International Journal of Innovative Research in Science and Engineering
Volume 08, Issue 11, 2022
www.ijirse.com
ISSN: 2454-9665

# DESIGN AND IMPLEMENTATION OF IOT BASED SMART HOME

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## ABSTRACT

*In this modern world digital technology becomes our ingredient part of our life. The reason behind it is that it makes our life simple and easier. The cornerstone of such development in industrial and commercial sectors of our life is the automation process as a field of modern technology.*

*This Paper concerns on commercial residential application of automation technique to design and implement advance conventional home known as smart home using Arduino UNO as the main microcontroller board, The designed system incorporates user appliances monitoring and control wirelessly using HC-05 Bluetooth module and android application; security alarm system involving buzzer and SMS alert notification using SIM900 GSM module; and a real time weather status display via 16x2 LCD using DHT11 sensor. In the implemented system, user could controls and monitors up to four (4) devices including sensors and also displays temperature and humidly status on the LCD by sending preset ASCII CODE character from his Smartphone Bluetooth terminal to the microcontroller wirelessly, each code the user sends has its predefined function to be executed by the respective end device. Furthermore the security system employs touch sensor and works automatically upon detecting an intruder. Arduino IDE software was use to write the entire program.*

***Keywords*:-***Arduino Uno, Home automation, LCD, Smart phone, HC-05 Bluetooth module, Sensor*

## INTRODUCTION

Home automation is essentially a branch of automation technology which is centered to improve life comfort and convenience to residence in a commercial or industrial place by involving zero or minimal human intervention [1]. It describes a residence of interconnected devices that could communicate among network and could be monitored and controlled effectively. Home is categorically classified to three main branches namely: smart home, connected home and smart connected home [2].

Smart home locally operates devices not necessarily needing an internet service, connected home monitors and controls the network system via internet remotely while smart connected room features all the attributes of the previous homes with advance system capability including decision making [2] etc.

This technology has been in existence as concepts and ideas since late nineteenth century and lately it has been getting much attention worldwide [3]. Research has shown that it could reach a share worth 114billion USD by 2025. [1]

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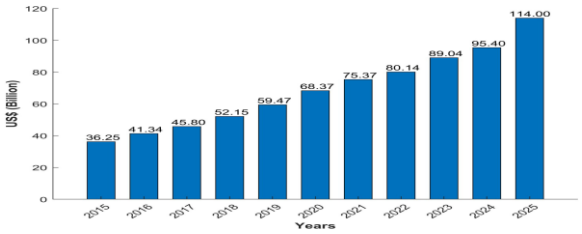
www.ijirse.com
ISSN: 2454-9665




**Fig,1. Global home automation market size (adopted from [1])**

Many designers of home automation use wired or wireless technology for devices communication. In wireless based system, internet or non-internet based protocols are used. Including wifi, Bluetooth, Zigbee, z wave etc. while wired protocols ware mostly dominant in the twentieth century but are still in use today include x-10, Insteon, Ethernet etc. all the protocols involve in home automation system have their respective pros and cons and is implemented depends on the consumers preference and system capabilities. Most home automation system available today suffers some feedback from lack of centralized control system, energy and power failure, continuous and interrupted internet connection which is costly, excessive use of wired lines, consumption of huge web server storage, maintainace difficulty and technical knowledge of operation as well as complexity in implementation. These problems among others make the technology not accessible for the majority poor masses.

However this paper design and implement smart home that is cost effective, robust, easy implementation and maintenance and user friendly. It is a preferred system for poor people and elderly or handicapped people. The proposed system is based on Arduino uno as the main controller and uses Bluetooth technology to enable devices locally communicate wirelessly. It also employs temperature and humidity sensor to record the quantities and then displayson an LCD real time weather status upon user's request, touch sensor to trigger security system. The security notification sounds buzzer and also send SMS to user's mobile. The system enables the monitoring and control of end devices from a Smartphone application.

In next section Literature review is discussed. In section III, overall system description is presented. Sections IV and V describe the hardware architecture and the software architecture respectivelyof the proposed design. Result and Implementation are highlighted in section VI. Finally section VII, described the conclusion and future work.

## LITERATURE REVIEW

In [4], the author implemented speech recognition system to be use in smart home to control the operation of the interconnected home appliances; the speech is set of some prescribed words. The main hardwires used were raspberry pi as the integrated controller for the recognition system and NODEMCU as a switch to turn on/off appliances. The system uses MFCC (Mel Frequency Cepstral Coefficient) algorithm to extract data from the processed acoustic signal obtains from the microphone and DTW (Dynamic Time Warping) algorithm is used to match speech with the trained speech or template stored. When the speech is matched successfully, the NODEMCU received a command using MQTT (Message queuing Telemetry Transport) Protocol from the Raspberry to perform the switching operation. Upon completion of the project, 30 tests were carried out and

accuracy rate of 86.67% was obtained. The input was a 6th input command with an average time of 5.28second and the time response for the entire matching process was 5.51sec. The entire identification test was carried out at the system for input sound intensity greater than 45DB

In [5], the paper described and tested a prototype design of home automation based on ARM Cortex M4 as the main microcontroller. The system comprises of ESP 8266 wifi module, sensors and relays. The WIFI module connects the system to the internet via IP/TCP connection and is use to communicate to the ARM controller via UART protocol. Sensors are interfaced to the controller and are use to detect and give information of the interconnected appliances, these updates from the sensor are transmitted to the WiFi module and are use to update a web interface. The web interface is an interactive interface that user's computer or Smartphone connected to internet to monitor and control the status of the appliances by pressing a button on the interface. The system however could automatically change the status of an appliance depending upon the defined set threshold value of the respective sensor. Relays are use as switches to turn on/off appliances and the ARM microcontroller was programmed using ARM Keiluvision IDE version 5.

[6] Designed and implemented home automation system based on GSM (Global system for mobile communication). The system comprises of PIC17F877A as the microcontroller, SIM 800L GSM module, relay driver ULN 2003, relay switch and connected loads. A user is required to send preset message to the 800L GSM Module registered number, the module would decode the message and then send it to the microcontroller, the microcontroller validated the received signal and turn on/off relay switch which eventually switch on/off a particular load. The relay switch ULN 2003 is used to interface the microcontroller with the relay switch, the driver is due for compatibility because the microcontroller output voltage is small to source the relay switch to start its operation. The output port of the system was designed to consist of two bulbs slots and two socket outlets slots. The system been tested was found to have an average delay of 19seconds from the time the message was sent before the switching takes place

In [7], the author designed and implemented prototype home automation controlled using Bit voicer. Bit voicer is voice controlling software that's compatible with Arduino and through which a user communicate voice command to the arduino. The other components used in the system are: sensors (particularly LDR and DHT sensors) to detect light intensity, temperature and humidity of the home respectively, Ethernet shield which enable the arduino microcontroller to be connected with the internet, RF receiver module that was used to transmit and receive data wirelessly and LEDs serving as actuators to demarcate the status of the electrical appliances. The system works in two modes: in automatic modes, the user sends the voice command by saying "keyword ON" and from that he has no control over the status of the appliance, the system therefore now relied upon the components to send information of the home wirelessly and base on these value controls the action of the home appliances. Similarly in manual mode, the user first sends the voice command "Autohome" and after that, he has to wait for at least 3 seconds to get the full responsibility of the appliances operation. By sending a particular voice command, the respective appliance is switched on or off.

The author in [8] designed and implemented an Arduino based smart home controlled wirelessly using android application (ArduDroid). The system has Bluetooth module HC-05 for serial wireless communication between Smartphone and microcontroller, LM35 temperature sensor to detects and measure temperature, two LDR

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sensors to check and count the number of people in a room and home appliances of TV, sitting room light, fan and security light. The software program was developed using Arduino IDE and was uploaded to the board main controller. ArduDroid is an interactive user interface or android application that enable user to send among the preset commands to the Arduino to control the respective home appliance, similarly if user sends a wrong command, the system reply by notifying the user invalid command. The system was finally implemented on a vero board after being tested as a prototype and was properly packaged in a house modeled using straw board. Several testing ware carried out however the system worked efficiently.

In [9], low cost smart home automation using Bluetooth technology was designed and a prototype was also implemented. The system is based on Arduino as the main controller and uses smart phone application to monitor and control up to 18 devices including sensors and appliances. The system uses Bluetooth module HC-06 to communicate wirelessly between Smartphone application and the microcontroller board, ultrasonic range sensors to monitor water level inside a tank, soil moisture sensor for automatic plants irrigation system and relays to switch on/off home appliances. The smart phone application has an interactive interface that makes wireless connection with the Arduinouno using the Bluetooth module, set of instructions were uploaded such that each among the preset ASCI code received from the smart phone has a particular operation on the respective appliance. The status of the sensors could also be displayed on the Smartphone by sending the respective ASCI code. The prototype was tested and was found to be 100% efficient with a distance range of 20m.

In [10], wheel chair control and home automation using hand gestures, the author proposed a system that could use air gestures to control wheel chair movement, door lock and other home appliances. The system consists of two Arduino boards that are connected wirelessly using Bluetooth technology. The first board is interfaced by electric motor and is dedicated to control wheel chair motion; similarly the second is placed to perform home automation by controlling home appliances. A disable user id required to make a gesture using his finger or complete hand, the gesture is captured by web camera and the video frame recorded is sent to a video processor. The video processor contains the algorithm to read the gesture and therefore it is decoded by the video processor, if the signal corresponds to the wheel chair movement, it is an input to the first board which triggers a motor control and controls the wheel chair movement. However if the signal corresponds to home appliances, then the second board receive the signal through Bluetooth communication and activate a relay which then controls the home appliances. The proposed system was aimed to provide ease of use for disable people with minimal gesture using fingers.

## SYSTEM DESCRIPTION

The proposed system is composed of mainly two parts namely, hardware and software components. The hardware comprises of Arduino Uno Board, HC-05 Bluetooth module, SIM900 GSM Module, DHT11 Temperature sensor, Touch Sensor, 16X2 LCD, Buzzer, Switch Relay and Electrical Home appliances. The software part consists of Arduino Integrated Development Environment (IDE) and Smart Phone Bluetooth Terminal. The block diagram and the flow chart of the proposed home automation are depicted in figure 2 and 3 respectively below.

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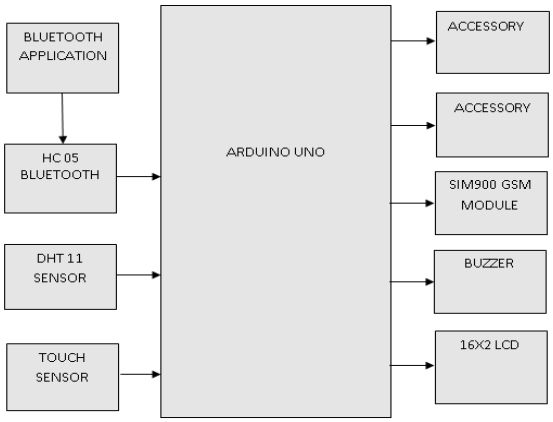
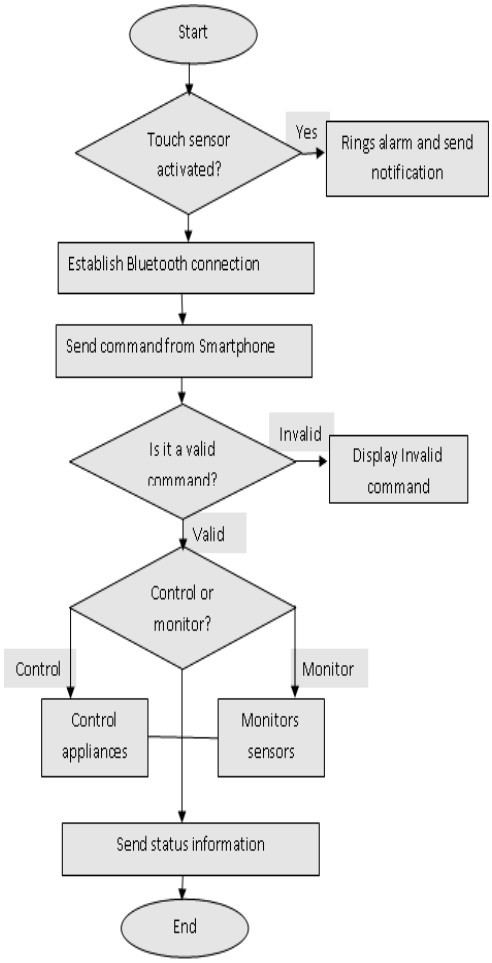
ISSN: 2454-9665




**Fig,2. Proposed system block diagram**




**Fig,3. Proposed system flow chart**

## HARDWARE ARCHITECTURE

### ARDUINO UNO BOARD:

This board was first established in Italy, it is an open source, general purpose development board based on ATMEGA 328 Microcontroller. Arduino boards are programmed using Arduino IDE software to enable user

create an interactive electronics project. Ithas 6 analog input pins, 14 digital input/output pins, and is powered through USB or 7V-20V external power source. It also consist of 32KB flash memory, 2KB SRAM and 1KB EEPROM and other on board pins and components. However theboard can be used in extension with other different boards for some applications.


**Fig,4. Arduino Uno**

### HC-05 BLUETOOTH:

This is a simple module that is based on IEEE8802.15.1 standard protocol; it provides full duplex interaction between two devices at 9600 baud rates using USART. The module can be operated at either Data or default AT COMMAND modes. HC 05 consists of 6 pins namely: Key/EN; VCC; GND; TXD; RXD and STATE and is powered by 3.3V voltage supply but also support 5V supply since it is equipped with embedded voltage regulator. Similarly on top of the module is designated RED LED to indicate connection status, before connection is established, the LED blinks fast continuously and after connection is made, it slows down to blink slowly.HC-05 is used in this project to provide communication channel between user'sSmartphone and Arduino microcontroller.

**Table 1. Interfacing HC-05 with Arduino Uno**

| HC-05 TERMINAL | CONNECTION | ARDUINO UNO PIN |
|---|---|---|
| VCC | Connected to | +3.3V |
| GND | Connected to | GND |
| TX | Connected to | RX |
| RX | Connected to | TX |

### 16x2 LCD

This is a component use to provide display capability in an electronics project. Liquid crystal display (LCD) doesn't produce their own light or are not self luminous as Light emitting diode (LED) counterpart, however it depends on internal reflectors to display characters on a flat screen. It is also popular for its availability, ease of use and cost effectiveness. The name 16x2 indicates that, the screen consists of 16coulumns and 2 rows and could display 16x2=32 characters in total such that each is 5x8 pixels. It is used here to display all system information's to the user.

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**Table 2. Interfacing LCD with Arduino Uno**

| LCD PIN | CONNECTION | ARDUINO UNO |
|---|---|---|
| Data pins 7,8,9,10 | Connected respectively to | d6,d5,d4, d3 |
| EN (Enable) | Connected to | d7 |
| RS (Register Select) | Connected to | d8 |

## DHT11 SENSOR

This is typically temperature and humidity sensor, it comprises mainly of negative temperature coefficient component and resistive humidity measurement component. It is a single wire temperature and humidity detector that simultaneously produces fully calibrated digital temperature and humidity output values serially employing a single wire protocol. This sensor is manufactured in a single row of 3 0r 4 pins package and is powered by 3.5V to 5.5V supply. It is use tomeasure temperature range of 0-50$^0$C with an accuracy of ±2$^0$C% and humidity ranging from 20-90% with an accuracy of 5%.

**Table 3. Interfacing DHT11 with Arduino**

| DHT 11 PIN | CONNECTION | ARDUINO UNO |
|---|---|---|
| VCC | Connected to | 5V |
| DATA | Connected to | A1 |
| GND | Connected to | GND |

## TOUCH SENSOR

As the name implies, this component performs action similar to human being skin, it senses and detect touch and then respond by sending an electric signal. Touch sensors works as a closed switch upon touched and is usually used in electronics circuit to initiate and enhance security system. These sensors are also termed as tactile sensor; they are however proximity sensors reduced to lowest distance.

**Table 4. Interfacing Touch Sensor with Arduino Uno**

| TOUCH SENSOR PIN | CONNECTION | ARDUINO UNO PIN |
|---|---|---|
| VCC | Connected to | +5V |
| GND | Connected to | GND |
| DATA | Connected to | A5 |

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## RELAY

Relay is an electrically operated switch which upon receiving an electronic pulse controls the turn ON/OFF of an electronic load. It consists of a movable part which makes or breaks electronics circuit. Relays are popular because they could be use for both AC and DC operated devices. It is also compatible with many developmental boards. E.g.PIC microcontroller, Arduino board etc. A channel relay module consists of six pins: VCC (+5V),GND, Digital input, normally closed and normally open pins. By default relay movable part is connected with the normally closed pin, and upon receiving electronic pulse it breaks the circuit and makes with the normally open pin.


**Fig,5. Relay Module**

## GSM MODULE

SIM900 GSM module is basically a GSM/GPRS shield which is coming packed with associated components to be easily interface in electronics projects to provide functions that a normal cell phone is used to accomplished. The module can be use to make and receive audio calls, send and receive SMS, connecting to internet through GPRS,TCP/IP etc. in this project, it is used to send notification message to the user's mobile phone when the smart system acknowledges an intruder.

**Table 5. Interfacing SIM900 with Arduino**

| SIM900 PIN | CONNECTION | ARDUINO PIN |
|---|---|---|
| TX | Connected to | 11 |
| RX | Connected to | 10 |

## BUZZER

A buzzer is an electronic component that adds sound capability to our project. It is a two terminal component device that produce a continuous beep sound when powered. It is usually used for security purpose.

**Fig,6. Buzzer**

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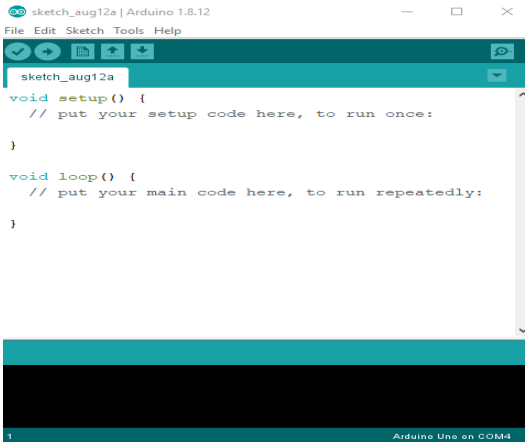
www.ijirse.com
ISSN: 2454-9665

## SOFTWARE ARCHITECTURE

In this Project, Arduino integrated environment (IDE) and Bluetooth terminal application software are used.

## ARDUINO IDE (INTEGRATED DEVELOPMENT ENVIRONMENT)

This is open source software and can be downloaded from official Arduino Web page. It is used to write the entire Arduino Sketch. A sketch is a program or set of instruction written In the IDE Software. Baud rate of 9600bit/s is chosen for the serial communication between Arduino board and Smartphone.




**Fig,7. Arduino IDE Environment**

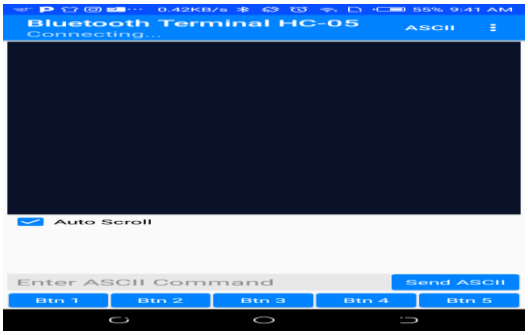
Every Arduino sketch has two main parts of the program:

- Void setup (): Executed only once; mostly contain declaration instructions, constants and other commands to Sets up things.
- Void loop() :Contains the instructions that are executed over and over until the board is turned off

The Arduino Sketch of the system is written in the appendix

## BLUETOOTH TERMINAL

This is also free source android based application downloaded from Google play store; it is used for wireless interaction between Smartphone and Arduino Board. The terminal has a display screen to show home appliances and sensors status information and user can use it to transmit ASCII character from Smartphone to the Arduino board through the Bluetooth HC-05 Module. The proposed system will be able to control four (4) devices including sensors and appliances.




**Fig,8. Bluetooth terminal interface**

**Table 6. ASCII CODE with their functions**

| ASCII CODE | FUCTIONAL OPERATION |
|---|---|
| 0 | Turn ON first bulb |
| 1 | Turn OFF first bulb |
| 2 | Turn ON second bulb |
| 3 | Turn OFF second bulb |
| 4 | Display weather status |

## RESULT AND IMPLEMENTATION

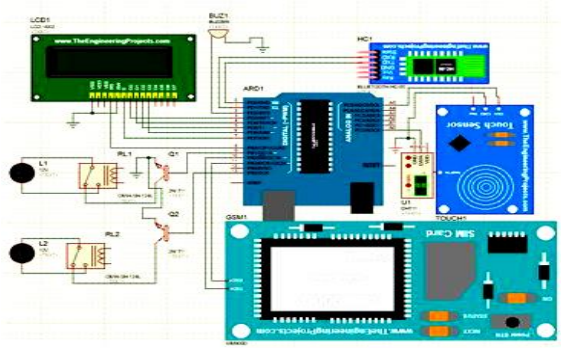
### PRINCIPLE OF OPERATION

The aim of this project is to design and implement smart home based on Arduino microcontroller, Bluetooth module and a user Smartphone. As shown in figure 14, all hardwires are connected and the software program compiled and uploaded successfully. The project works as follows:

When power is supplies to the system, the LED on the Bluetooth module starts fast blinking, user now open his installed Bluetooth terminal on Smartphone, scan the available Bluetooth devices and get connected with the Bluetooth module, now the LED on the module will be stable or not blinking as faster as it was before the successful connection.

However, the user can control and monitor the home network by sending ASCII Code to the Arduino Microcontroller, the Bluetooth terminal has a display as well as the system to display appliances status, similarly the terminal has an interactive interface to enable user to send the command. The command is in the form of ASCII Character, the preset characters with their respective operation ware given in table 6. When user pressed a character, the module receives it wirelessly and then transmits it serially to the controller. The controller receives the character and compares it with the prescribed characters written on the Arduino sketch and accordingly performs the respective operation. Switching operation is completed by relay switch which is triggered by the controller.

Furthermore, when introducer touches a touch sensor, automatic security system is activated; buzzer alarm rings and a SMS notification is sent to the user mobile number. Using this system, user can controls and monitor up to four (4) devices including sensors and also ensure secured home during his absence.



**Fig,9. Proposed system circuit diagram**

ISSN: 2454-9665

## IMPLEMENTATION

Before implementing the final permanent system on a vero board, the circuit diagram was first run and simulated on proteus V8 application software to ensure the circuit connections as well as the program written ware free of error. Temporary connection on bread board was then carried out, again the system was tested for the second time and it worked perfectly as anticipated, this was to ensure the workability of the components used. Finally the permanent system as shown in figure 15 below was implemented.

**Fig,10. Smart home implementation**

## RESULT

Theproposed plan of this paper leads to its real implementation and all the goals required of the smart home was observed and tested. Excellent communication between our smart phone android application and Arduino UNO was obtained first, the accessories were then fully controlled independently and simultaneously by sending the right numerical command also the LCD displayed the real time weather status information on the LCD by sending the appropriate command. Finally the security system was tested, the touch sensor was touched and buzzer alarm sound was heard as well SMS was received.

The system is very important for home residence, economic friendly and easily implemented.

## CONCLUSION

Arduino based smart home wasdesigned,implemented and tested. The system comprises of Arduino uno board, Bluetooth module, temperature and humidity sensor, touch sensor, buzzer, GSM module, Bluetooth terminal and two outlets for appliances. It is also cost effective and user friendly that enables monitoring and control of four (4) devices including sensors, automatic security notification and real time weather status display.

## FUTURE WORKS

The proposed system was only able to control few appliances due to limited Arduino input/output pins and it used short range Bluetooth technology which limits user's control to within local area network of the Bluetooth module. Therefore, further research should be based on advance controllers, with multiple input/output pins to be able to control many home appliances and to be interfaced with many sensors in order to optimize the system capability and utility. Similarly, internet enabled communication module such as NodeMCU module should be use to provide remote control to user over the home appliance from any location.

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