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Development of an Android Based Home Automation System

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ABSTRACT
As automation technology keeps advancing, the future of modern homes is continually changing from manual system into automatic ones that include remote control process. A Conventional means of accessing home electronic appliances is rigid and demands user presence to attend to different locations of such appliances before they can be used, this can be stressful for the elderly, the cripples, and provides limited ease of operation for everyone. The need for wireless communication function of the home appliances becomes very important in order to increase the flexibility of accessing them remotely by a user. Accessing and control of electronic devices and appliances used at home through a remote process is the main purpose for the development of a portable home automation system using app that is based on an android phone. ESP8266 microcontroller was interfaced to a servo motor that controls door movement and also to an AC bulb through a relay at the signal receiver end of the system. An MIT application inventor platform was used to build a mobile app on an android phone at the signal transmitter end of the system; this enables the transmission of on and off signals to the receiver end through Wi-Fi connection to access the connected loads (door and lamp). The hardware and software architecture of the developed home automation system was described in this paper. Implementation of a prototype of the designed system was carried out after which the system was tested on hardware as it yields expected results.

Keywords: *Home automation, internet of things, MIT application, node MCU microcontroller, relay*

1. INTRODUCTION

Reducing the participation of humans in the operation of home appliances have been the major objective of home automation. Once the involvement of humans is minimized in the manual control of this appliances, programmable systems are introduced to make flexible the use and control of the connected loads and appliances. Home automation systems can be applied for both high and low number of electronic devices connected to electrical power depending on the design of the system [1, 11]. Awareness of home automation systems has tremendously increased in the world today and is hopefully anticipated to increase in popularity in years to come in order to attract high marketing consumption. Distributed, centrally, and individual controlled device systems are the categories of operations in which home automation can function. Light controls, thermostat, temperature, and sensor positions are the most common home automation systems which are programmable and can be altered according to user preferences. The remote control and communication of individual appliances can be categorized as distributed and centrally controlled systems of home automation [2]. Distributed and central systems are differentiated with the means of control mechanism. Distributed systems do not have central control process while central controlled systems require the assistant of a mobile or computer networked systems in order to control all connected devices centrally.

The disadvantage of centrally controlled system is that once the controller breaks down, the system automatically fails. The cost of device installation, customized equipment, and the nature of components are major reasons for expensive commercial home automation systems. In order to limit the effect of this bottleneck, open-source platforms and internet of things (IoT) sensors may be applied in the design process to customize the home automation system towards the users demands [14]. This approach may also not be favorable due to internet protocol-based device cost and inability of the user to operate the open-source control procedure linking to their lack of experience in the field. Devices of this form do not possess any special Internet Protocol (IP) connector or internet of things circuit. Internet protocol based smart electronic devices like the Philips hue bulb and others cost much more than these appliances. The sensors working status and the state of electronic home appliances of the system can be altered by the user. Air conditioners, radio and tv sets, electric light, heaters, and ventilation systems are some of the appliances that can be manipulated by the system. Users can control and set appliance usage to an energy saving level from the information gathered through the online status of different appliances [3, 12]. An android smartphone application connected to a Bluetooth module provides the platform for control of the system. Many sophisticated electronic devices based on internet protocol are required in the installation of a home

automation system and are very expensive, making it out of reach to low-income homes. The procedure that provides the solution to this problem through the development of a low-cost home automation system is presented in this paper. Connections are made with relay circuits through Bluetooth device and android based smart phone to manipulate the appliances in the proposed system [4]. The appliances termed to be ordinary electrical appliances are those which are already present in today's market and most are built based of Arduino microcontroller [5]

2. RELATED WORK

The project developed in [6] utilized a hybridized wired and wireless approach of communication. A Bluetooth module, Cytron Blue Bee was used to activate the control unit in order to communicate with an android based phone through wireless means [13]. Relays were used to connect the home appliances to the control unit. The controller receives a signal from the android and the signal was processed by the control unit to suit the demands of controlling the appliances. The controller also sends a signal that can change the status of the appliance from ON to OFF and notifies the android phone to display thus. Java programming was used to develop the android application by applying Eclipse IDE with an android platform API8. The lowest version of android supported by the application is android 2.2. Difficulties in programming will be experienced when using high level language like Java to develop this system when compared with programming using Arduino. Strict measures need to be considered in coding process of a hybridized system in order to handle exceptions through modes of communication. The system developed worked but with less speed compared to that of Wi-Fi.

In the journal, wireless automation using ZigBee protocol, the design of a wireless home automation network using IEEE 802.15.4 protocols and ZigBee, and the evaluation of its application in sensor networks was proposed by [7]. Two functional ZigBee modules were connected with the sensors using wireless means. Mesh network topology was applied in the collection of individual sensors nodes in the network. The mesh was controlled using the wireless ZigBee which acted as a network. Easy maintenance and alteration of the mesh is achievable once the system is established. Actualizing future demands will be easily realized through the addition and deletion of the nodes to configure the mesh. ZigBee system encourage the manipulation of a section of the system with no interference with the remaining part of the mesh. Low power consumption is an attribute of ZigBee systems and this aids the setup of low cost, and improved personal wireless computer networks. The limitation in signal strength over a very long range is a disadvantage in the use of ZigBee technology in this project.

In the journal [8], worked on research presenting smart home system for the disabled through a wireless Bluetooth device. A system with Graphical User Interface (GUI) was designed and implemented using mobile phone android applications, it also has similar HTML version for desktop and PDAs and provides services of a mini weather station. This system aids the handicaps and normal people in accessing devices remotely from a mobile phone application. PIC16F877A microcontroller was used in this design while the interface for desktop and mobile system were developed particularly for windows 7 and mobile operating systems. The Bluetooth device links up the user interface system serially with the PIC microcontroller which triggers the relays attached to it and finally controls the operation of the home appliances. Input data from environmental temperature and humidity were also captured with the aid of sensors and displayed by the system. Internet protocol cameras were applied in the system to aid the home monitoring through the internet. A single pole double throw 5 volts direct current relay and a ULN2003APG relay were included in the design for switching among appliances. Traditional programming approach of the device was exhibited using the PIC microcontroller and this minimized the speed of the project development [9]. Though the system performs wonderfully well with the cross-platform function, but the limitation in signal speed of the Bluetooth is a setback.

The development of a low-cost home automation system was proposed by [10]; this journal presented an android based smart home system which is triggered through a Bluetooth device and an internet connectivity [14]. A web service module termed REST framework and Bluetooth unit are incorporated in this system. An MIT application inventor tool was used in designing of the smart home application. The web server introduced in the design is the Arduino ethernet shield while Arduino mega 2560 portrays as the major controller of the home automation system. Radio module nRF24L01+ was used for signals communication and coordination with other sensor nodes. Android application can be used to activate the system through voice activation, Bluetooth based control, and internet-based control mechanisms. Passworded applications requires authentication to access them. Correct entered password allows the user to operate the system and control the appliances. Voice controlled activation of the system requires the need of google speech recognizer. Sensor values are realized with the aid of interrupts while radio frequency communication is applied in getting back the values from sensor to master control. User can apply any one method towards the control of home appliances, operations like gate control, door lock control, and fire detection systems can be manipulated using this method. Once emergency is detected, the system automatically sends email to the user. An effective and complex system was developed, but using only one means of communication at a time is a downside which is not encouraging to hybridized systems.

Smart Android Based Home Automation System Using IOT was Developed by [11]. They used Raspberry pi boards and ESP8285 chips which are costly and connected to sensors and actuators as the hardware framework while they developed an API that is based on android phone to control home devices remotely through the smart phone. The ESP8285 chip is an external component applied to the raspberry pi controller to support as a Wi-Fi adapter that integrate antenna switches.

An Internet of Things based office automation system was developed in [12]. They used an ESP8266 device as the server which connects to an Arduino hardware circuit that acts as the microcontroller to control electrical appliances connected to it. They were able to widget office appliances through website through the means of Wi-Fi system integrated in ESP8266 chip.

A Bluetooth based automation system using android application was developed by [13]. They used an Arduino uno microcontroller to manage the operation of home appliances through Bluetooth wireless connection technology. An app was developed to be based on an android smart phone to send user demand signals to the Arduino microcontroller through the Bluetooth module. This triggers an actuator through a relay system connected to the microcontroller to manipulate home appliances.

3. DESIGN METHODOLOGY

The circuit was designed and simulated in Proteus 8.1 Professional software. Afterwards, the design code was uploaded through a Type C USB (Universal Serial Bus) cable into the Node MCU Microcontroller, with a HP Pavilion 15 Laptop running on Windows 10 Operating System, eight gigabyte ram and core i5 processor. Figure 1 below is the detailed Proteus design. The following steps were followed for implementing the system. The Node MCU microcontroller was mounted on the Vero board through the holes on the board serving as a female connector while the microcontroller pins as the male connector. The implementation follows the circuit diagram in Figure 1.

The servo motor has 3 color coded ports:

1. Red: Power Port
2. Black: Ground Port
3. Yellow: Signal Port

Also, the relay has three ports at one end and three at the other, the first three ports are:

1. Red: Power Port
2. Black: Ground Port
3. Yellow: Signal Port

At the other end it has three ports

1. Normal Open
2. Normal Close
3. Common/Pole

The signal pins of the relay and servo motor were connected to pins D1 and D2 respectively to transmit data signal in the microcontroller. Also, the power cables were also connected to 5 voltage power while a common ground was established between the loads and the microcontroller. As shown in Figure 1, the relay contains a transistor and the base of the transistor is connected to Normal Open which serves as the signal port for the relay. One end of the lamp is connected to the AC power source while the other end is connected to the Pole of the relay. When the Android GUI sends an “ON” signal to any of the load, let’s say the relay, it triggers the relay and makes it be in the high state then the Lamp is switched on vice versa. The servo motor works by the principle of servo mechanism and angular precision movement. That means the main electric motor controls the remaining gear motors at the angle received from the signal port. When the “ON” signal is sent from the Android GUI the servo motor swings to 180° which replicates same movement on the lever attached to it and makes the door open. On pressing “OFF” same protocol is followed as Opening the door but this time the servo motor moves in the opposite direction that is -180°. The system block diagram and flowchart are shown in Figure 2 and Figure 3 for more detailed step to operate the system.

The program code was written on Arduino IDE environment with Arduino C# programming language. Also, it was compiled on the Arduino IDE with the inbuilt compiler. The program code is divided into two main parts:

1. The Header and declaration session: here, libraries were imported and variables were declared. Three libraries were imported first is the servo library, Servo.h which contains all components needed to write to the servo motor. Example of such is servo write () which is used to control angular movement off the motor. The second and is the Wifi Server and Web Server libraries used to create Wi-Fi connection and setup web server respectively.

2. The Set Up: for the initialization of the Wi-Fi connection and APIs (Application Program Interface). The IP address and other related components were declared in the setup. Also states for the components were also declared. Serial displays were initialized to also test the microcontroller.

3. The Program Logic: contains the main logic of the program. It contains software implementation of the program.

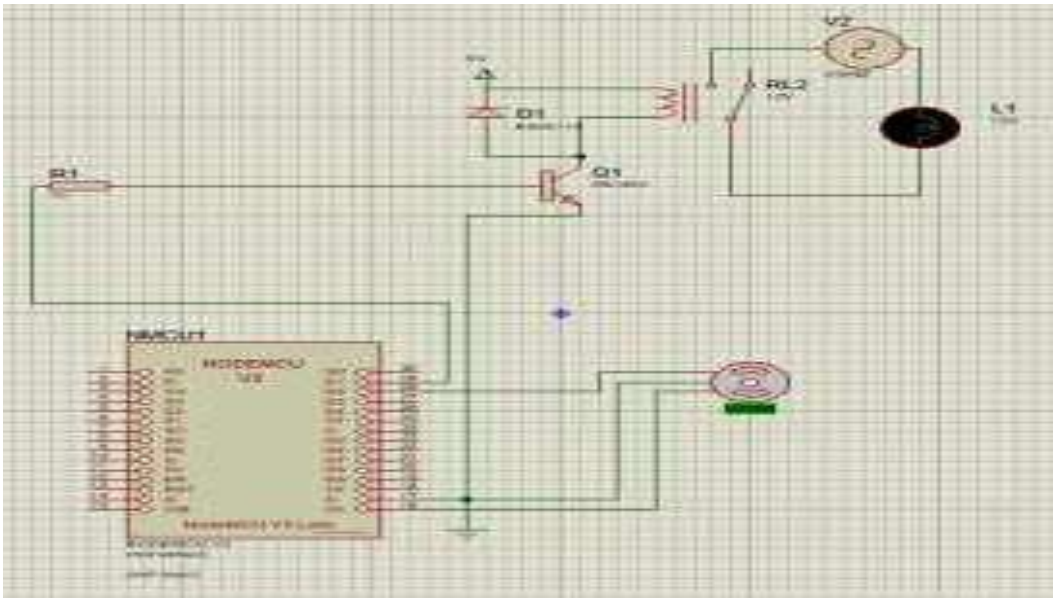

Figure 1: Circuit diagram of the home automation

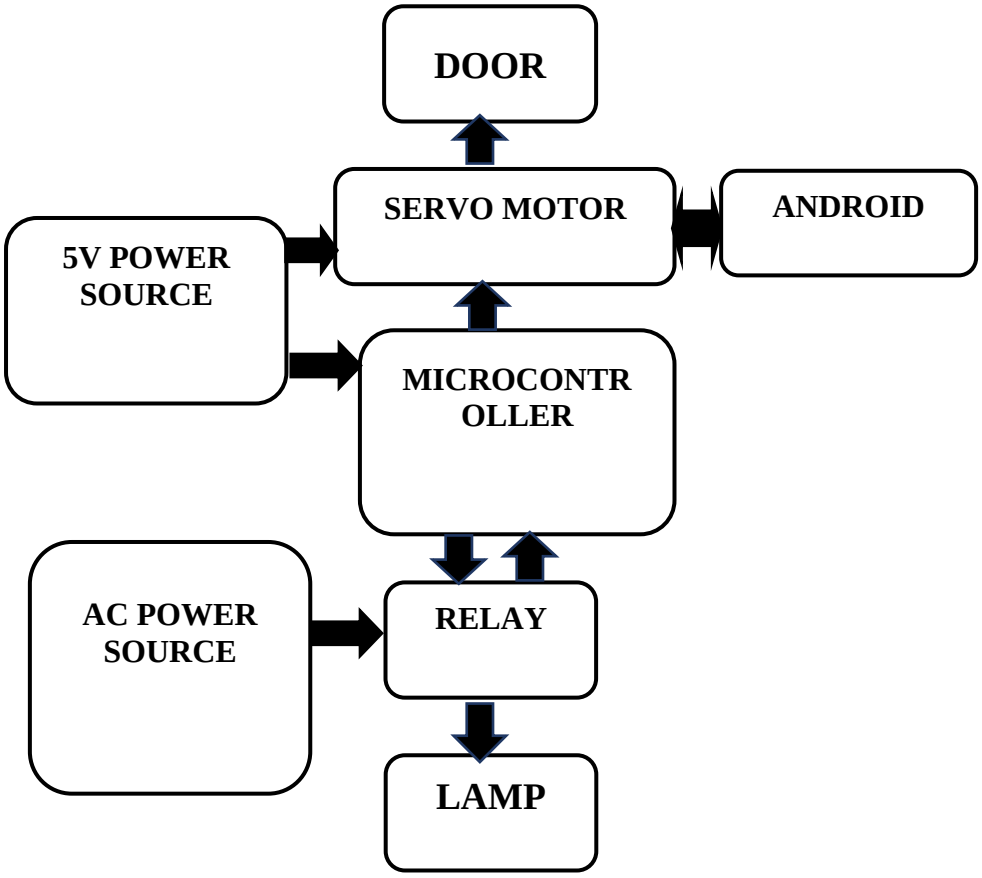

Figure 2: Block diagram of the home automation

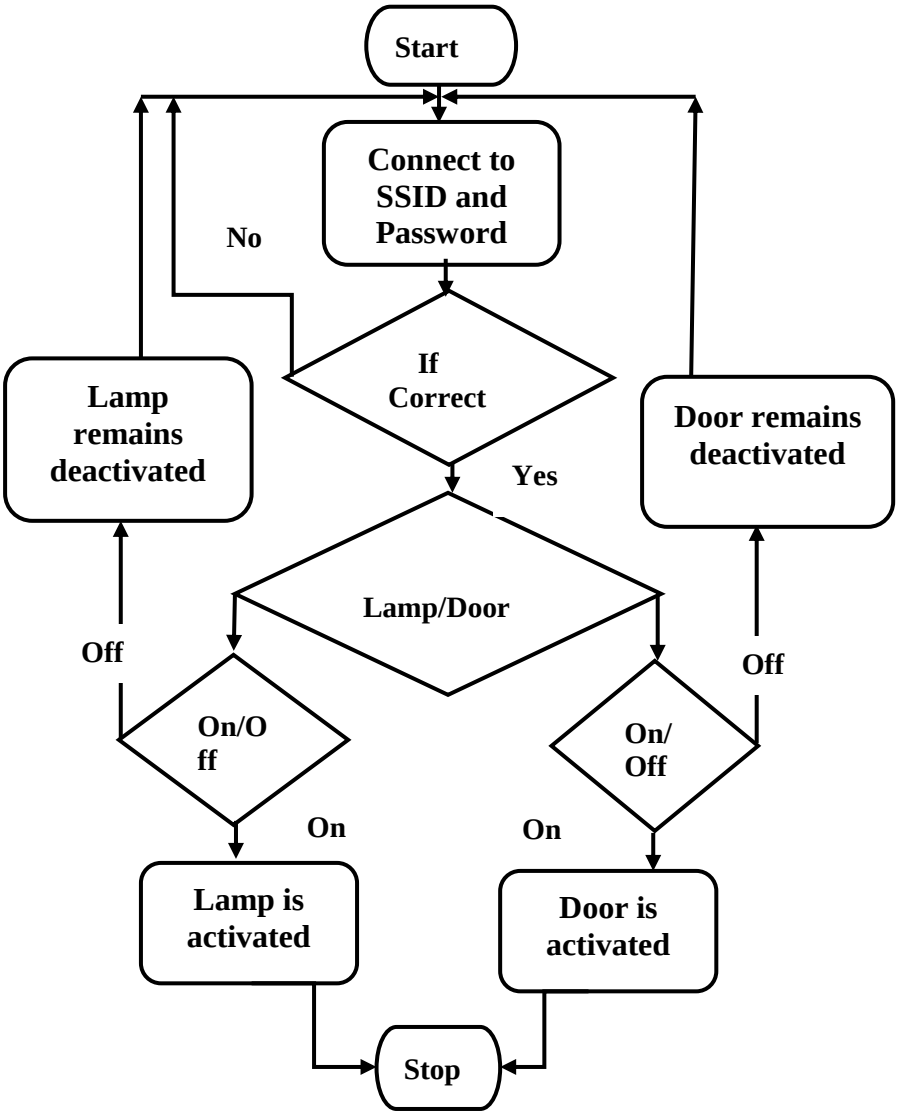

Figure3: Flowchart of the home automation system

Figure 4: Screenshot of the design layout of the mobile application in MIT web platform

The image in Figure 4 displays the screenshot of the mobile application built in MIT web platform while the main logic is seen in Figure 5 below:

Figure 5: Screenshot of the program logic of the mobile application in MIT web platform

Figure 6: Image of the prototype system

4. RESULTS AND DISCUSSION

The breadboard, Veroboard, and android device were tested at low and high temperature while developing this system, it was realized that the units were working properly. The systems response time when a command signal is sent through the android phone to either turn on the bulb or open the door will help determine the speed at which the system respond to instructions. This test is carried out multiple times during morning, noon, and night hours of the day over a distance below and above one kilometer, in order to realize the average system performance time. The system seizes to perform at distance above one kilometer, but functions well at a range below one kilometer from the internet. The results

specifying the time of response of both the bulb and door when triggered is shown in Table 1, while Figure 6 specifies the image of the packaged developed system

Table 1: Time response of home appliance

Bulb response	**Test1**	**Test2**	**Test3**	**Signal response below 1km**	**Signal response above 1km**	**Average time**
Morning	1.00sec	1.50sec	2.00sec	ON	OFF	1.50sec
Afternoon	2.00sec	2.50sec	3.00sec	ON	OFF	2.50sec
Night	1.00sec	1.00sec	1.50sec	ON	OFF	1.16sec
Door response	**Test1**	**Test2**	**Test3**			**Average time**
Morning	2.00sec	2.00sec	2.50sec	OPEN	CLOSE	2.16sec
Afternoon	3.00sec	3.50sec	3.00sec	OPEN	CLOSE	3.16sec
Night	1.50sec	2.00sec	2.00sec	OPEN	CLOSE	1.83sec

4.1 Integrity Test (Using different passwords and SSID)

Different service set identifier (SSID) was created with the same password "password" but the system microcontroller did not connect with it. Another scenario was created by creating same SSID but different password, the system was also unable to connect to this network. A perfect connection was established when the same SSID and Password as specified in the program was used.

5. CONCLUSION

The developed home automation system is more flexible and provides attractive user interface compared to other home automation systems. Bottlenecks encountered using complex java programming, Bluetooth with low speed and limited coverage were addressed with the help of the developed system. In the developed system, a mobile device was integrated using relatively fast Wi-Fi communication technologies. The system consists of mainly three components is a mobile phone, Node MCU (microcontroller unit), relay circuits and loads. Wi-Fi is used as the communication channel between android phone and the Node MCU. The android interface has been made very simple for the user(s) to interact with whilst still being simple, this simplification is needed to fit as much of the functionality on the limited space offered by a mobile device's display. The NodeMCU microcontroller development board uses ESP8266 microcontroller chip and it is adopted in the implementation of the designed system. Its positive qualities in performance, low cost, low power consumption, larger memory, fast processing, and presence of wi fi facility gives it an edge in the developed system over Atmega 328p microcontroller used on Arduino board. The software implementation involves the programming of the microcontroller using a modular approach and developing an android based mobile app for the system. This system permits easy checking of errors and debugging. MIT app inventor was applied in developing the mobile application used in the input unit on the phone. The mobile app was developed for android platform and can be used for any smart phone running on android operating system. The system developed is a low cost, secure, and configurable solution.

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