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Wireless Controlled Smart Home System

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Abstract *in recent years popularity of smart Home has been increasing due to low price and simplicity through tablet and Smartphone connectivity. It is an automation of house or home activity. Raspberry Pi3 is a small computer with digital input output capability and it was introduced in 2016; input/output ability besides the availability of all computer features make this system very suitable to be central unit can for smart home. Smart Home may contain centralize controller which control heating, lightning, ventilation in the home, HAVC(Heating, Ventilation and air conditioning),Safety locks of gates, doors and other system to provide improve comfort, better energy efficiency and security. The aim of this Paper is to develop a smart home application using RPi3, wemose-d1 and GSM. Programming has been developed in C++ in wemose-d1 and Python environment for RPi3 operation. The MQTT (Message Queuing Telemetry Transport protocol) technologic used to connect between raspberry pi3 and nodes.*

Index Terms— RPi3, GSM SIM900A, ESP8266, Smart home, IOT.

I. INTRODUCTION

Smart home represents technology and solutions utilized to automate, manage, and control devices located within residential dwellings and small businesses by means of various wireless networks and automation methods. Remote control has evolved a long way since the devices first used to remotely control various consumer electronics and appliances such as Computer, air conditioners, and televisions to support more integrated and comprehensive control. In this project, a system capable of controlling home appliances and sending notices using SMS has been developed. Some of the smart home systems developed earlier includes a PIC16F887 IC integrated with GSM module enabling SMS based automation [1]. However, unlike this project, it did not use any Wi-Fi network in it and involved extra task of writing message. In [2], Elkamouchi also gave a prototype of home automation and used actuators and sensors for the home appliances to get them connected to microcontroller. Another home automation was built in [3], where Xbee was used for communication instead of GSM. In 2011, a wireless remote power controller was built in [4], which could control power consumption in ahome through TC35 module. Han in [5], built a smart home energy management system using IEEE 802.15.4 and Zigbee module for communication. A computerized system was developed in [6], where a GSM was interfaced with a desktop computer. Home appliances had wired connection with desktop and users were connected through Wi-Fi. Doors and Windows were monitored in [7] using PIC18F452 with security that required ID for entering through the door. The work of A. Alheraish [8] proposes a smart home system using SMS. The proposed system detects illegal intrusions at house and allows legitimate users to change the passkey for the door and control lights in the home. The illegal intrusion into the home is identified by monitoring the state of the home door, which is done using Light Emitting Diode (LED) and infrared sensors. The passkey to the door can be any 4 digits, which can be set either by using the keypad or by using SMS from a registered user's mobile number. A user can control the lights in their home remotely using SMS from their registered mobile number; by turning the lights on in different rooms at random intervals of time, one can give the impression that the home is occupied, even when it is not. The work of M.S.H Khiyal et al. [9] proposes an SMS-based home security. In their work, homeowners can control their home using SMS messages from a preset registered mobile number. If the SMS is not from a legitimate mobile number, the system ignores the message. In the case of an intrusion, the appliance control subsystem and security subsystem in the proposed system informs the owner through SMS. The work of U. Saeed et al. [10] also proposes an SMS-based home automation system. The system has a Java application running on the phone. Legitimate users can log into the application using their username and password, and can select the building/floor/room/device that they wish to remotely control along with an appropriate action from the list of available user actions. The Java application will compose the appropriate SMS message and send it to the home's GSM modem. The GSM modem will receive the SMS message, decode it, and pass it to the home network to perform the action specified. The researchers use a 4-digit passkey and facial recognition for security. In the work of A.R Delgado et al. [11], GPRS communication is used as a backup for an Internet-based home automation system. This adds to the fault tolerance of the system. The homeowner will be able to get alerts on their mobile phone about the unusual state changes in the sensors. The user could then react either by messaging or using a web interface. In any case, there will be two possible ways to access the home, so if one fails the user can rely on the other.

There are three ways to describe the proposed smart home centrally controlled system, Individual control devices and Distributed control systems. In this paper, the discussed techniques are;

1-python based smart Home System.

2- Smart Home with GSM.

3- Smart Home based on SMS.

Table 1. Comparison of Different Smart home system

System	Cost	Range
Bluetooth	Low	10 m
ZigBee	High	10-100 m
IR wireless	Low	<10 m
Wi-Fi	High	50-100 m
GSM	Low	Very large

II. THE SMART HOME

In this work, a smart system is designed and implemented for home managements. There are some features that are available in GSM communication which make it suitable for the proposed system like small size, low cost, emergency alarm generated, user friendly interface, very short response time and the main feature is the wide area coverage. So the user can interact with the system even from anywhere. Our design use MQTT (Message Queuing Telemetry Transport) Publish/Subscribe Protocol and python to give client the capability to integrate many open source tools with open-source devices and site mobile optimization. The MQTT publish/subscribe protocol between machines that have the capability of connecting to a network (e.g., Raspberry pi3 B and ESP8266 Wemos-D1).

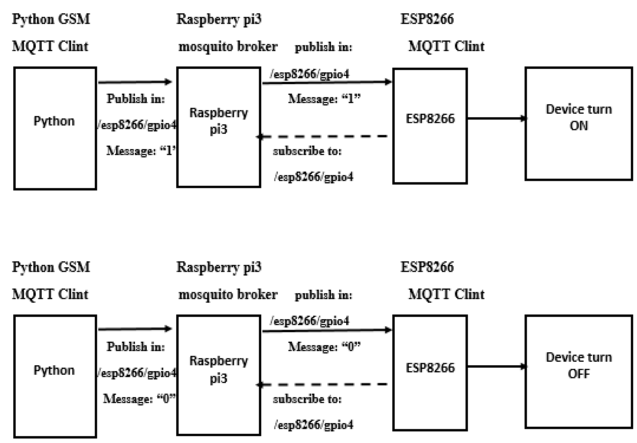


Fig.1. show overview of the system

III. MESSAGE QUEUING TELEMETRY TRANSPORT

Message Queuing Telemetry Transport (MQTT) is a light weight transport protocol that efficiently uses the network bandwidth with a 2 byte fixed header. MQTT works on TCP and assures the delivery of messages from node to the server. Being a message oriented information exchange protocol, MQTT is ideally suited for the IoT nodes which have limited capabilities and resources. MQTT was initially developed by IBM in 1999 and recently has been recognized as standard by Organization for the Advancement of Structured Information Standards (OASIS). MQTT is a publish/subscribe based protocol. Any MQTT connection typically involves two kinds of agents: MQTT clients and MQTT public broker or MQTT server. Data that is being transported by MQTT is referred to as application message. Any device or program that is connected to the network and exchanges application messages through MQTT is called as an MQTT client. MQTT client can be either publisher or subscriber. A publisher publishes application messages and subscriber requests for the application messages. MQTT server is a device or program that interconnects the MQTT clients. It accepts and transmits the application messages among multiple clients connected to it. Devices such as sensors, mobiles etc. are considered as MQTT client. When an MQTT client has certain information to broadcast, it publishes the data to the MQTT broker. MQTT broker is responsible for data collection and organization. The application messages that are published by MQTT client is forwarded to other MQTT clients that subscribe to it. MQTT is designed to simplify the implementation on client by concentrating all the complexities at the broker. Publisher and subscriber are isolated, meaning they need not have to know the existence or application of other [17].

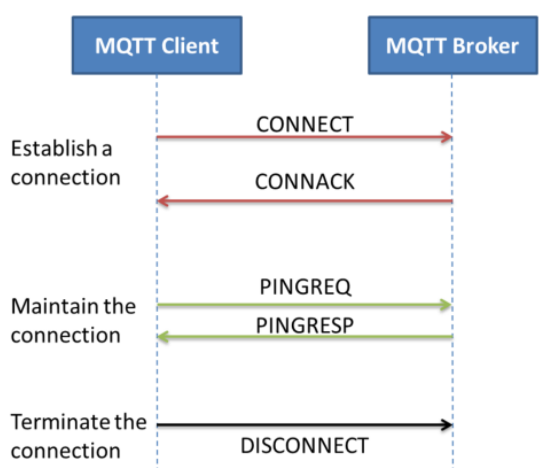


Fig. 1. Establishing, maintaining and terminating MQTT connection

IV. SYSTEM DESCRIPTION

In this system, real-time monitoring parameters for humidity, temperature, water tank level, the intensity of the garden light and motion detection in the home. To implement this system, the field must be divided to numbers of zones. Each zone contains at least one node; these nodes are the sensor units (SUs) and must communicate with a central unit that called a base station unit (BSU). The system is planned to be implemented using distributed wireless sensor network (WSN) that utilizes Wi-Fi technology. According to this wireless technology, the distance between the BSU and the SUs in practical experiments is about 200m with consideration that the obstacles availability (as building) and 250m without obstacles. The sensors used in this system are LM35 sensors, temperature and humidity sensor (DHT-22), ultrasonic sensor and LDR sensor.

The raspberry pi3 board which will be the brain for the system, the actuator that is a lights and other appliance for implementing the wireless technology in this system. The system consists from many SUs and BSU as shown in Fig. 2. The BSU (raspberry pi3) is the main control unit for the whole system and the nodes respond to the base station what it need and execute its instructions. The area that can be covered by a SUs is determined by many factors.

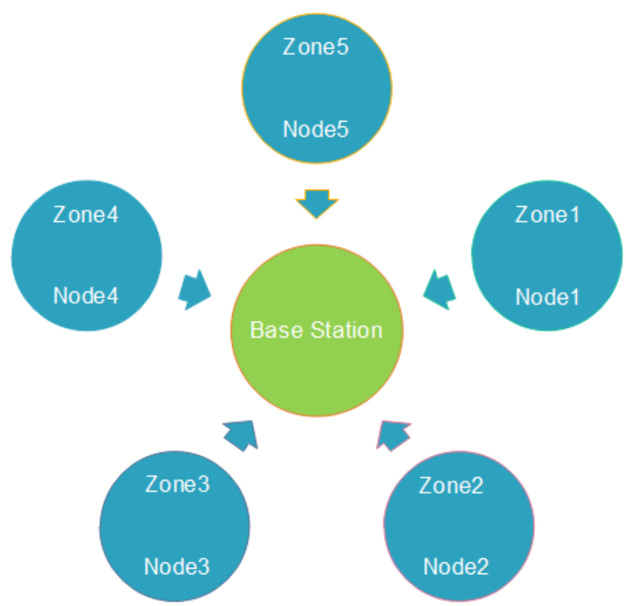


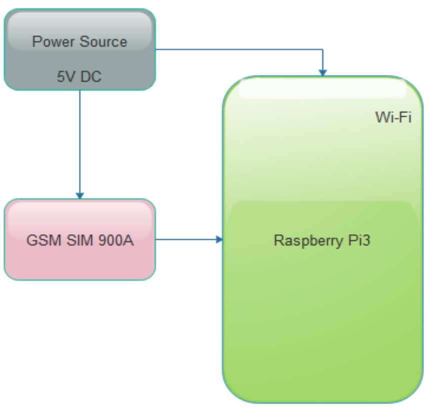
Fig. 2 Proposed system diagram.

V. HARDWARE DESCRIPTION

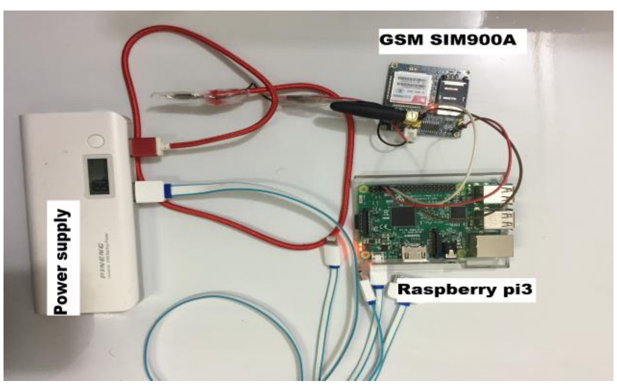
The system hardware consists of a single BSU and numerous SUs. The details are as follows:

A. The Base Station Unit (BSU)

The base station plays a key role in the designed system. The hardware of base station consists of a Raspberry pi3 board, GSM SIM 900A, which is used for monitoring the required parameters and Wi-Fi used to communicate wirelessly between the SUs and BSU. Fig. 3(a), shows the BSU schematic diagram and Fig. 3(b), shows the internal construction of a prototype BSU that used for implementing the system.



(a)



(b)

Fig. 3 Base station unit. (a) Schematic diagram. (b) Internal construction.

1) The Raspberry pi3 Board raspberry pi3 turn as a main controller of our system, it is a small size and flexible platform for experimentation and is an open source minicomputer. The raspberry pi3 runs on raspbian OS and can be programmed using different programming languages such as python, One can install numerous different type of software's for different purposes. We have used model B+ of raspberry pi3 which uses system on chip (Soc) BCM2835. It comes with 1GB of RAM memory and does not have storage drive but uses SD card for booting and long term process, external storage devices can be added through the USB port. Also it includes an ARM11microcontroller having clock frequency of 700 MHz [12] [13]. Fig. 4 shows the raspberry pi3 model B board.

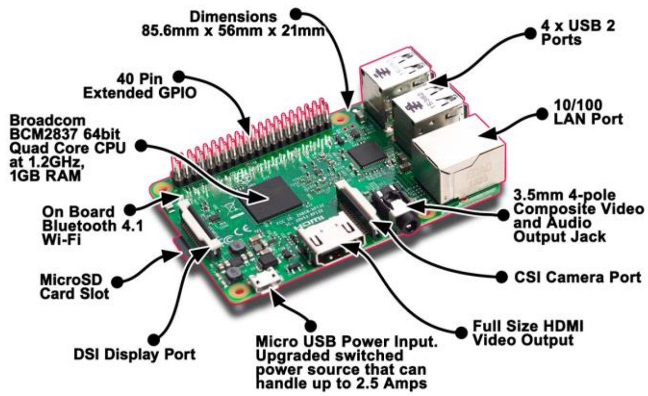


Fig. 4 Raspberry Pi3 Board.

1) GSM SIM 900A Interfacing

The Global System for Mobile (GSM) communication is used to alarming the user by receiving and sending the messages, which is controlled by AT command. The Raspberry Pi3 and GSM were connected via UART. The connection was a serial communication as Full Duplex since there was two ways that data could be transmitted via pin TX and RX. A direct connection between the Raspberry Pi3 and GSM was not prohibited, because of its electrical potential differences, which is 3.3 volts for the Raspberry Pi3 and 5 or 3.3 volts for the GSM SIM 900a. The dimension is reliable and small wireless module. It communicates with raspberry pi3 using RS232 serial interface. Double frequency band operates on 900 MHz to 1800MHz. The security mechanism of GSM is implemented in three different elements. The Subscriber Identity Module (SIM), GSM handset and GSM network The SIM contains the IMSI and The individual subscriber authentication key, the code key generating algorithm, the authentication algorithm, as well as a PIN. The GSM SIM 900a handset contains the code algorithm. The GSM SIM 900a network contains encryption algorithm. In order for the authentication and security mechanism to function, all three elements are required for the system. Also system controls the lights, TV, door, window using GSM by sending message to the raspberry pi3. It is very possible that GSM will remain the only communication network technology to be adopted by each and every country of the world. The interfacing of the GSM to the Raspberry pi3 board shown in Fig. 5.

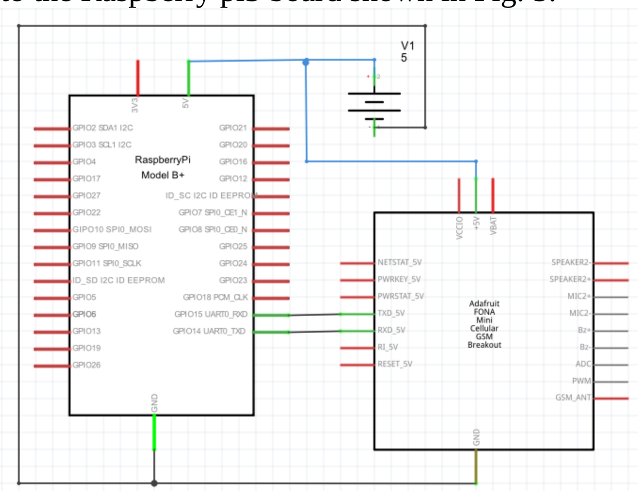


Fig. 5 Interfacing GSM with Raspberry pi board.

3) The Wi-Fi Module

In this work, the Wi-Fi modules are used for implementing local wireless communication between BSU and SUs. Wi-Fi is built in the Raspberry pi3 board as shown in Fig.4.

B. The Sensor Units (SUs)

The SUs are the microcontroller system that responsible for the measurements of temperature, humidity, gas, flam, water level and light intensity depending on the sensors content in the nodes. Each node is implemented using wemose-d1 microcontroller board, which is an Arduino uno like with Wi-Fi.

A). wemose-d1

The wemose-d1 is a low cost Wi-Fi module which is a great platform for any smart home project. Comparing the wemose-d1 with other Wi-Fi modules in the market, this is definitely a great option for most "Internet of Things" projects. It's easy to see why it's so popular: it only costs a few dollars and can be integrated in advanced projects. It can be used to create an MQTT communication, control outputs, read inputs and interrupts. The wemose-d1 comes with Arduino uno GPIOs compatible. Fig. 7 shows an overview of wemose-d1 [6].

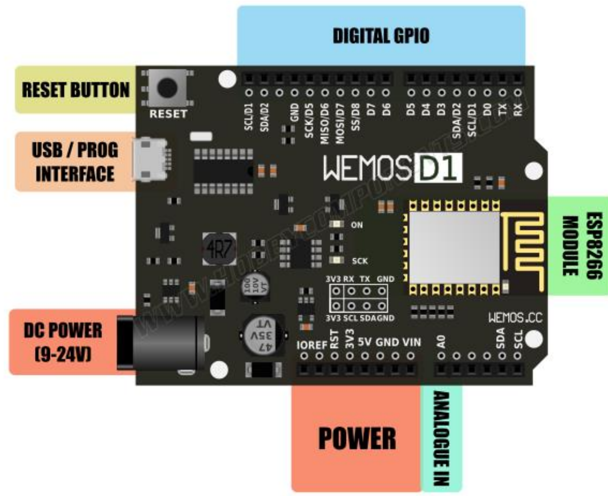


Fig. 6 Wemose-D1 Board.

1) The First Sensor Unit for the Bedroom

The First Sensor Unit are the microcontroller system that responsible for the measurements of temperature and control (turn on/off) of light, Air condition and control (open/close) door and window. The LM35 sensor for sensing the temperature. Fig. 7, shows the schematic diagram of a system node, Fig. 8, shows the internal construction of a prototype node that used for implementing the system and Fig. 9 shows the interfacing of LM35 sensor, light, air condition, door and window with the wemose-d1 board.

A) Temperature Sensor (LM35) Interfacing

The LM35 series are precision integrated circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature.

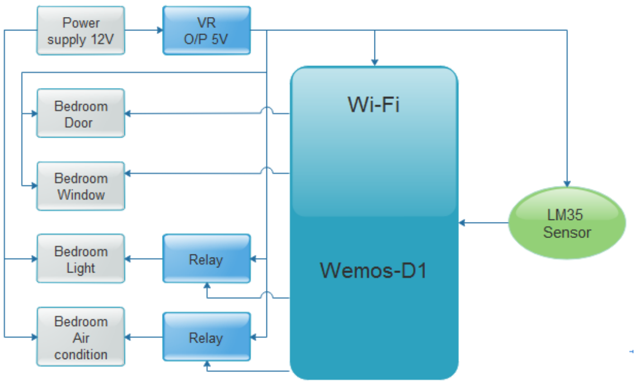


Fig. 7 The system first node schematic diagram.

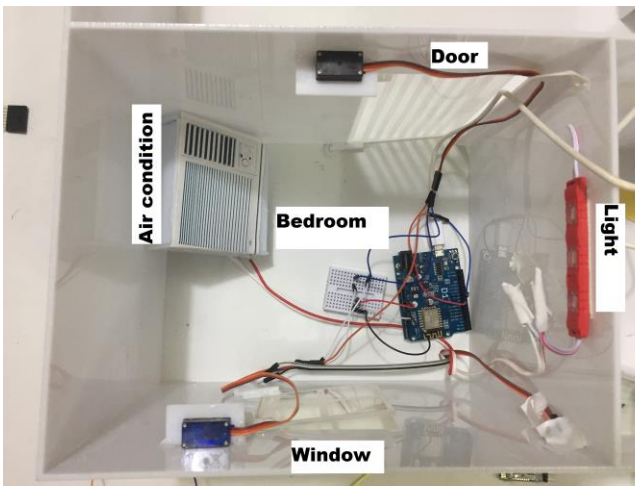


Fig. 8 The internal construction of the system Prototype first node.

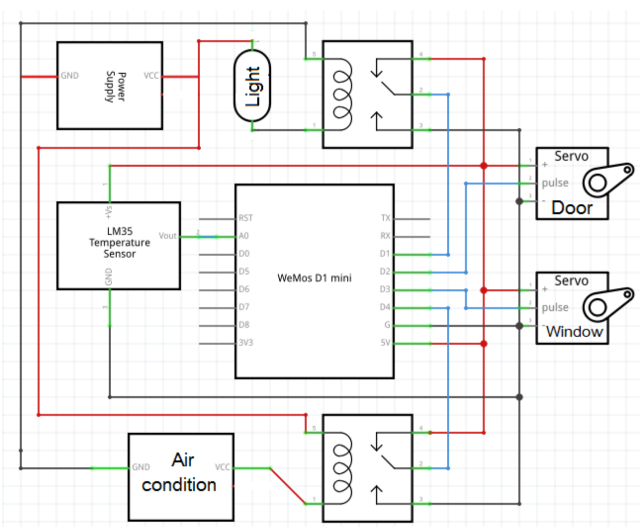


Fig.9. Interfacing schematic bedroom diagram.

2) The Second Sensor Unit for hall, garden and water tank.

The Second Sensor Unit are the microcontroller system that responsible for the measurements of Water level of the tank, the intensity of the garden light. Control (turn on/off) of garden light, water pump, hall light. Control (open/close) hall door. The ultrasonic sensor for sensing the Water level of the tank. The LDR sensor for sensing intensity of the garden light. Fig. 10, shows the schematic diagram of a system node, Fig. 11, shows the internal construction of a prototype node that used for implementing the system and Fig. 12, shows the interfacing of water level sensor, LDR sensor, hall light, garden light and hall door with the wemose-d1 board.

A) water level *Sensor Interfacing*

First, let us talk about some theory behind ultrasonic method of liquid level measuring. The idea behind all contactless methods is to measure distance between transceiver and liquid. As said before, we transmit short ultrasonic pulse, then measure travel time of that pulse from transceiver to fluid and back to transceiver. Ultrasonic pulse will bounce from fluid level because change of density of ultrasonic pulse travel medium (ultrasonic pulse first travel through air and bounce of liquid with higher density than air). Because water has higher density, majority of pulse will bounce off.

B) Light Dependent Resistor (LDR) Sensor Interfacing

A LDR is a light-controlled variable resistor. The resistance of a photoresistor decreases with increasing incident light intensity; in other words, it exhibits photoconductivity. A photoresistor can be applied in light-sensitive detector circuits, and light- and dark-activated switching circuits.

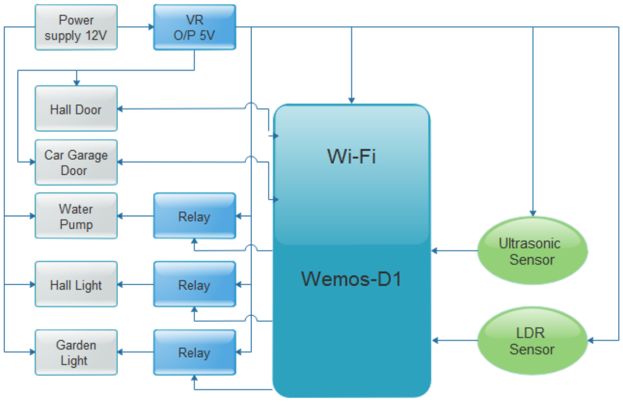
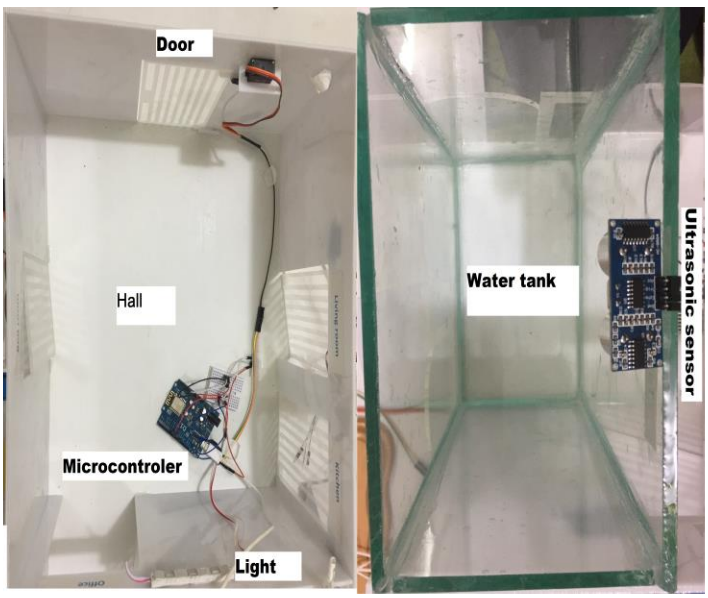
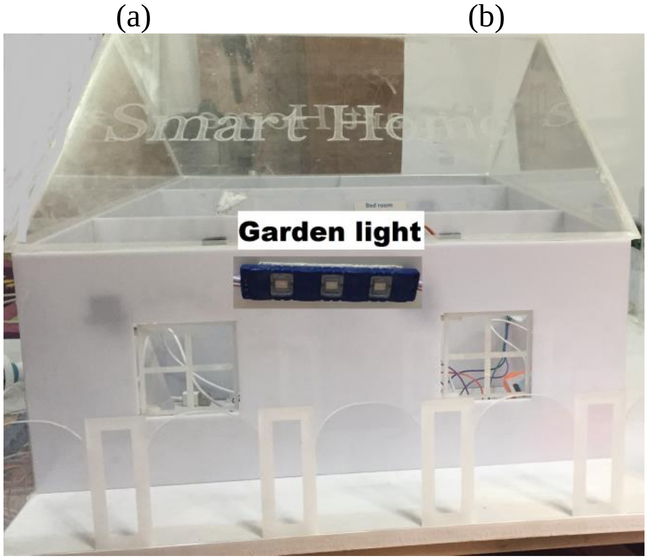


Fig.10 The system second node schematic diagram.



(a) (b)



(c)

Fig. 11. The Second Sensor Unit. (a) Hall Internal construction. (b) water Tank Internal construction. (c) Garden Internal construction.

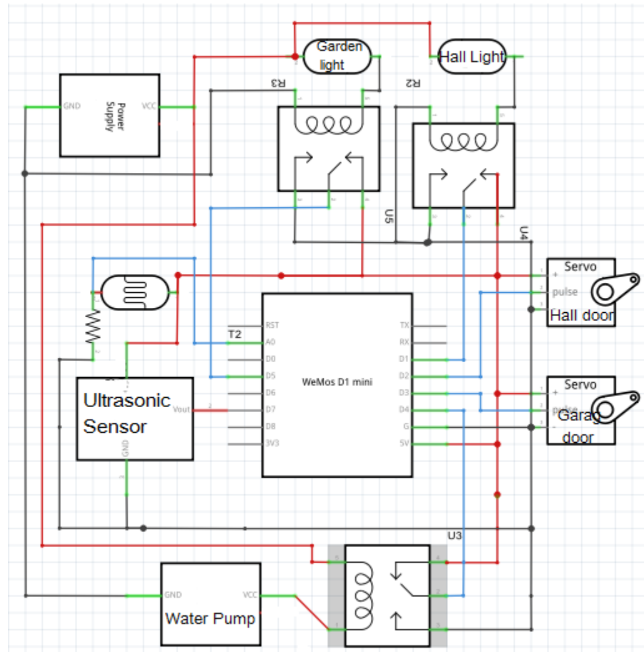


Fig.12. Interfacing schematic hall, garden and car garage diagram.

3) The Third Sensor Unit for living room.

The Third Sensor Unit are the microcontroller system that responsible for the measurements of temperature and control (turn on/off) of light, TV and control (open/close) door and window. The DHT sensor for sensing the temperature and humidity. Fig. 13, shows the schematic diagram of a system node, Fig. 14, shows the internal construction of a prototype node that used for implementing the system and Fig. 15, shows the interfacing of DHT11 sensor, light, air condition, door and window with the wemose-d1 board.

A) Humidity and Temperature Sensor Interfacing

DHT-22 is a combined temperature and humidity sensor used for sensing surrounding humidity and temperature. It’s a capacitive humidity sensing. Application of a dedicated digital modules collection technology and the temperature and humidity sensing technology to ensure that the product has high reliability and excellent long-term stability [14]. Fig. 15, shows the interfacing of DHT-22 sensor with the ESP8266 board.

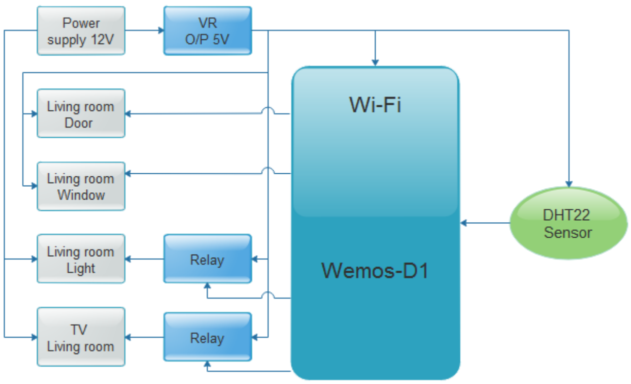


Fig. 13 The system third node schematic diagram.

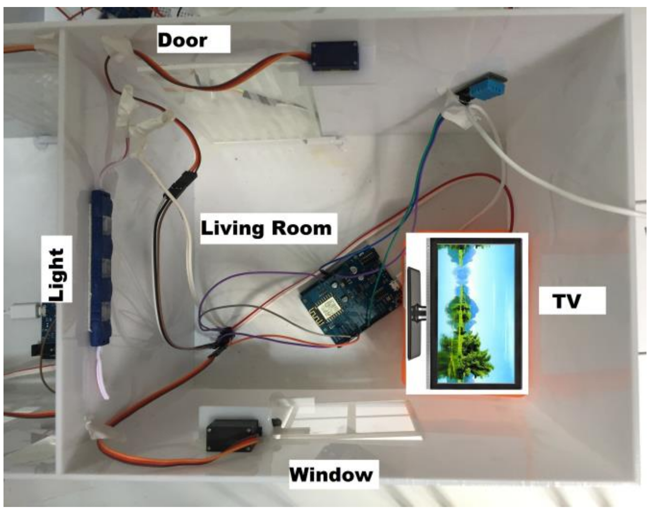


Fig. 14 The internal construction of the system Prototype third node.

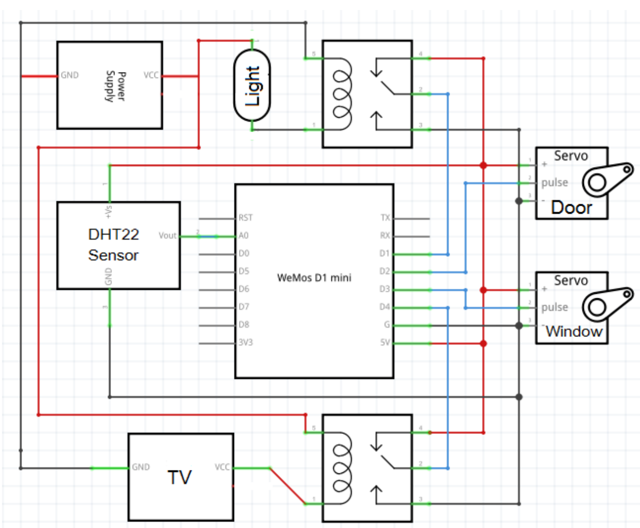


Fig.15. Interfacing schematic living room diagram.

4) The forth Sensor Unit for kitchen.

The forth Sensor Unit are the system motes that responsible for the measurements of gas and flam. Control (turn on/off) of light, refrigerator. Control (open/close) kitchen doors and windows. Fig. 16, shows the schematic diagram of a system node, Fig. 17, shows the internal construction of a prototype node that used for implementing the system and Fig. 18, shows the interfacing of GAS sensor, Flam sensor, light, air condition, door and window with the wemose-d1 board.

E. Gas Sensor module

The module works as a Air Quality Detection Gas Sensor, this is sensitive to gas dangerous to human, applied to measure NOx, NH3, Benzene, Alchohol, CO2, and CO [15].

F. Flam sensor

A flame detector is a sensor designed to detect and respond to the presence of a fire or flam [16].

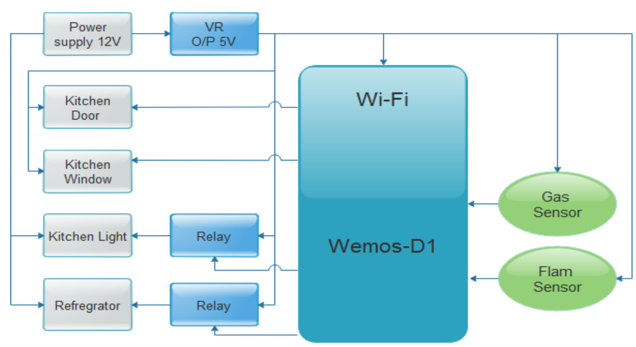


Fig. 16 The system forth node schematic diagram.

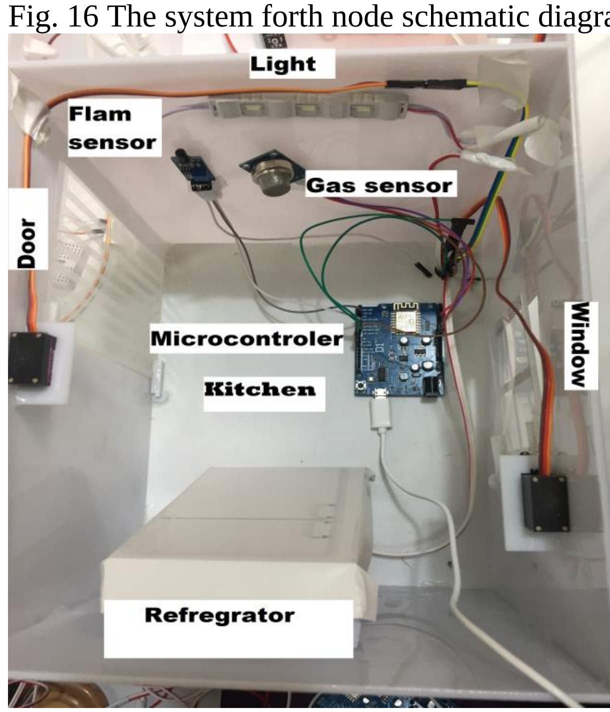


Fig. 17 The internal construction of the system Prototype fourth node.

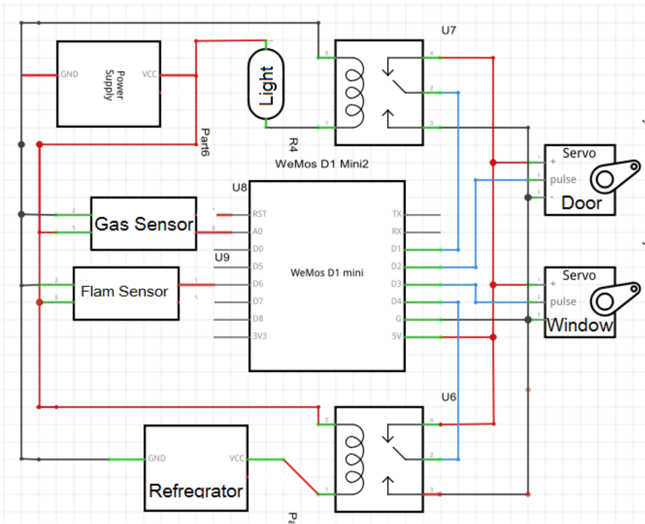


Fig.18. Interfacing schematic kitchen diagram.

5) The fifth Sensor Unit for office.

The fifth Sensor Unit is the microcontroller system that responsible for the measurements of office motion. Control (turn on/off) of light, computer. Control (open/close) office doors. Fig. 19, shows the schematic diagram of a system node, Fig. 20, shows the internal construction of a prototype node that used for implementing the system and Fig. 21, shows the interfacing of GAS sensor, flame sensor, light, air condition, door and window with the wemose-d1 board.

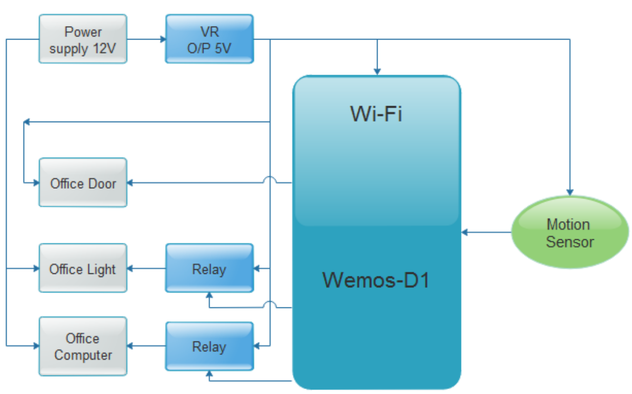


Fig. 19 The system fifth node schematic diagram.

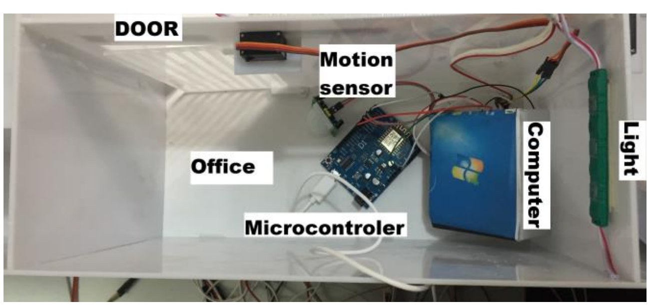


Fig. 20 The internal construction of the system Prototype fifth node.

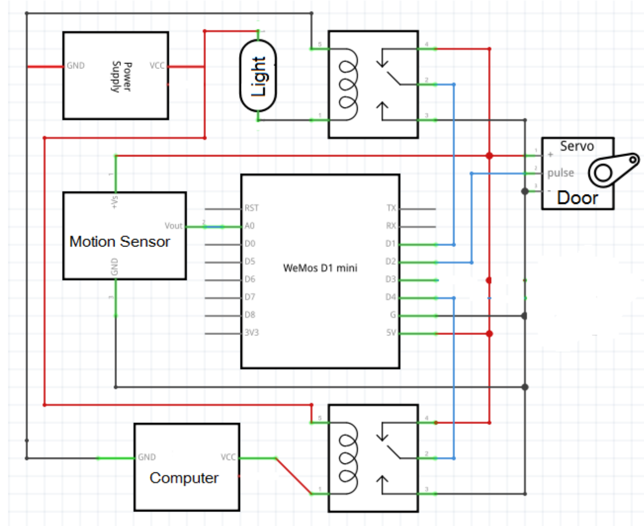


Fig.21. Interfacing schematic office diagram.

VI. SOFTWARE DESCRIPTION

The software part contains the programming of Wi-Fi network, the system protocol using the wemose-d1 Integrated Development Environment (IDE) and raspberry pi3 with python.

A. Wi-Fi Network

In this work, a simple point-to-multipoint topology is used. We achieved that by using python and Arduino IDE software that used for Wemose-d1 and raspberry pi3 module configuration for building the wireless Wi-Fi network. In this simple network, all nodes are managed by a central node which called a coordinator or master or base station. Fig. 22, shows part of the base station configuration by using python software and Fig. 23, shows part of the node configuration.

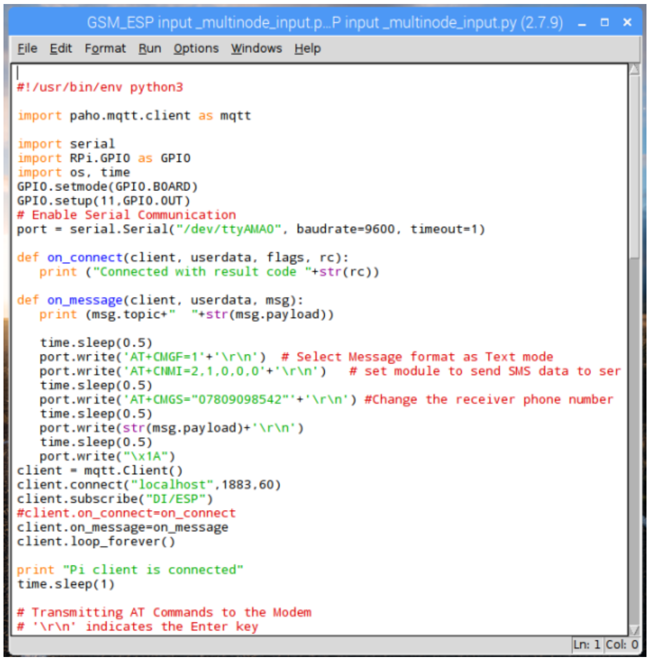


Fig. 22 The base station configuration by using Python software.

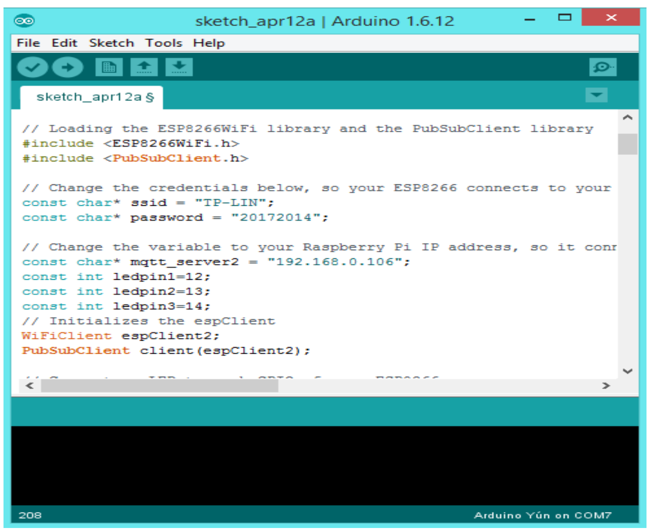


Fig. 23 The node configuration by using Wi-Fi software.

B. The System Protocol

We can describe the system protocol as following, after power up, the base station Unit (BSU) sends addresses data to all SUs for getting the data. The SU responds according to its address from the BSU, if the SU address matches the BSU, it can evaluate the sensors measurement, then sends these data with its address to the BSU. The BSU checks the data according to the determined threshold values and sends the control signals to the required node to the turn on or off the devices. These threshold values should be chosen according to the plants water requirements with the environmental parameters. The data and the node state will be displayed by the raspberry pi screen in the BSU. Fig. 24, shows flowchart of the BSU and Fig. 25, Fig. 26, Fig. 27, Fig. 28, Fig. 29 shows flow chart of the SUs.

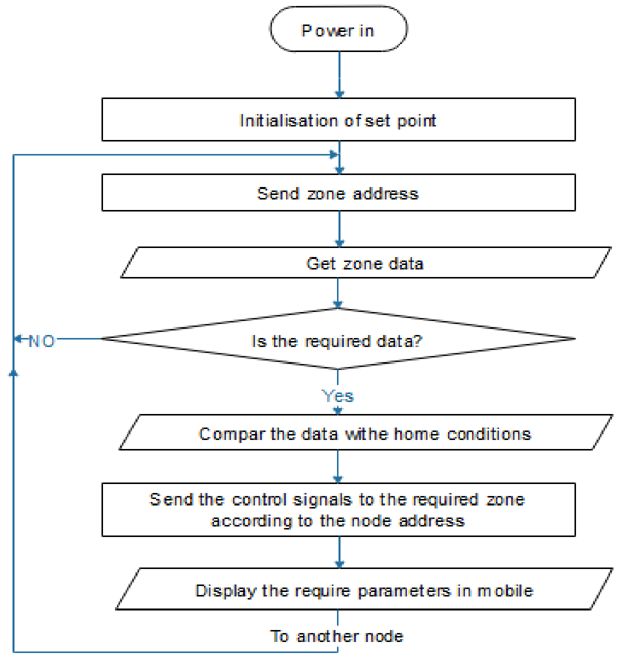


Fig. 24 BSU flowchart.

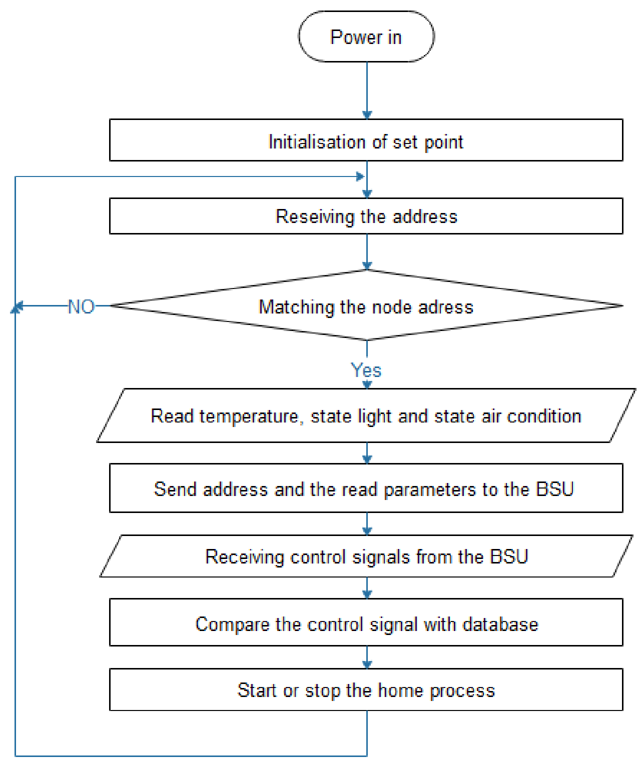


Fig. 25 first SU flowchart.

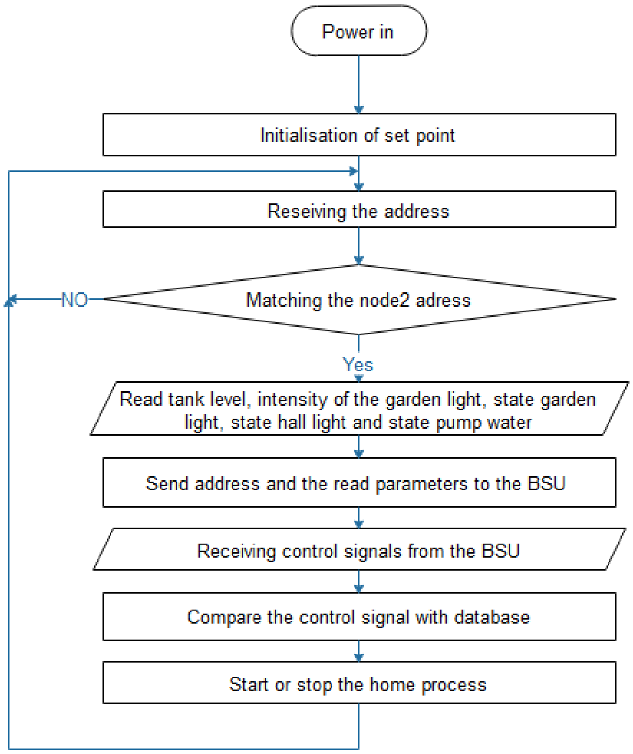


Fig. 26 second SU flowchart.

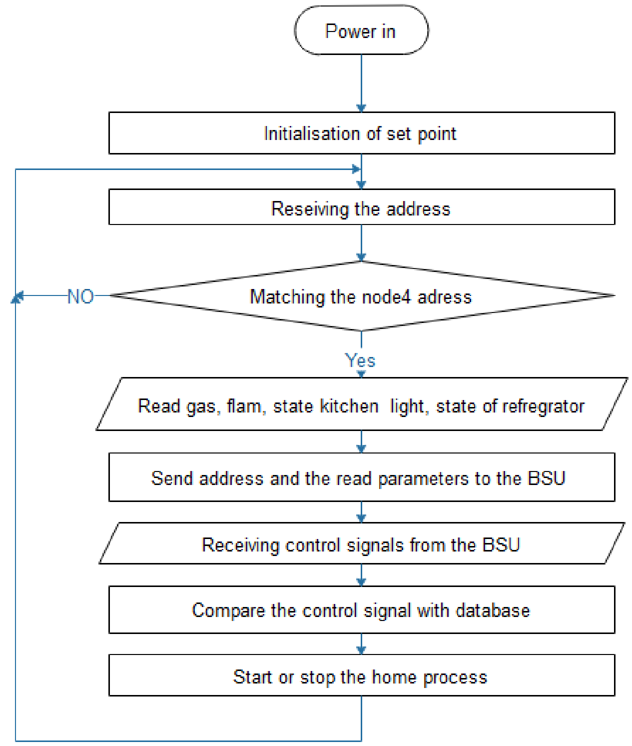


Fig. 28 forth SU flowchart.

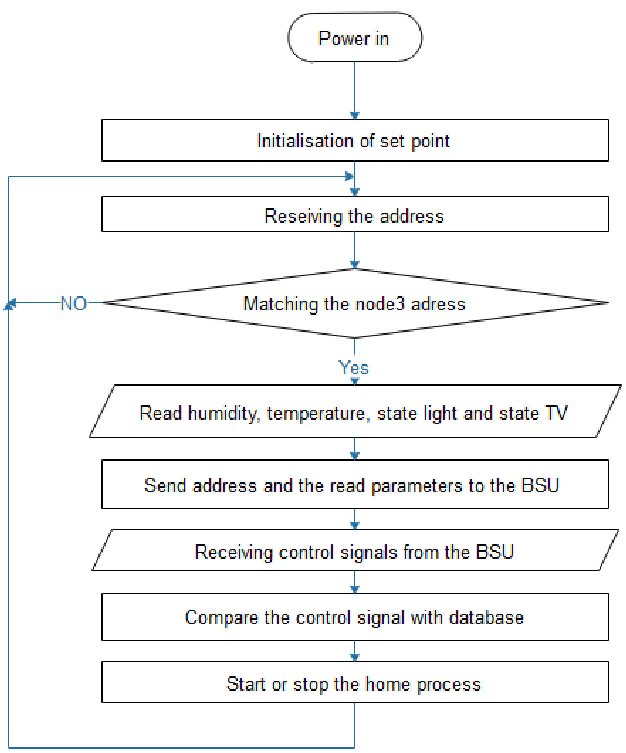


Fig. 27 third SU flowchart.

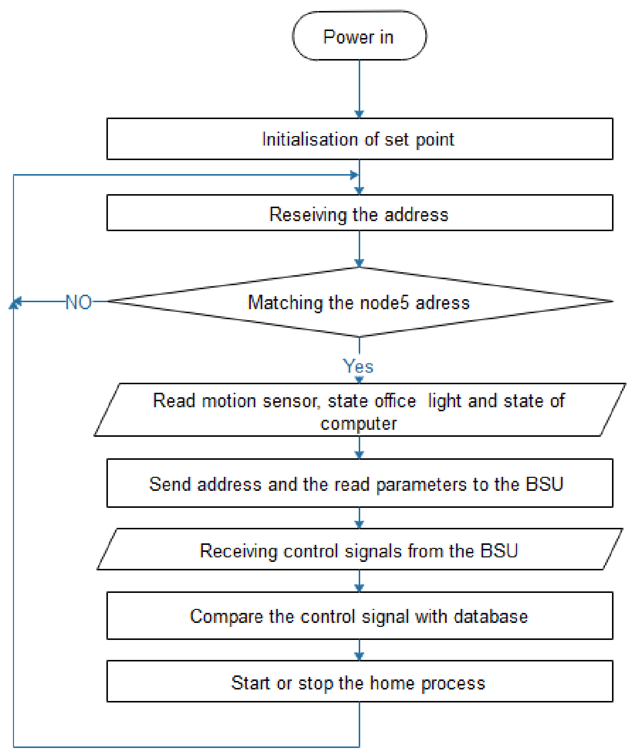


Fig. 29 fifth SU flowchart.

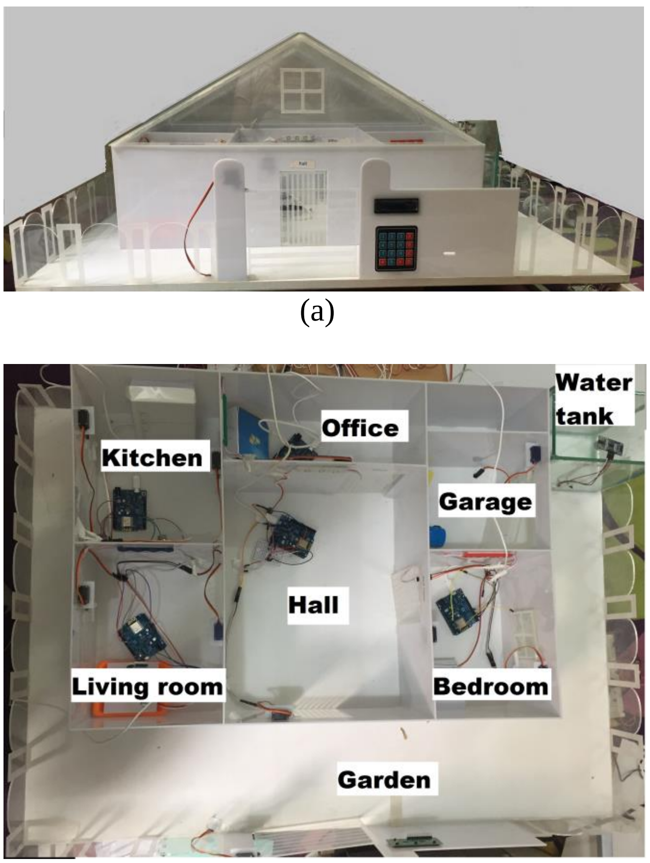
C. wemose-d1 IDE

The wemose-d1 board which contents an ESP8266 microcontroller is programmed using

IDE software that utilizes C language. The screenshot of the wemose-d1 software can be seen in Fig. 23.

VII. RESULTS AND DISCUSSION

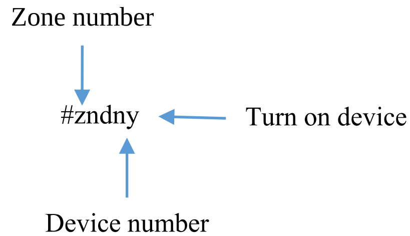
The proposed system was applied on a prototype house and in actual field for measuring required data using LM35 sensor, temperature and humidity sensor, motion sensor, water level sensor, intensity light sensor, flame sensor and gas sensor. Control lights, doors, windows and other device by SMS sent by owner.



(a) (b)

Fig. 30 typical home. (a) and (b).

Devices control (switch on and off) is performed by sending a code as SMS from a mobile code 's formula is shown below:-



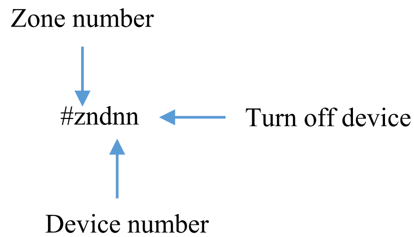


Table 2.1 shows the different cases of zone1 working

Commands from user mobile phone	Actions carried out by the first microcontroller	message to user mobile phone
#z1d1y	Bedroom light turn ON	Light of bedroom turn ON
#z1d1n	Bedroom light turn OFF	Light of bedroom OFF
#z1d2y	Bedroom air condition turn ON	Air condition of Bedroom turn ON
#z1d2n	Bedroom air condition turn OFF	Air condition of Bedroom turn OFF
#z1d3y	Open the bedroom door	Door of bedroom open
#z1d3n	Close the bedroom door	Door of bedroom close
#z1d4y	Open the bedroom window	window of bedroom open
#z1d4n	Close the bedroom window	window of bedroom close

Table 2.2: The work of the first zone sensor

Sensor sensitivity	message to user mobile phone
LM35	Value of temperature

Table 3.1 shows the different cases of zone2 working

Commands from user mobile phone	Actions carried out by the second microcontroller	message to user mobile phone
#z2d1y	Hall light turn ON	Light of hall turn ON
#z2d1n	Hall light turn OFF	Light of hall turn OFF
#z2d2y	Garden light turn ON	Light of garden turn ON
#z2d2n	Garden light turn OFF	Light of garden turn OFF

#z2d3y	Open the hall door	Door of hall open
#z2d3n	Close the hall door	Door of hall close
#z2d4y	Open the car garage door	Door of car garage open
#z2d4n	Close the car garage door	Door of car garage close

Table 3.2: The work of the second zone sensor

Sensor sensitivity	message to user mobile phone
LDR	Value of light intensity
ULTRASONIC	Value of water level

Table 4.1 shows the different cases of zone3 working

Commands from user mobile phone	Actions carried out by the third microcontroller	message to user mobile phone
#z3d1y	Living room light turn ON	Light of living room turn ON
#z3d1n	Living room light turn OFF	Light of living room turn OFF
#z3d2y	Living room TV turn ON	TV of living room turn ON
#z3d2n	Living room TV OFF	TV of living room turn OFF
#z3d3y	Open the Living room door	Door of living room open
#z3d3n	Close the Living room door	Door of living room close
#z3d4y	Open the Living room window	window of living room open
#z3d4n	Close the Living room window	window of living room close

Table 4.2: The work of the third zone sensor

Sensor sensitivity	message to user mobile phone
DHT22	Value of temperature and humidity

Table 5.1 shows the different cases of zone4 working

Commands from user mobile phone	Actions carried out by the forth microcontroller	message to user mobile phone
#z4d1y	Kitchen light turn ON	light of kitchen turn ON
#z4d1n	Kitchen light turn OFF	light of kitchen turn OFF
#z4d2y	Kitchen refrigerator turn ON	Refrigerator of kitchen turn ON
#z4d2n	Kitchen refrigerator turn OFF	Refrigerator of kitchen turn OFF
#z4d3y	Open the kitchen door	Door of kitchen open
#z4d3n	Close the kitchen door	Door of kitchen close
#z4d4y	Open the kitchen door	window of kitchen open
#z4d4n	Close the kitchen door	window of kitchen close

Table 5.2: The work of the fourth zone sensors

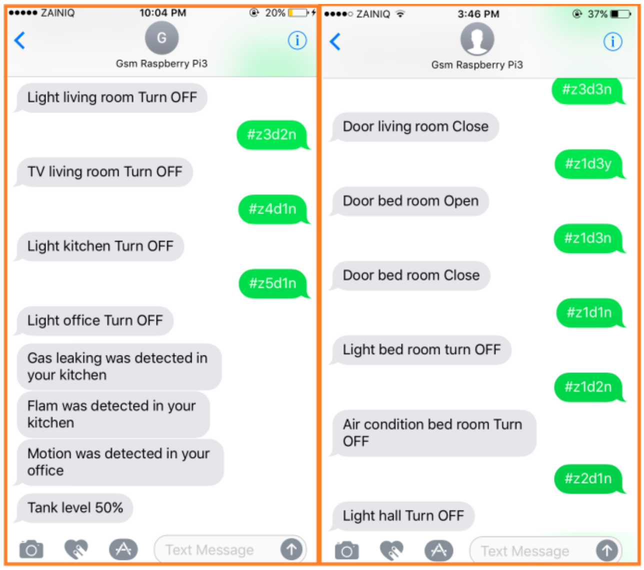
Sensor sensitivity	message to user mobile phone
GAS great threshold	Gas leaking was detected in your kitchen
FLAM great threshold	Flam was detected in your kitchen
Gas less from threshold	No gas
Flam less from threshold	No flam

Table 6.1 shows the different cases of zone5 working

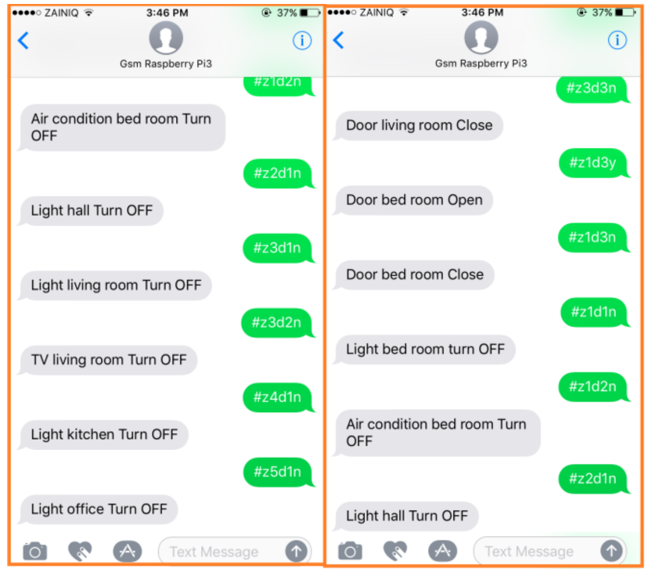
Commands from user mobile phone	Actions carried out by the fifth microcontroller	message to user mobile phone
#z5d1y	Office light turn ON	light of office turn ON
#z5d1n	Office light turn OFF	light of office turn OFF
#z5d2y	Office computer turn ON	Computer of office turn ON
#z5d2n	Office computer turn OFF	Computer of office turn OFF
#z5d3y	Open the office door	Door of office open
#z5d3n	Close the office door	Door of office close

Table 6.2: The work of the fifth zone sensor

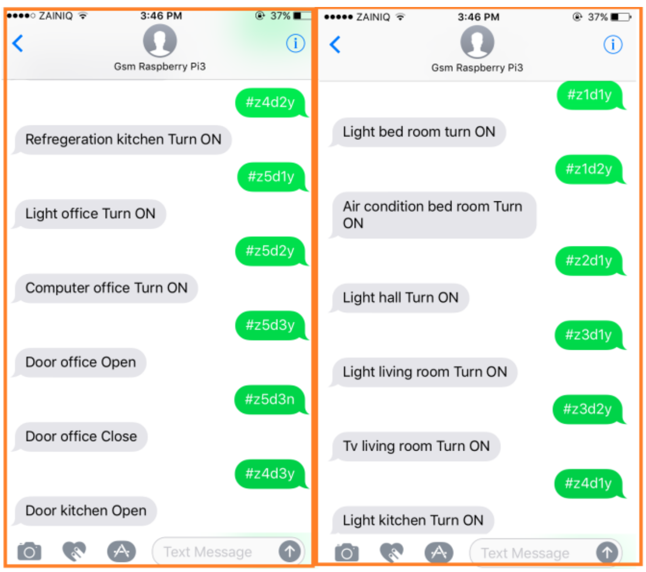
Sensor sensitivity	message to user mobile phone
Body in front of motion sensor	Motion was detected in your office
No Body in front of motion sensor	No motion



(a)



(c)



(b)

Fig. 31 displays the required system parameters.

VIII. CONCLUSION

Home automation is a statement used to define a house that has highly feature smart systems for humidity, temperature, security, lighting controlling doors, windows and appliances and many other functions. A wireless sensor network with ESP8266, Raspberry Pi3, and a number of open source software packages has a very attractive features including scalable, low cost, compact, easy to maintain, easy to deploy and easy to customize. This paper offering the design and implementation of a low cost and secure home security system for overall users. The security level is increased due to the usage of Raspberry pi3 which sends the SMS to the user, has in built capabilities and is easily connectible to external devices.

Implementation of the designed system on prototype house showed clearly the effectiveness, reliability and low cost of this system compared with the traditional available systems.

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