which the relay turns ON/OFF the home appliances.

C. Security System / Intruder Detection System

Security is one of the major components of smart homes. By installing security system we can easily detects the suspicious, unwanted movement. In traditional security system we use CCTV (Close circuit TV) which only record the video and does not give warning about the intruder. In this project we use advance system which detect the intruder / suspicious activity and intimate us timely by turning on the Buzzer/ Alarm. Following items are required for the said task:

- PIR Motion Sensor
- Arduino Board
- Buzzer
- Jumper Wires

1) PIR Motion Sensor: PIR Motion Sensor is used in this project to detect suspicious / unwanted movement. PIR Motion sensor is small in size, easily available, easy to use therefore used in large no of project. Its output when PIR Motion sensor detects movement then (digital high) otherwise (Digital Low) and its sensitivity range is up to 20 feet's Power: 3.3v or 5v There are three pins in PIR Motion sensor VCC, Out and GND

2) Arduino Board / Microcontroller: Arduino board works as gateway. PIR Motion sensor and Buzzer is connected with arduino board. Program/ sketch is uploaded to arduino board using arduino IDE.

3) Buzzer: Buzzer is used as Alarm (When intruder detected buzzer the alarm).

4) Jumper Wires : Jumper wires are used to make connection among the arduino board, soil moisture sensor and relay. Power Adapter 5v or USB cable We can start/ turn on the arduino board by using power adapter 5v or by connecting it to computer through USB cable. PIR Motion Sensor is install in sensitive areas (like Entrance, doors, window, etc) of home. PIR Motion Sensor and buzzer are connected to arduino board/ micro controller. Arduino board is programmed in such a way that when PIR Motion sensor Detects Movement it will buzzer the Alarm.

TABLE III
CIRCUIT

PIR Sensor	***Arduino***
VCC of PIR is connected	5V
GND of PIR is connected to	GND
Buzzer	***Arduino***
S is connected to	pin9
-.....	GND

VI. RESULT AND DISCUSSIONS

Results are achieved after successful testing and experimentation's of remotely control Home Appliances, safety system and security system. In remotely control home appliance smart home user successfully control lights, fans and other home appliances successfully through their mobile phones (by using Blynk App). When user switch on the button by using the Blynk app it will turn on the lights and fans in smart home and when he switch off the button lights, Fans and appliances are successfully turn off In safety system when user generated flame through lighter or match stick the flame sensor detects the flame / fire and send alert to ESP8266 Wi-Fi module which intimate us by sending message/ alert to Blynk app which was installed and configured in our smart phones. In security system unwanted or suspicious activity is detected by the PIR Motion sensor which send alert to Arduino board/ Microcontroller. After getting the alert from the PIR sensor the Arduino board buzzer the alarm and intimates us timely. The results show that all three experiments are successfully done and gives us accurate results.

VII. CONCLUSION

The IoT can be describing as collection of large no of interconnected devices, objects, services with the ability to connect, share and communicate with each other. IOT is used and implemented in different domains like health care, agriculture, smart homes, smart cities, transportation, energy production and distribution. One of the most important domains of IOT is smart home system. Smart homes bring comfort and ease in our lives. Smart home operations are usually control through the mobile devices. A user-friendly interface allows users to control the home appliance more effectively as compared to complex one. If the system is complex, then numbers of interactive smart home items are misused because they are quite difficult to operate and understand. The smart home system that are available in the market are expensive and are not affordable for families of middle and lower middle class. Therefore, there is need that users of smart home system should be clearly identified and develop a system that is flexible, cost effective, adaptable and easy to use by users of all age group. In this project a cost effective smart home system is presented by using Arduino microcontroller, ESP8266 WiFi module, different sensors (flame sensor, PIR

sensor). Three different potential experiments are successfully performed (remotely control lights, fans and appliances, safety system and security system). Home appliance can be control remotely without putting any extra effort. Security system, safety system is successfully implemented and used in this presented smart home model. The smart home user can detect unwanted or suspicious activity and enhance security of their home, they also increase safety of their homes by installing the safety system which detects Fire and timely intimates the smart home user. The presented system is low cost, user friendly and brings comfort in our life.

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