# DEVELOPMENT OF AN ENHANCED SMART HOME AUTOMATION SYSTEM

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**Abstract**
*Sustaining energy is a must in the civilized society in order to provide some basic amenities for the citizenry. Unfortunately, the available and limited forms of energy are seriously mismanaged. Means by which energy is being wasted in the homes include failing to switch off appliances when they are not being used. This challenge is being attributed mainly to the type of switching devices available; since in most instances they require our physical presence to turn them on/off. In this study, an Android based application control system is developed to remotely control the state of appliances in the home. The system eliminates the need to be physically present to switch on/off the appliances, thus, eliminating the distance factor. In order to evaluate the performance of the developed system, a home scenario was emulated using a modelled various lighting bulbs and sockets to represent home appliances. Consequently, the derived result show that system's capability of switching the appliances at remote locations from the prototype model with an average of 120 secs maximum delay. This proves the elimination of the physical presence and distance barrier.*

**Keywords: -** Android OS, Arduino System, Home Automation System.

## Introduction

Globally, there has been an increase in the requirements of home users which have resulted in varieties of sophisticated home gadgets now available. As these requirements increase, the need for a suitable and affordable means of controlling these gadgets also increases. Over the years, the field of home automation systems has revolutionized; from the use of manual control of home gadgets and appliances to the high improved techniques. This techniques does not only allow for control but also helps in monitoring (Alam, Reaz, & Ali, 2012; Bromley, Perry, & Webb, 2003; Pandey & Sen, 2014).

Home Automation System (HAS) has the capability of controlling electrical and electronic gadgets and devices in the home (Alam et al., 2012; Bromley et al., 2003). The application of the HAS solely depends on the affordability and simplicity which the system offers to the home user (Panth & Jivani, 2011). Basically, the use of the HAS involves the integration of a central controller, mostly embedded systems, to ensure the monitoring and control of the devices in the home via an Adhoc network. Most often, these Adhoc Networks are based on the use of Bluetooth, zigbee, RF (Bromley et al., 2003; Pandey & Sen, 2014; Ramlee et al., 2013). The major challenge faced by the use of these aforementioned network strategies is that the range of control is too short, only a few meters, from the device being controlled (Alam et al., 2012; Kumar, 2014).

In lieu of these challenges, the purpose of HAS is being undermined as features such as flexibility of monitoring, control and remote operation becomes difficult to implement (Alam et al., 2012; Delgado, Picking, & Grout, 2006). Other HAS features not dependent on network includes: the overall convenience for old and physically challenged persons, flexibility in the control of devices, high tendency to improve security, time saving and most importantly energy saving (Delgado et al., 2006; Pandey & Sen, 2014; Ramlee et al., 2013).

Virtually in all parts of the world today, energy is crucial in ensuring the availability of basic amenities for people (Ahuja & Tatsutani, 2009). The issue of sustaining energy and its advantages cannot be over emphasized. Unfortunately, the available supplied energy is sometimes mismanaged in wasteful and unproductive activities. This includes the careless act of not switching off a device when not being used, such as our room lights, air conditioner units and lots more.

To address the identified issues, this paper adopts the application of Arduino based microcontroller and android mobile operating system in developing a suitable HAS monitoring and control system for selected devices in the home. The paper is therefore structured thus: Section 2 presents the review of related works, section 3 System Design, section 4 presents Results and Discussion while section 5 concludes the paper.

## Review of Related Work

Kumar, (2014), developed a remote operated HAS with the use of a micro-web server in the monitoring and control of home devices. The Arduino Ethernet board was employed to enable network connection with an Android application developed to control the system. The work brings forth the advantages of the use of either 3G or 4G or Wi-Fi connection between the android App in the phone and the control module through the Ethernet board. Additional functionality of automatic mode activation was included and the elimination of PC use in the system. This system has a loophole in relation to the limited range of the Wi-Fi. Its functionality is confined to the coverage of the Wi-Fi and cannot be used outside the range.

Ramlee et al. (2013) observed that previously made home automated systems do not include graphical user interfaces (GUI) for user monitoring. A system was therefore developed which uses personal computer as well as a smart phone for home automation. The control system was provided with an alternative system as backup depending on the case at hand. The PC or mobile phone connect with a Bluetooth interface to the control module. Consequently, two GUIs were developed to cater for the two systems making the system more costly and complicated to use. The coverage distance of Bluetooth also adds up to the limitation of the system (Kumar, 2014).
Wireless Home Automation System using ZigBee was developed by Devi (2012), through voice automation command to control home devices. A microphone captures the voice and compares it with the content of the database, then a speech-to-text translation with multilingual feature is carried out. This enables the user to command each device to be controlled to either ON or OFF. The deficiencies in the work include no Graphical User Interface (GUI) for user feedback purposes, close range for microphone usage and no noise cancellation mechanism to cancel background noise.

A Real-Time Operating System (RTOS) was presented in Anwaarullah and Altaf (2013), based on a wireless Android controlled HAS. Special attention and work was done on the security aspect of the system. Google voice identification and Android patterned password feature were adopted into the access control system of this work. Special Real Time Operating System Chip, relay circuits, Bluetooth module and an Arduino board were used in achieving the objective of an automated home. An application was developed on the Android mobile specially for the purpose of controlling devices via Bluetooth technique. A major disadvantage is the restriction of the functionality within a confined distance range that the wireless technology can cover.

Heat system, Air-conditioner and the integrated security system (HACS) was designed to control appliances and also monitor the security of the home in Khiyal, Khan, and Shehzadi (2009). Having two sub-units of unique functionality and usage, the appliances control subsystem and the security subsystem were integrated together using specially selected GSM technology and Radio frequency wireless technique. The RS232 port of the GSM module with preference to the SMS mode was connected to the user's cell phone and communication was made with a PC. This PC already had installed on it the software for the device control. The advantage of the work includes the automatic generation of SMS to the user's cell phone from the control system to change the condition of the system. The aim of reducing cost was not fully achieved because it required lots of expensive material such as computers, Radios Frequency modules, GSM module and Cell Phone which amount to a lot in terms of cost.

In Felix and Raglend (2011), a home automation system was introduced which used GSM and ZigBee technology in achieving its aim and objectives of providing a more secured home automated system. ZigBee network was created and each device had a network it connects to. Every device has a private key which it uses in connecting to a network and encryption is carried out during authentication. Every device was attached to a ZigBee module, therefore the ZigBee network became very complex due to the large number of ZigBee devices contained in the network.

In this work, the development of a multiplatform control system for the HAS via user's mobile phone and employing the continual presence of the GSM Network in ensuring steady connectivity is developed. The choice of methodology and components is to offer solutions to the key limitations affecting HAS controlling as outlined in the literatures earlier discussed. These limitations include system interoperability, scalability, security and lastly limited network coverage (Delgado et al., 2006). The proposed system aims to provide solutions to the issue of limited network coverage, user friendliness, security and energy conservation.

**System Design**

This section focuses on the method adopted in the design and development of the Home Automation System (HAS). In order to achieve the desired objective, the overall architecture of the system is divided into three major subsystems which include: the Hardware control unit subsystem, the Software (GUI) subsystem and the interconnection interface subsystem as depicted in Figure 1. Each of the units has a dedicated and unique role within the entire system. The Hardware control subsystem houses the Arduino controller unit which interfaces directly with the devices to be controlled. It further receives instruction from the software subsystem on what to do with the devices it is set to control. Unlike the hardware subsystem which is resident on the developed HAS device, the software subsystem is resident on the user's Android mobile device as an application. It is from the software subsystem that instructions are issued out to the hardware unit, while the interconnection interfacing subsystem is responsible for ensuring communication between the software and hardware subsystems. The block diagram of the system is as depicted in Figure 1.

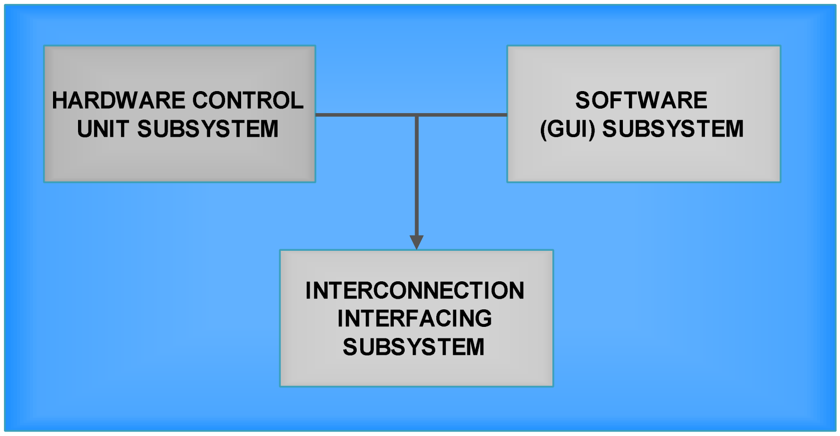



**Figure 1: HAS Subsystems**

A detailed block diagram of the overall system is also presented in Figure 2 showing the individual constituent components of the system. Basically the system consists of the following:

i. A Graphic User Interface; resident on the user's mobile phone from where the control and monitoring is visualized,
ii. The HAS controller; which houses the GSM module and the Arduino controller,
iii. The Power control section; that interfaces the device(s) to the HAS controller and
iv. The device to be monitored and controlled via the controller.

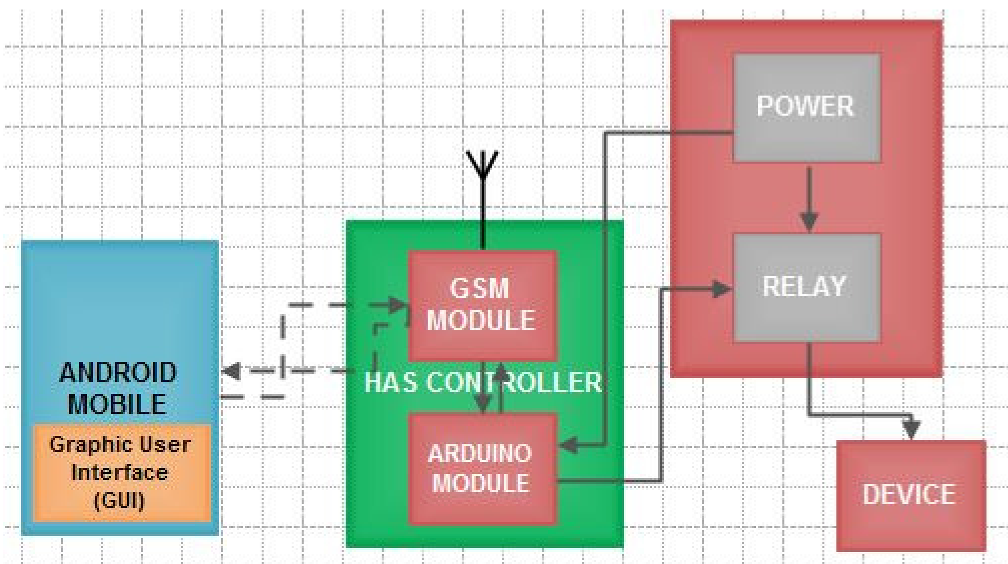



**Figure 2: The Enhanced HAS System**

**Hardware Control Unit Subsystem**

The hardware control unit houses the HAS controller as well as other electronic circuitry. The main element of the Hardware control unit is the HAS controller. An Arduino Uno ATMEGA 328P is used to implement the HAS controller. Characteristically, the Arduino Uno with ATMEGA 328P is a 28 Pin device with 14 digital pinouts and it uses a dual power source of 5V and 9V. Furthermore, the chip is operated via a 16MHz clock signal and it supports the In-Circuit Serial Programming (ICSP) interface, which allows for easy programming via the open source Arduino programming interface. Figure 3 depicts the circuit diagram showing the interconnection of the controller and the device to be controlled. The device to be controlled is simulated using an inductive load as shown in Figure 3 and is being interconnected to the controller via two normally open relay switches which are only energized whenever the desired control signal is received from the controller via the interfacing module on the mobile device. The PNP transistors, diodes and resistors are used to serve as protective measures for the controller against backward current effect. Other cascaded section of the hardware unit is the Power Supply unit which supplies the regulated DC 5V and 9V for all the electronic circuitry in the hardware unit and the interfacing module respectively. The Power supply circuitry is as depicted in Figure 4.

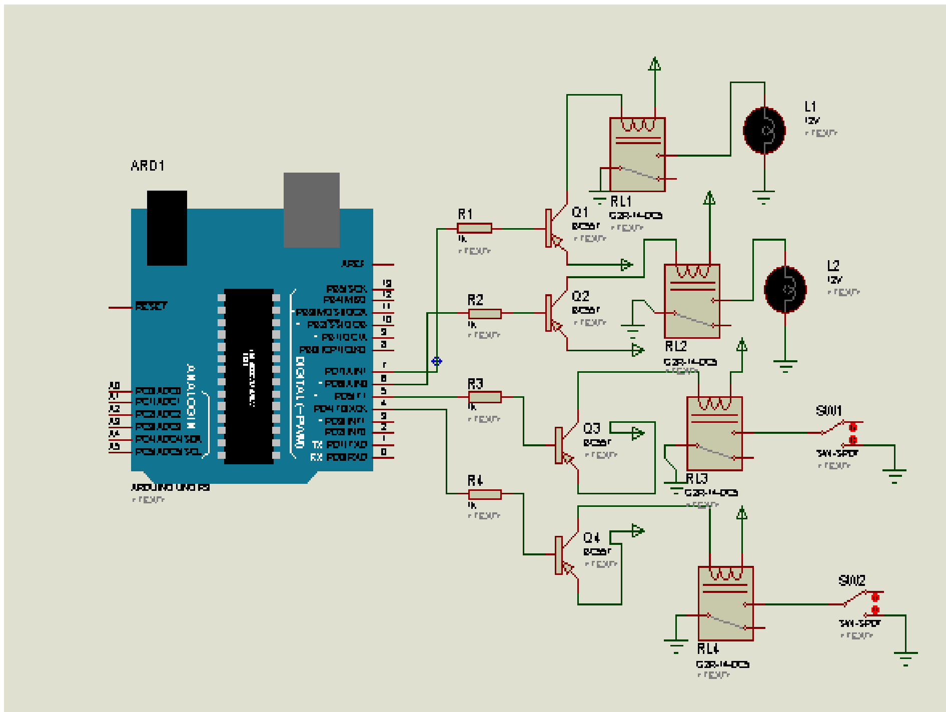



**Figure 3: Circuit Diagram of HAS Controller to Controlled Device**

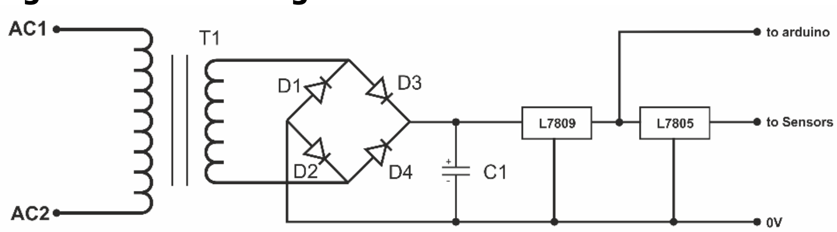



**Figure 4. Power supply unit**

The power supply unit receives 220V supply that is passed through a full bridge rectifier. The ripple factor of a full wave rectification is given by:

$$\gamma = \frac{1}{4\sqrt{3fCR_L}} = \frac{I_{L(ac)}}{I_{L(dc)}} \quad (1)$$

*where,* $I_{L(dc)}$ =peak dc component of load current

$I_{L(ac)}$ =peak ac component of load current

$f$ = frequency of AC voltage

$C$ = Capacitance of the filter

$R_L$ = Load resistance

Peak primary voltage ( $V_{pm}$) = Supply voltage x $\sqrt{2}$ (2)

Supply voltage = 220VAC

$$V_{pm} = 220 \times \sqrt{2} = 310V \quad (3)$$

Maximum secondary voltage ($V_{sm}$) = K x $V_{pm}$ (4)

where K $= N_2/N_1 = V_2/V_1$= 12/220= 0.05454
$V_{sm}$= 0.05454x 310 = 16.91V
$V_{LM} = V_{sm}$ = 16.91V

Maximum Load Current ($I_{LM}$) = $V_{LM}/R_L$ (5)
*where,* $V_{LM}$= Maximum load Voltage
$I_{LM}$= Maximum load Current
16.91/100 = 0.1691A
$I_{L(dc)}$ =0.636 x 0.1691= 0.1075A
$I_L$ = 0.707 x 0.1691 = 0.1195A
$I_{L(ac)} = \sqrt{0.1195^2 - 0.1075^2}$ = 0.1075A
Recall from equation (1), that:

$$\gamma = \frac{1}{4\sqrt{3fCR_L}} = \frac{I_{L(ac)}}{I_{L(dc)}} = \frac{0.1075}{0.1075}$$

$$\therefore\ \gamma = 1$$

Therefore:

$$\frac{1}{4\sqrt{3fCR_L}} = 1$$

Making C the subject of the equation, we get:

$$C = \frac{1}{75fR_L}\ (\mu\text{F})$$

Given: $R_L$ = 100Ω, $f$ = 50Hz

$$C = \frac{1}{75 \text{ x } 50 \text{ x } 100} = 2.667\mu F$$

The minimum value of filter capacitor is equal to 2.66µF. Thus, a 10µF capacitor was use to filter out ripples before passing the voltage to a 5 V and 9V voltage regulator.

**Software Subsystem**

The software subsystem entails all that is involved in the development of the control application of the Enhanced Home Automation System. This control application dictates the activities to be performed by the HAS controller via the Graphical User Interface of the application installed on the user's Mobile device. The development of the application incorporates both Mobile and Web application technologies namely the HTML5 (Hyper Text Mark-Up Language 5), CSS (Cascaded Style Sheet) using the Apache Cordova Software and its Plug Ins. These combination allows for large extent of flexibility and portability in the development as well as cross platform usability, thus providing the much required interoperability required of the HAS. The basic requirement and functionality for the control application was developed using the Unified Modeling Language (UML) as presented in Figure 5.

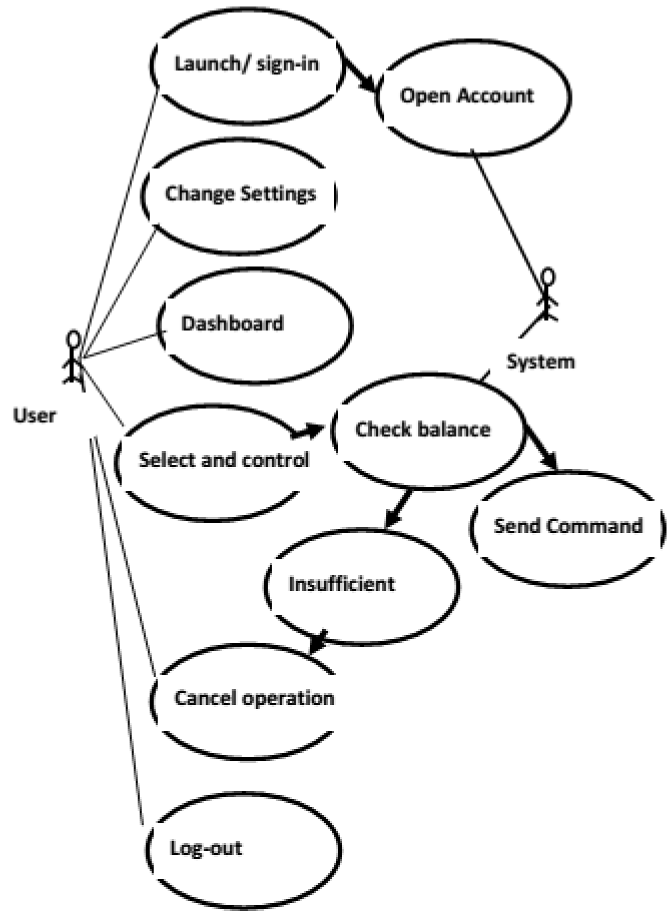



**Figure 5: Use Case Model for Control Application**

## Interconnection Interface Subsystem

The Interconnection Interface Subsystem serves as an integrator of the hardware control unit and the software subsystems. This subsystem comprises of the communication device and technique used to connect the hardware control board and the software subsystem. In achieving this, a Global System for Mobile communication (GSM) Module SIMCOM SIM900A V3.6 as depicted in Figure 6 was used and configured with AT command and using the SMS feature for communication. The developed software application uses the SMS feature of both the Android Operating System and GSM SIM900A module in sending and receiving command from the Arduino HAS Controller. For every command (ON/OFF) initiated on the Graphical User Interface (GUI) of the application on the mobile device, a message is sent to the subscriber Identification Module (SIM) on the SIMCOM SIM900A. Thereafter, the HAS controller in turn decodes the message and gives the appropriate command on either to turn ON or OFF the device as applicable. The inclusion of the SIMCON GSM module helps to address the issues of scalability with respect to the primary issues affecting the typical HAS development. Thus ensuring that the geographical location and distance of the user are not barriers to the operation of the system.

**Figure 6: SIMCON SIM900A GSM Module**

The interface subsystem operates in a simple and sequential order as depicted by the following Pseudo code;

**Table 1: Pseudo Code for Interconnecting Interface**

```
Start
Step 1: Connect to Network
Step 2: Initialize AT commands
Step 3: Set to SMS Mode
If (True);
        Begin
        Read content on Arduino Serial Monitor.
          Check for Specified device
         Send to designated pin for the device
        Power the device ON or OFF
       Delete SMS
Else
       Keep checking for incoming SMS
End
```

The overall system development flowchart is as shown in Figure 7, indicating the requirements and development stages of the hardware and software subsystems.This also shows the integration of the two subsystems via the interconnecting interface unit down to the development of the prototype of the system.

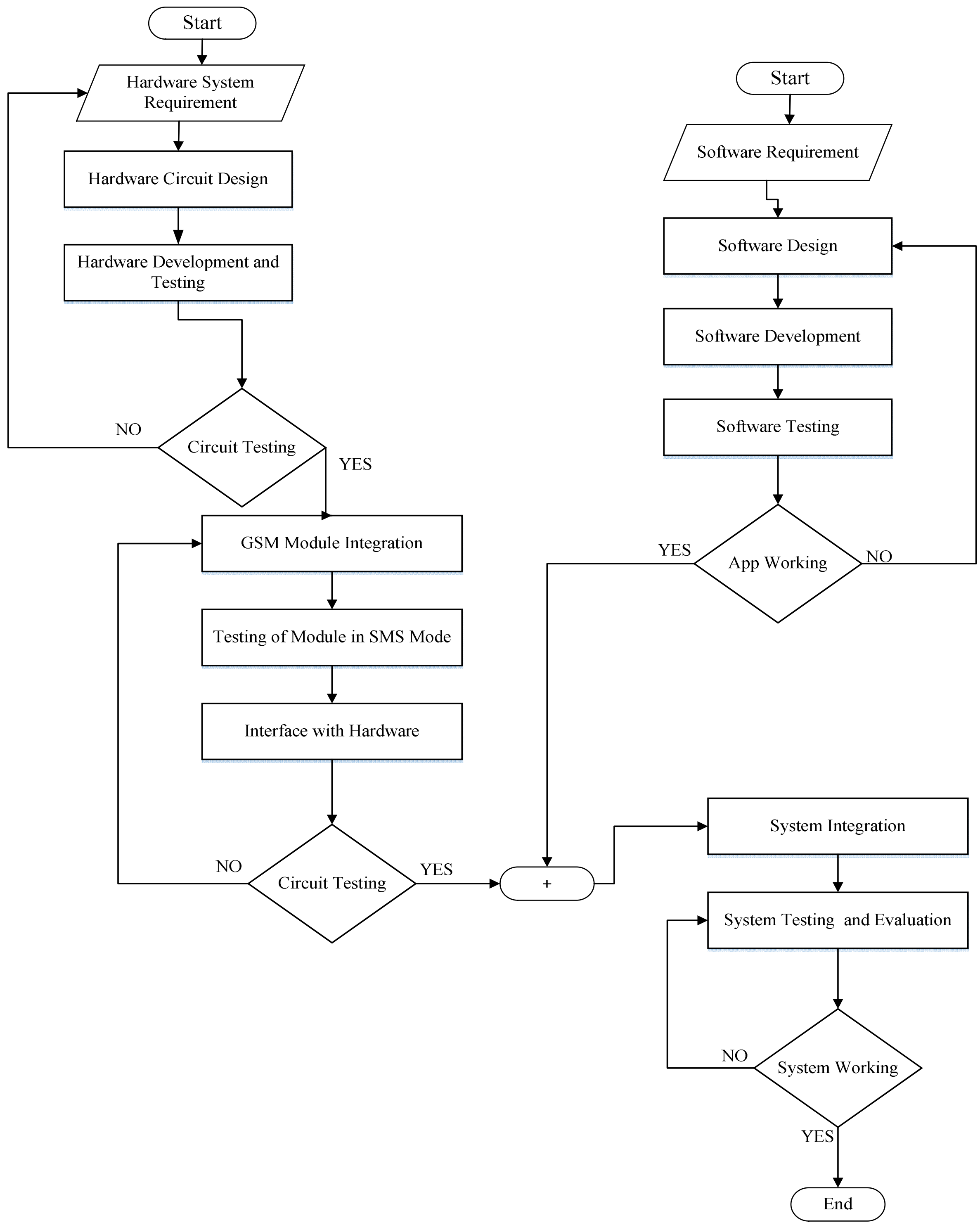



**Figure 7: Overall System Development Flow**

## Results and Discussion

Figure 8a-l shows the different stages of the development of the Enhanced Home Automation System from the software application to the hardware prototype.

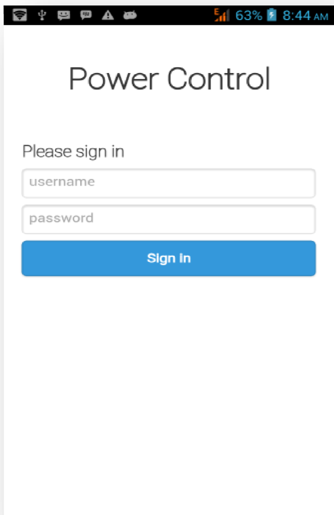



**Figure 8a: Log-in**

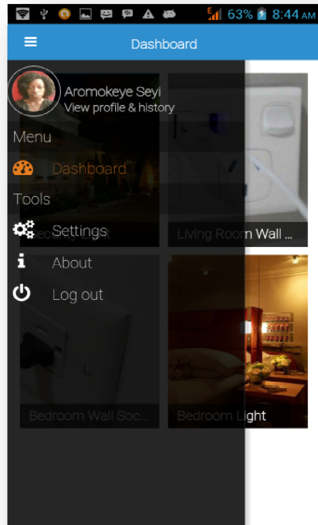



**Figure 8b: Setting Page**

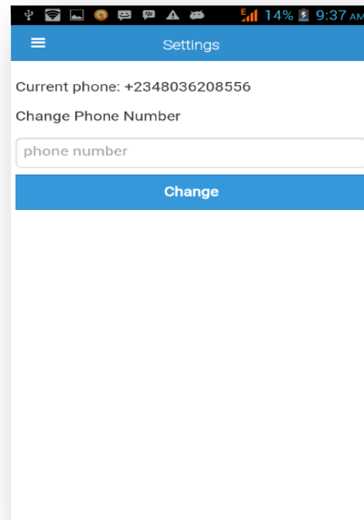
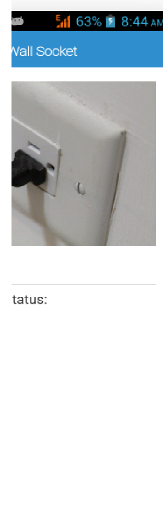
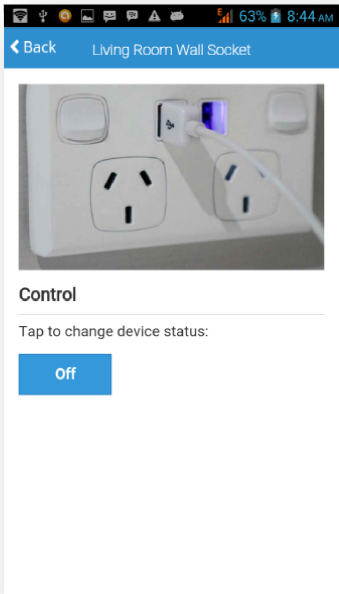
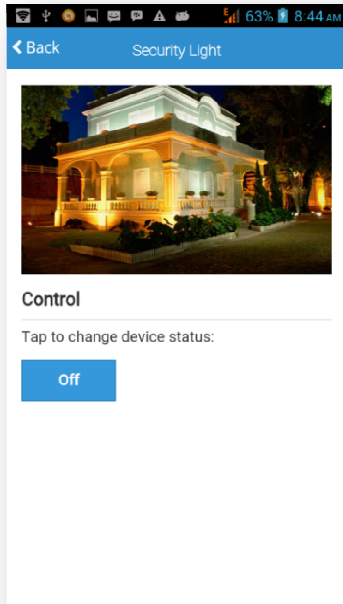



**Figure 8c: Settings Page**




**f: Applicable Control**



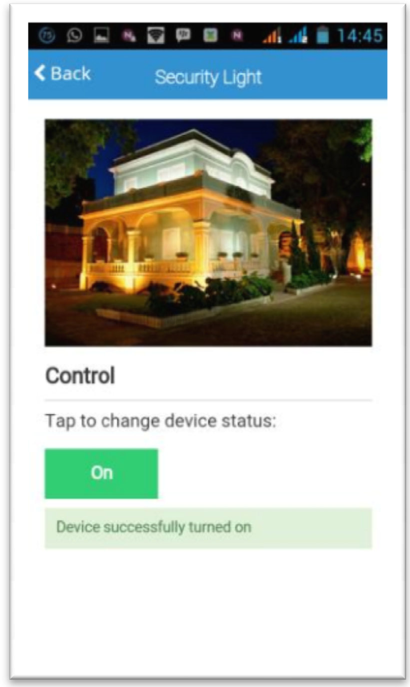




**Figure 8g: Applicable Control** **8h: Applicable Control** **Figure 8i: Successful Turn On**

In ensuring the required access control which serves as a form of security for the system as well as the user, the enhanced HAS application is equipped with a Login page as depicted in Figure 8a. This inclusion provides access to only the user with the unique password identification that would be required upon use of the system. Furthermore, the system is designed to allow for any password combination. Thereafter, the system also offers great amount of flexibility such that the user can make changes to the default setting as depicted in Figures 8b and 8c, thus providing additional level of security and comfort to the user. These addictive features in Figures 8a – 8c shows the security features of the developed HAS, which gives the users different layers of security flexibility. In addition, Figure 8d depicts the icons for all the applicable device for control by the system, while Figures 8e to 8h shows the individual appliances and the control log to them ON or OFF.

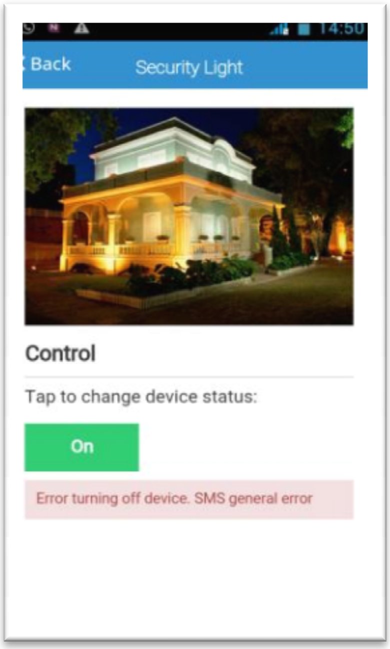



**Figure 8j: Failed Delivery** **Figure 8k: Prototype in OFF state** **Figure 8l: Prototype in ON state**

Another remarkable achievement recorded in this study as compared to other existing works, is the development of a feedback mechanism that ensures the continual communication between the Control Application and the devices. These features help to check the status and the fidelity of the sent control signal if delivered or not as depicted in Figure 8i showing a successful control signal delivery and the applicable device turned ON. While Figure 8j depicts a situation with a fail signal communication between the applicable device and the controller. Furthermore, the Figure 8k shows the completed system model in an OFF state or a signal failure state. Signal success state is depicted in Figure 8l.

Furthermore, the challenge of scalability which has to do with mobility of the control and the distance barrier was also addressed in this work. With the inclusion of the SIMCON SIM 900 GSM Module in the interconnecting Interface this challenged was eliminated. Thus, ensuring flexibility in the use regardless of the distance and location user can turn on or off appliances from near and remote locations. The HAS Controller was tested for different appliances at varying distance from the developed model and the result of the distance and the computed response time of the controller is presented in Table 2.

**Table 2: Distance versus Response Time**

| S/N | Characteristics | | |
|---|---|---|---|
| | Device | Distance | Response Time |
| | | 100 | 120 |
| 1 | Security Light | 200 | 120 |
| | | 300 | 120 |
| | | 100 | 120 |
| 2 | Bedroom Light | 200 | 120 |
| | | 300 | 120 |
| | | 100 | 120 |
| 3 | Bedroom Socket | 200 | 120 |
| | | 300 | 120 |
| | | 100 | 120 |
| 4 | Living Room | 200 | 120 |
| | Socket | 300 | 120 |

## Conclusion

In this work, we have presented the design and development of an enhanced Home Automation System, with the view of addressing the main and pertinent issues associated with the ideal and typical Home Automation System as already identified earlier. The developed system, characteristically comprises of a hardware controller interfaced with a corresponding mobile application via a user-friendly interfacing unit laced with SIMCON SIM900 GSM Module which can be used to control home appliances remotely, thereby providing a great extent of flexibility in mobility for the user without fear of distance, location and proximity to the appliance or device to be controlled. Due to the usage of SIM card by the GSM module, it is dependent on the mobile network available by the service provider. From the evaluation conducted, it was observed that it takes an average of 120sec response time for each device to be controlled and it is dependent on the network available at the particular point in time. Thereby, regardless of the distance of usage, the system response is still desirable. Furthermore, the developed system presented has the capability of operating on multiple platform thereby addressing the issue of interoperability of the Home automation system. However, the result presented herein was based on the android version. In addition to the aforementioned, the application of the enhanced home automation system such as the developed system would help in the conservation of energy especially in developing countries of the world where generated power is insufficient. Also with the application of the system, the user can control the amount of energy consumed, save the time it takes to control devices and generally enhance the living conditions.

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