IJCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Vol. 9, Issue.8, August 2021 E-ISSN: 2347-2693

Development of a Smart Home Control System

H.A. Okemiri[1*], S.C. Chukwu[2], E. Uche-Nwachi[3], K.C. Oketa,[4] S.C. Eze[5], V.I. Aniji[6], A.Y. Idris[7]

[1,2,3,4,5,6,7]Dept. Name, Name of Computer Science/Informatics, Alex Ekwueme Federal University Ndufu-Alike, Ebonyi State, Nigeria

[*]*Corresponding Author: henry.okemiri@funai.edu.ng, Tel.: +234-8066-708308*

DOI: https://doi.org/10.26438/ijcse/v9i8.720 | Available online at: www.ijcseonline.org

Received: 11/Aug/2021, Accepted: 20/Aug/2021, Published: 31/Aug/2021

Abstract— In the past, before the advancement of computer technology, the control of home appliances was done manually at their various locations by a user. This kind of control has shortfalls such as lack of control of home appliances remotely and displeasing stress and discomfort to home appliance users, to mention but a few. However, these problems lead to this project research which is on the design and implementation of a Smart Home Control System, with the following objectives; to solve problems involving the lack of ease and comfort in the use and control of home appliances, provide help and support for home appliance users and generally bring technology and automation into various home appliances and devices. This research work followed the structured project design methodology with tools such as the Arduino Uno microcontroller, NodeMCU WIFI Module, Ethernet + WIFI Router, Smartphone with Android 2.3+, Arduino IDE platform with C++ programming language. The result of this research is to prove that the control of home appliances can be done wirelessly. The system when implemented, would be able to control electrical appliances and devices in the home with a relatively low cost design, user-friendly interface and ease of installation.

Keywords—ArduinoUno, Ethernet, SmartSystems, NodeMCU

I. INTRODUCTION

A. Background of the study

The "Home Control" concept has been in existence and in popularity since late 1990s, as Internet Technology developed fast and smart homes suddenly became a more affordable option. Terms like "Smart Home", "Intelligent Home" has been used to introduce the concept of connecting and networking appliances and devices in the home. Domestic technology or "domotics" was a highly discussed topic as domestic appliances were being combined with computing. Early home Control began with labor-saving machines. Self-contained electric or gas powered home appliances became viable in the 1900s with the introduction of electric power distribution and led to the introduction of washing machines (1904), water heaters (1889), refrigerators, sewing machines, dishwashers, and clothes dryers [1].

In 1975, the first general purpose home Control network technology, X10, was developed. It is a communication protocol for electronic devices. It primarily uses transmission wiring for signaling and control, where the signals involve brief radio frequency bursts of digital data, and remains the most widely available. By 1978, X10 products included a 16 channel command console, a lamp module, and an appliance module. Soon after came the wall switch module and the first X10 timer [2].

Smart Home Control Systems (SHCSs) presents a great research opportunity in creating new fields in Engineering and Computing. SHCSs includes centralized control of home lighting, doors and other appliances to provide improved comfort and energy efficiency. However, end users do not always accept these systems because of its complexity, cost and difficulty in installation.

This project forwards the design of a Smart Home Control using an Arduino Uno. The Arduino Uno is a microcontroller board based on the ATmega328P processor. The home appliances are connected to the input/output ports of the Arduino Uno along with the power strip and their status is passed to the Microcontroller board. An Android OS running on any phone or tablet, connected to the network can access and control the status of the home appliances via an application[1][2].

Following the advancement of wireless technology, several connections have been introduced such as WIFI, Bluetooth and Infrared. Each of these connections has its own unique specifications and applications. Among the three popular wireless connections that are often implemented in SHAS project, the WIFI technology has been accepted to be the most preferable because of its suitable capabilities. Most laptops, notebook and Smartphones come with built-in WIFI adapter and the capabilities of WIFI technology are popular and user friendly.

Home mechanization has been around since the World War 1 (1914), actually, the TV remote (a home automation system) was planted in 1893 [3]. From that point forward various home control frameworks have advanced with a sharp ascent after the Second World War. Its development

has experienced casual research and plan by innovation lovers who need a superior method for completing things at home absent much exertion on their part. The framework advanced from one that can naturally do routine errands like switch on/off lights, to progressively refined ones that can modify lighting, put the TV slot to most loved station and control door.

2.1.1 Conceptual Review

Automation/Control is the use of information technology to control equipment, industrial machineries, tasks and processes, reducing the need for human intervention. It involves the use of advanced technology which includes the use of computer hardware and software(s) to control devices, objects or things.

Automation is very significant in the world today which includes the global economy and daily user experience. Technology enthusiasts strive to combine automated devices with mathematical and organizational tools to create complex systems for a rapidly expanding range of application and human activities. xHuman-level, pattern recognition, and language production ability are well beyond the capabilities of modern mechanical and computer systems[5].

2.1.2 Types of Automation

A. Building Automation

Building automation describes the functionality provided by the control of a building. The control system is computerized, intelligent network of electronic devices, designed to monitor and control the mechanical and lighting system of a building. A building automation system is an example of a distributed control system. The building automation system (BAS) core functionality keeps the building climate within a specific range, provides lighting based on an occupancy schedule and monitor system performances and device failures and provide email and/or text notification to building engineering staff. The building automated system functionality reduces building energy and maintenance costs when compared to a non-controlled building [6].

B. Office Automation

Office automation refers to the varied computer machinery and software used to digitally create, collect, store, manipulate, and relay office information needed for accomplishing basic tasks and goals. Raw data storage, electronic transfer and the management of electronic business information comprise the basic activities of an office automation system, office automation helps in automating existing office procedures.

C. Home Automation

Home automation may designate an emerging practice of increased automation of household appliances and features in residential dwellings, particularly through electronic means that allow for things impracticable, overly expensive or simply not possible in recent decades [7]. Home automation includes all that building automation provides like climate controls, door and windows controls, and in addition, control of multimedia home theatres, pet feeding, plant watering and so on. But there exist a difference in that home automation emphasizes more on comfort through ergonomics and ease of operation.

Home automation systems may designate electronic systems in homes and residential buildings that make possible the automation of household appliances. The new stream of home automation system has developed into a vast one and the current market is flooded with a furry of home automation system and device manufacturers [4].

2.1.3 Types of Home Automation System

Types of home automation system based on their control systems are:

A. Individual Control System

These types of devices were the first to hit the market in the early years, here each device like air conditioner will have an independent control system dedicated to it.

B. Distributed Control System

The main feature of these types of system is emergency shut-down. With this system you can present or change the control parameters or several similar devices, for example, the thermostat of several air conditioners and their ON/OFF timings.

C. Central Control System

These are computerized systems programmed to handle all functions of multiple utilities like air conditioning, home entertainments, doors, windows, refrigerators, bulbs and cooking systems, all at the same time regardless of whether you are at home or away. You can connect to the control system through telephone or internet from anywhere in the world.

2.1.4.1 Home Automation Channels

The types of home automation system based on the carrier mode are:

I. Wireless System

Also available are wireless home automation systems that utilize radio-frequency technology. They are often used to operate lights, sometimes in conjunction with a hardwired lighting control system.

II. Hardwired Systems

Wired, or “hardwired” home control systems are the most reliable and expensive. These systems can operate over a high-grade communication cables such as Category 5 or 5e, or their proprietary “bus” cable. That is why it is best to plan for them when a house is being constructed. Hardwired systems can perform more tasks at a time and do them quickly and reliably, making them ideal for larger homes. They can also integrate more systems in the home, effectively trying together indoor and outdoor lighting, audio and video equipment, system security, even the heating and cooling system into one control package that will be easy and intuitive to operate.

2.1.5 Home Automation Implementation Platforms

Home automation can be implemented over a number of platforms namely: Arduino Microcontroller, RS232 serial communication, Ethernet, Bluetooth, Infrared and GSM. Each platform has its own peculiarity and area of application.

1) 2.1.5.1 Ethernet

Ethernet defines a number of wiring and signaling standards for the physical connection of two or more devices together. Ethernet was originally based on the idea of computers communicating over a shared coaxial cable acting as a broadcast transmission medium. The method used show some similarities to radio systems, although there are fundamental differences, such as the fact that it is much easier to detect collisions in a cable broadcast system than a radio broadcast. The common cable providing the communication channel was likened to the ether and it was from this reference that the name "Ethernet" was derived [7][8]. From this early and comparatively simple concept, Ethernet evolved into the complex networking technology that today underlies most local area networks. The coaxial cable was replaced with point-to-point links connected by Ethernet hubs and/or switches to reduce installation costs, increase reliability and enable point to point management and troubleshooting. StarLAN was the first step the evolution of Ethernet from a coaxial cable hub to a hub-managed, twisted-pair network. The advent of twisted-pair wiring dramatically lowered installation costs relative to competing technologies, through the physical connections, Ethernet stations communicate by sending each other data packets, blocks of data that are individually sent and delivered.

Despite the significant changes in Ethernet from a thick coaxial cable bus running 10 Mb/s to point-to-point links running at 1 Gb/s and above, all generations of Ethernet (excluding early experimental versions) share the same frame formats (and hence the same for higher layers) and can be readily interconnected. And due to the ubiquity of Ethernet, the ever-decreasing cost of the hardware needed to support it, and panel space needed by twisted pair Ethernet, most manufacturers now build the functionality of an Ethernet card directly into computer and laptop motherboards, eliminating the need for installation of a separate network card [9].

2.1.5.2 Internet Protocol Control System

Internet Protocol (IP) control automation system uses the internet, gives, each devices under its control an Internet Protocol address, and creates a local area network (LAN) in the home. Hence, the home can be interacted with over the internet with a possibility of live video streaming and real-time control.

2.1.5.3 Microcontroller

A microcontroller is a single-chip computer in which the entire computer system lies within the confines of the integrated circuit chip (Byte, 2002). The microcontroller on the encapsulated silver of silicon has features similar to those of our standard personal computer. Its ability to store and run unique programs makes it extremely versatile, and its ability to perform maths and logic functions allows it to mimic sophisticated logic and electronic circuits. Microcontrollers are used in automatically controlled products and devices, such as automobile engine control system, remote controls, office machines, appliances, power tools and toys. Hence, microcontrollers do not function in isolation, they accept input from one or more devices and provide output to other devices within a given system, in fact, they are responsible for the intelligence in most smart devices in the consumer market.

a) 2.1.5.3.1 Arduino Uno Microcontroller

The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 Digital pins, 6 Analog pins, and programmable with the Arduino IDE (Integrated Development Environment) via a type B USB cable. It can be powered by the USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts [8].

Figure 1: Arduino Uno Microcontroller

b) 2.1.5.3.2 NodeMCU

NodeMCU is an open source IoT platform. It includes firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module. The term "NodeMCU" by default refers to the firmware rather than the development kits. The firmware uses the Lua scripting language. (Wikipedia, NodeMCU, 2019). NodeMCU Dev Kit has Arduino like Analog (i.e. A0) and Digital (D0-D8) pins on its board. It supports serial communication protocols i.e. UART, SPI, I2C etc. Using such serial protocols we can connect it with serial devices like I2C enabled LCD display, Magnetometer HMC5883, MPU-6050 Gyro meter + Accelerometer, RTC chips, GPS modules, touch screen displays, SD cards etc (ElectronicsWings, 2010)

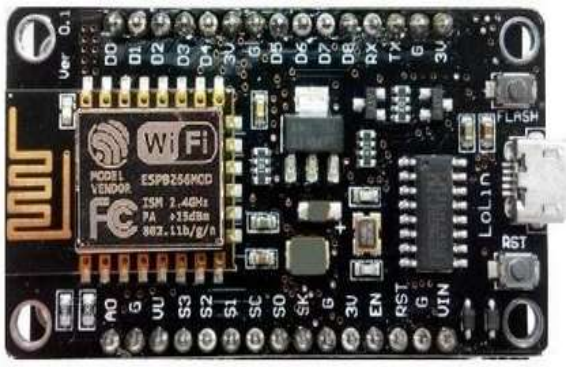

Figure 2: NodeMCU

As per our survey, there exist many systems that can control home appliances using android based phones/tablets. Each system has its unique features. Following models describes the work being performed by others.

2.2.1 Android Voice Controlled Home Automation System

This presents the design of Home Automation System (HAS). This system is designed to assist and provide support in order to fulfill the needs of elderly and disabled in home. The switch mode and voice mode are used to control the home appliances. The video feedback is received in the android application which streams the video of IPCamera. The main control system implements wireless technology to provide remote access from smart phone.

The project's objective was to Control Home Appliances through voice mode using an Android smart phone. (Sabin Adhikari, 2014)

2.2.1.1 Tools and Technology used for the design of the system

The following tools and technology were used:

i. Raspberry Pi Computer
ii. Wi-Fi Adapter
iii. Android device
iv. Electromagnetic Relays

2.2.1.2 Advantages of Android Voice Controlled Home Automation Project

The project has the following advantages:

i. Ability to Control Home appliances Wirelessly
ii. Ability to control Home appliances using voice commands such as "POWER ON" and "POWER OFF".

2.2.1.3 Disadvantages of Android Voice Controlled Home Automation Project

The system has the disadvantages/Limitations:

i. Android devices having API version lower than 16 requires internet access to convert the speech data to string data.
ii. During control, external noises (voice) may affect result
iii. The speech instruction that we command in our voice may not give exact result as expected hereby leading to inefficient control of devices.

2.2.2 Other Related works

Similar work in [10], presents the ARM based automation system that can monitor and control home appliances and able to establish successful communication with unknown outdoor person or visitor. This system not only provides Smart Home Automation as well as it provides smart communication system which provides communication with unknown visitors visiting home. In the first phase i.e. smart home automation system phase commands received from user cell phone and present sensor conditions, microcontroller system send signal through its port to switch ON/OFF appliances like light, fan, siren etc was done. But in the second phase presents incorporated features to establish successful communication with unknown visitors visiting home. In this phase doorbell switch acts as a mediator that is when no one at home, after some pre-specified delay, call will be established with user through cell phone this new feature provides a user opportunity to establish communication and avoid any losses or event due to no contact at all. ARM LPC-2148 Microcontroller and cell phone can make possible smart home automation.

It is found in [8], presents smart home automation system using AVR microcontroller. This system incorporates with sensors, microcontroller and Bluetooth module to provide automation capability to various appliances. This system can monitor the changes in temperature, lighting, detect fire and keep a check on the safety of the house.

[3] Implemented Internet based wireless flexible solution where home appliances are connected to slave node. The slave nodes communicate with master node through RF and master node has serial RS232 link with PC server. The nodes are based on PIC 16F877 µc. PC server is formed of a user interface component, the database and the web server components. An Internet page has been setup running on a Web server. The user interface and the Internet front end are connected to a backend data base server. The control of devices is established and their condition is monitored through the Internet.

II. METHODOLOGY

The development of this project follows a structured software engineering methodology with the *waterfall model*. It is suitable for projects whose requirements are well understood at the beginning of the project. The choice of this methodology emanates from the fact that basic requirements of this project are well and clearly defined. Other enhancements could come in form of feedback which could be incorporated to enhance the system. The stages involved include:

a) Problem identification
b) Requirement analysis
c) System design
d) Implementation
e) Testing
f) Deployment
g) Maintenance

Figure 2 is a diagrammatic depiction of structured engineering methodology with Waterfall Model

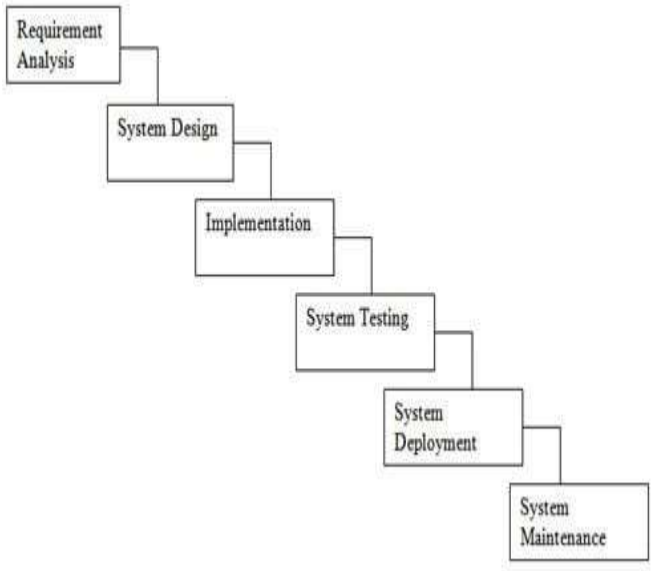

Figure 2 Waterfall Model

A. 3.2 System Analysis

System Analysis is a systematic method of figuring out the basic elements of a project and deciding how to combine them in the best way to solve a problem. It involves solving a problem through analyzing the requirements of a system and designing systems by applying analysis and design techniques.

The design of a Smart Home Control System involves the analysis, identification of problems with the existing system, design and implementation of the new system and final testing [11].

1) 3.2.1 Data gathering Technique

Information gathering are the several approaches deployed in data collection. These data serve as justification to the solution of the project. These will provide tangible inputs for the completion of the project in a more accurate and precise manner. A couple of approaches can be classified into two: primary and secondary sources.

A. Primary Source

These include data collection from individuals directly concerned with the existing system.

The approaches used here include observations, interviews etc.

i. **Observation:** Impartial observations were made over the existing system from the angle of a typical home appliance user in Nigeria. The usability and efficiency of the existing system was also observed.

ii. **Interviews:** Oral interviews were conducted on the users of the existing Home Appliance Control System. Home appliance users were interviewed to obtain the challenges they faces with the old system.

B. Secondary Source

This class of data collection was based on data collected from the following:

i. Online Journals
ii. Websites
iii. Past Home Control Projects

2) 3.2.2 Analysis of the Existing System

The Manual Control of Home Appliances is a way in which people controlled home appliances by going to the various locations of those appliances and controlling them using a designated switch mostly for the purpose of powering those appliances either on or off.

This control method brought displeasing stress and discomfort to home appliances users as it involved having the user at the location of those appliances to make changes in the current state or control.

3) 3.2.1 Advantages of the existing System

The existence of Manual Home Control System irrespective of the stress and displeasing comfort it brings to home appliances users, has several significance which includes:

i. Security: Manual Home Control System is less prone to system penetrators and/or hackers.

ii. Proper care of appliances: Home appliance users tend to handle manually used appliances with care and ease as rough handling could shorten the lives of those appliances.

iii. Usage of home appliances at the right time

4) 3.2.4 Disadvantages of the Existing system

The existing system has the following limitations:

i. The Operator has to move to the location of the appliances' switches.
ii. Displeasing stress and Discomfort in home appliance(s) control.

5) 3.2.5 High Level Model of the Proposed System

The high level model of the proposed system is a top level abstract view of the proposed system represented by the Process model (process decomposition diagram) and Use case diagram.

Process model-This illustrates the processes or activities that are performed and how data moves among them. Below is a high level diagram for the proposed system.

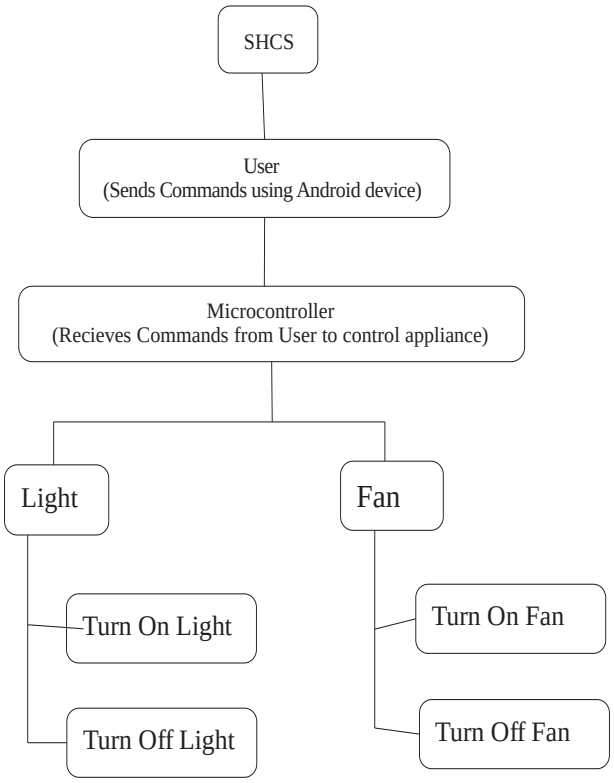

Figure 3: High Level Model Diagram:

3.2.6 Analysis of the Proposed System

Smart Home Control System is a lost cost wireless system that controls home appliances remotely and wirelessly to assist and provide support in order to fulfill the needs of the people in the home. It is a system designed to solve problems involving the lack of ease and comfort in the use and control of home appliances and generally bring technology and automation into various home appliances and devices.

3.2.7 Justification of the Proposed System

The design and implementation of this System would be significant in the following ways:

i. It would grant home appliances users extreme convenience as they can conveniently control or operate devices wirelessly.
ii. Gives added safety on appliances. With a Smart Home Control Technology, users will have full control of home appliances (lights, fans etc.).
iii. It can help save a lot of time. Home appliances users would not have to waste their time to go back home to turn off a light or any other appliance which was forgotten powered on.
iv. Having a Smart Home Control System contributes to the Economy because it helps reduce the wasted energy at home.

a) 3.2.7.1 Tools used for the design of the proposed system

The following tools were used for the design of a smart home control system. They include:

i. The Arduino Uno Microcontroller
ii. NodeMCU Wi-Fi Module Development Board
iii. Electromagnetic Relays

b) 3.2.7.1.1 Arduino Uno Microcontroller

The **Arduino Uno** is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter [12].

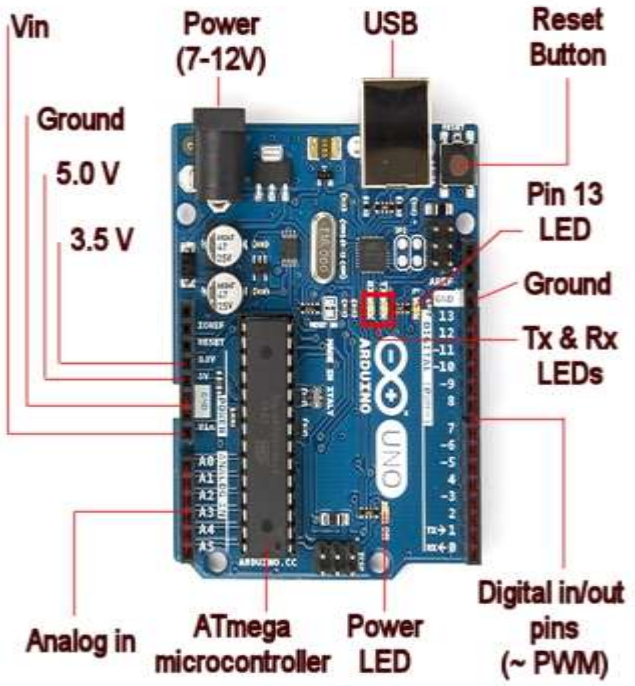

Figure 4: Arduino Uno (GPIO and Power Pins)

c) 3.2.7.1.2 NodeMCU Wi-Fi Module Development Board

NodeMCU is an open source IoT platform. It includes firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module. The term "NodeMCU" by default refers to the firmware rather than the development kits. The firmware uses the Lua scripting language. (Wikipedia, NodeMCU, 2019). NodeMCU Dev Kit has Arduino like Analog (i.e. A0) and Digital (D0-D8) pins on its board. It supports serial communication protocols i.e. UART, SPI, I2C etc. Using such serial protocols we can connect it with serial devices like I2C enabled LCD display, Magnetometer HMC5883, MPU-6050 Gyro meter + Accelerometer, RTC chips, GPS modules, touch screen displays, SD cards etc (ElectronicsWings, 2010)

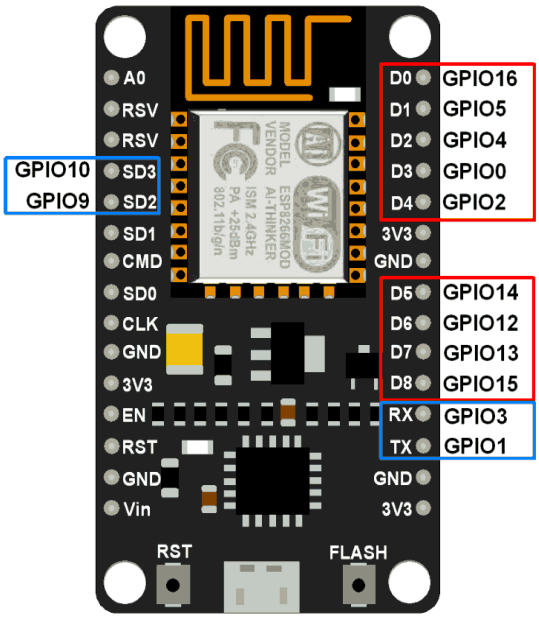

Figure 5: NodeMCU (GPIO Pins)

d) 3.2.7.1.3 Electromagnetic Relays

A **Relay** is an electrical switch. It opens and closes under control of electric current applied. The switch is operated by an electromagnet to open or close sets of contacts. When a current flows through the coil, the generated magnetic field attracts an armature, mechanically linked to a moving contact. The movement either makes or breaks a connection with a fixed contact [5].

Figure 6: Electromagnetic Relay

B. 3.3 System Design

System design is an approach systematically taken in the design of a system. This approach takes into consideration all variables surrounding it, which includes the architecture, required hardware and software and as well as the data flow, how it changes from one point of the system to the other.

1) 3.3.1 Objectives of the Design

This design is basically centered on the development of a System that will control electrical home appliances by any Smart Device with WIFI capability. Also, to provide an easy, affordable and convenient way to control home appliances both locally and over the internet.

3.3.2 System Architecture

System Architecture refers to the structure of a Software System. It is a calculated model that characterizes the structure, conduct, and more perspectives on a framework. This segment gives a state structure of the proposed system, the connections among the parts and also the guideline overseeing their plan. This segment provides a structure of the proposed system which includes the connections amongst all the components in the system.
Figure 8 shows the architecture of the entire system.

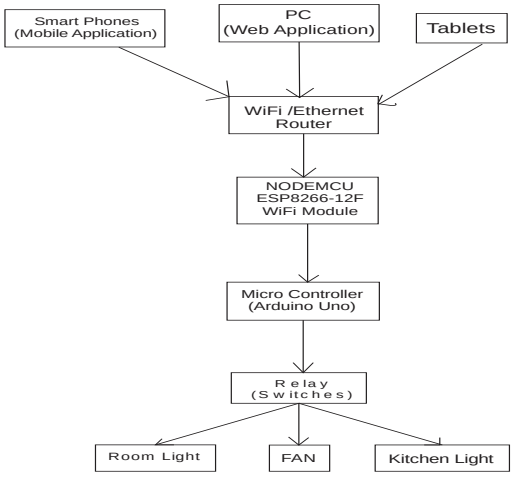

Figure 7: System Architecture

3.3.3 Main Menu Design

The main menu of the system was designed in such a way that it provides access to various parts of the system. The main menu is designed with the end goal that a user is authenticated before being granted access to other submenus to control appliances.
This main menu design was intended to make the introduction of the use of the entire framework effectively open by a typical client of the system without express headings.

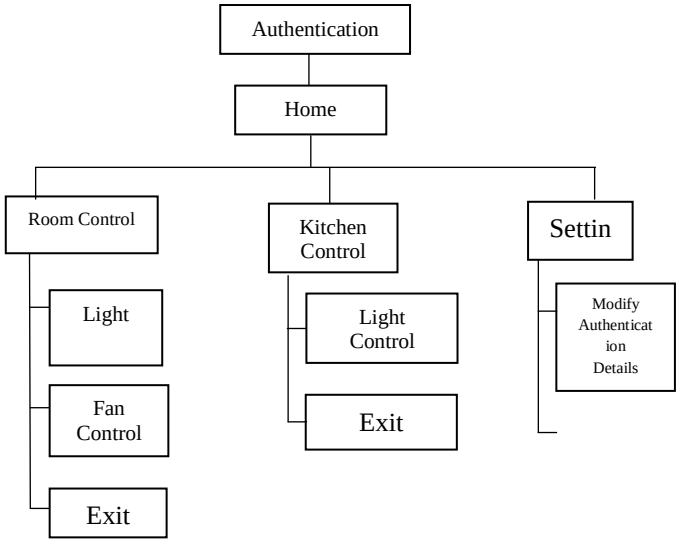

Figure 8: Main Menu Design

3.3.4 Sub Menu Design

The Sub Menu design is the design of the various sub menus or sub Systems that make up the entire Home Control System. These Sub Menus include:

i. Room Control Sub Menu
ii. Kitchen Control Sub Menu
iii. Settings Sub Menu

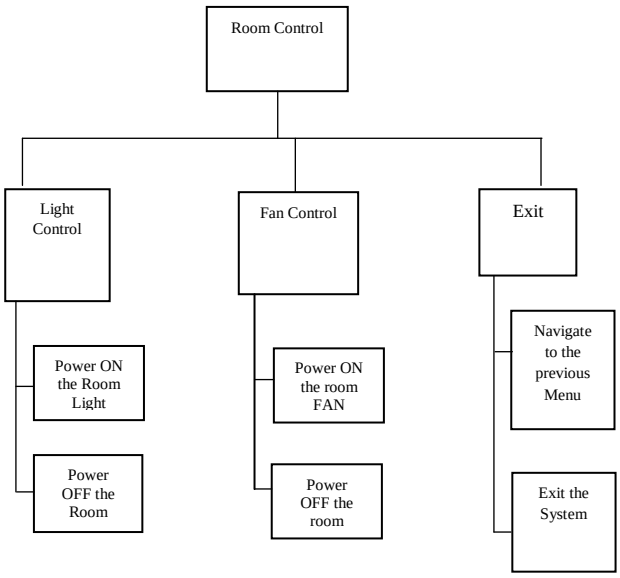

Figure 9: Room Control Sub Menu Design

These three sub systems interoperate to achieve a successful Smart Home Control System which is interactive and easy to operate.

3.3.4.1 Room Control Sub System Design

The Room control system was designed in such a way that the relays controlling the Room were connected to the Arduino Uno Microcontroller which receives commands from the NodeMCU Microcontroller) and triggers those relays which controls the appliances. The appliances Connected to room control relays include:

i. The room light
ii. The room Fan

a) 3.3.4.2 Kitchen Control Sub System Design

The Kitchen control system was also designed in a way that the relay controlling the room light was connected to the Arduino Uno Microcontroller which also triggers those relays and controls the appliances.

2) 3.3.5 Program Module Design

The system basically consist of several modules. They represent the major functionality of the system which is to control home appliances. These modules include:

i. **NodeMCU Wi-Fi Module creates a WEB server** which provides a web interface through which home appliance users would connect to using an End Device (with Wi-Fi and web capabilities).
ii. **NodeMCU Wi-Fi Module receives request** from the WEB Client (End-Devices).
iii. **NodeMCU Wi-Fi Module processes request and sends command** to the Arduino Microcontroller.
iv. **Arduino Microcontroller receives and processes command** from the NodeMCU Wi-Fi Module and then controls the relays which is connected to the home appliances.

3.3.5.1 NodeMCU Receiving and processing requests from the web client and sending command to Arduino

This module design has to do with programming the NodeMCU Wi-Fi Module to receive request from Clients (End-Devices), processing the request and sending a command to the Arduino Uno microcontroller. Data is sent from the NodeMCU Wi-Fi Module to the Arduino Uno Microcontroller in the form of an integer data type (8bit), and it is sent through the Communication Serial Pins which includes the RX (Receive) and TX (Transmit).

3.3.5.2 Kitchen Control Module Design (Arduino Receiving 8bit data from NodeMCU and controlling the relay)

This module has to do with programming of the Arduino Uno Microcontroller to receive and process an 8bit data from the NodeMCU Wi-Fi Module. The Arduino Uno then controls the relays depending on the command/instruction received from the NodeMCU Wi-Fi Module. The control of the relay is done by sending a “HIGH” (5volts) or a “LOW” (0volts) to the relay.

3.3.10 Input / Output Format

The system only takes input from the user and it is being done in the form of Toggle Buttons. These Buttons include:

i. Room Light Power On
ii. Room Light Power Off
iii. Room Fan Power On
iv. Room Fan Power Off

3.3.11 Algorithm

An algorithm is a step by step (procedures) set of instructions which is followed to carry out a task or solve a problem. The steps in which the proposed SHCS (Smart Home Control System) followed in order to control appliances in the home wirelessly are as follows:

Step 1: Start
Step 2: NodeMCU connects to home Local Area Network via Wi-Fi and displays local IP Address on LCD screen.
Step 3: NodeMCU creates web server after successful connection to Home Network and waits for Clients (Devices) to connect to the server.
Step 4: NodeMCU Receives HTTP request from web client
Step 5: Process request and determine instruction
Step 6: Node MCU sends command to Microcontroller
Step 7: Microcontroller processes command and controls relay by sending a “HIGH” (5volts) or a “LOW” (0volts) to the relay.

Step 8: NodeMCU waits for next HTTP request from client
Step 9: Go back to Step 4

4.1 System Implementation

In SDLC, implementation stage is the next stage after the system design stage.
It is the part of software development process where system coding is actually done.
For effective implementation of the system, system requirements are to be met. These requirements include:

i. Hardware requirements
ii. Software requirements

4.1.1 Hardware Requirements

Hardware are those computer devices that we can feel, touch and carry about. They include Monitor, etc. The hardware requirements is the specifications of the hardware systems required to use the system.
For effective use of this system, a user would be required to have the following hardware devices:

i. A **Router** used for Home Local Area Network (LAN), which has the ability to connect to devices via Wi-Fi.
ii. A **Smart Phone** running on Android OS.

4.1.2 Software Requirements

Software is the collection of computer programs (instruction) that enables computer users operate and communicate with the computer hardware.
Google Chrome web browser

4.1.3 Program Development

These consist of all the process involved in the design of a system.
These processes include:

i. The planning phase
The planning phase is the process of having an in-depth understanding of why a system should be built and determining how the system is going to be built. It has two steps: during the project initiation and when the project has been approved.
ii. Analysis phase
The analysis phase determines and defines who the user(s) of the system would be, what the system will do, and where and when it will be used. During this phase investigation is carried out to identify any other system and identifies improvement to be done.
iii. Design phase
The design phase decides the operation of the system in terms of the hardware, software, and network infrastructure that will be in place; the user interface, forms, and reports that will be used; and the specific programs, databases, and files that will be needed. Although most of the strategic decisions about the system are made in the development of the system concept during the analysis phase, the steps in the design phase determine exactly how the system will operate.
iv. Implementation phase
This is the phase where the designed system is implemented by coding the design and deploying the new/proposed system after which maintenance is carried out.

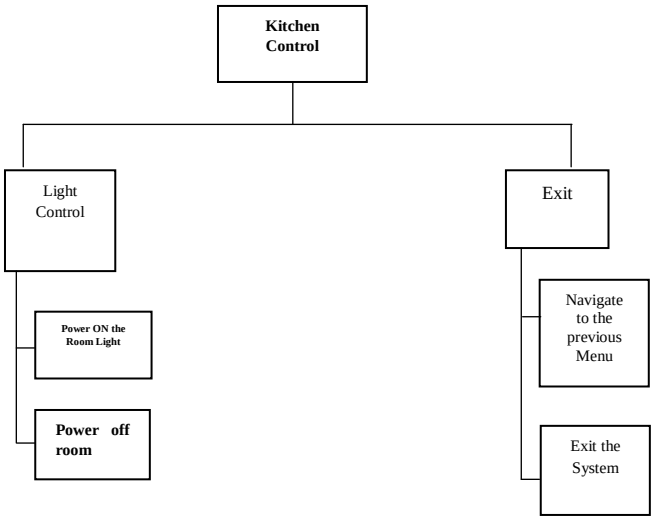

Figure 10: Kitchen Control Sub Menu Design

4.1.3.1 Choice of Programming Language

The NodeMCU module uses the ESP8266 Wi-Fi Module and its firmware can be flashed (replaced) by an Arduino Sketch. Therefore, the NodeMCU Wi-Fi module and the Arduino Uno microcontroller runs machine code compiled from any programming language that has a compiler for Arduino instruction set.

The Arduino compiler/IDE accepts C and C++ as its native language for writing Arduino sketch. As a result of this, the C++ programming language was used to program the system.

Other programming languages used for the development of the system include:

i. HTML (Hyper Text Markup Language)
ii. CSS (Cascading Style Sheet)

a) 4.1.3.2 Language Justification

I. C++ programming language: C++ is a statically-typed, free-form, (usually) compiled, multi-paradigm, intermediate-level general-purpose middle-level programming language.
II. HTML: Hyper Text Markup language is a mark-up language which was adopted in laying out the user Interface pages that make up the front end of the System.
III. CSS: Cascading Style Sheet, it was used in styling the User Interface of the system.

3) 4.1.4 Main Menu Implementation

Figure 10: Screen shot of the main menu of the system

4.1.5 Sub Menu Implementation

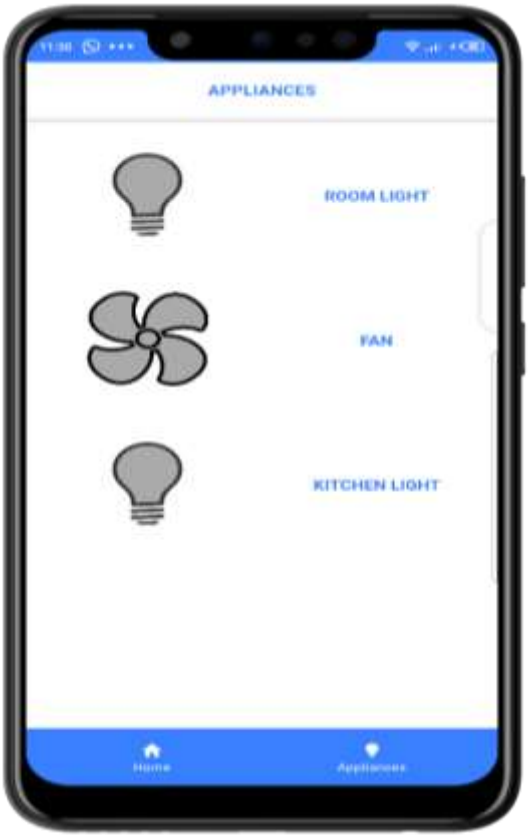

Figure 11: Screen shot of the Sub Menu of the system

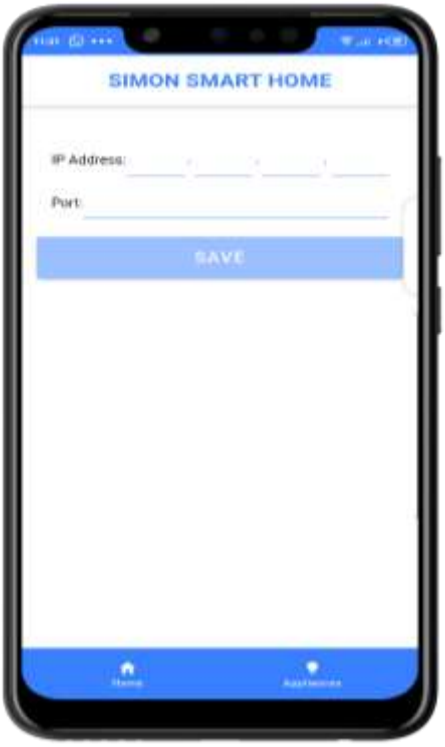

Figure 12: Screen shot of the Setup menu of the system

C. 4.2 System Testing

System testing is the testing of a complete and fully integrated software product[7]. System testing is split into two categories, they include:

i. White Box testing
ii. Black Box testing

4.2.1 Test Plan

The testing of the SHCS is done in two forms, White Box testing and Black Box testing.

a) 4.2.1.1 White Box Testing

This has to do with testing the inner workings of the system to determine if there is an accurate and lossless transfer of data

i. From the Web Client to the NodeMCU module
ii. From the NodeMCU module to the Arduino microcontroller
iii. Finally, from the Microcontroller to the relays.

b) 4.2.1.2 Black Box Testing

This has to do with testing the usability and efficiency of the SHCS Smart Home Control System from the users' perspective

4.3. Results

Result is output realized from the development of a project. They are the changes or effects expected to take place after implementing the project. The results are generally positive improvements to the lives of the beneficiaries[8].

4.3.1 Actual Test Result versus Expected Test Result

Table 4.1 Test Results

S/N	Data Tested	Expected Result	Actual Result
1	Powering the Room Light Bulb ON/OFF	HTTP request (power ON or OFF room light) would be sent wirelessly from the Client device to the NodeMCU Wi-Fi Module through the web server over the Wi-Fi network.	The NodeMCU receives the request and instructs the Arduino Microcontroller to trigger the relay controlling the room light. The Microcontroller performs the task (triggered the relay controlling the Light Bulb)
2	Powering the room Fan ON/OFF	HTTP request (power ON or OFF room Fan) would be sent wirelessly from the Client device to the NodeMCU Wi-Fi Module through the web server over the Wi-Fi network.	The NodeMCU receives the request and instructs the Arduino Microcontroller to trigger the relay controlling the room fan. The Microcontroller performs the task (triggered the relay controlling the Room Fan)

4.3.2 Performance Evaluation

During performance evaluation, the following data were used to determine the efficiency and effectiveness of the system, they include:

i. Was the time used in controlling the appliances reduced?
ii. Was the controlling of those appliances efficient?
iii. Did you experience ease and comfort in the control of those appliances?

The table below shows a record of the response gotten

Table 4.2 Performance Evaluation Results

S/N	Evaluation criteria	Yes	No
1	Was the time used in controlling the appliances reduced?	8	2
2	Was the controlling of those appliances efficient?	9	1
3	Did you experience ease and comfort in the control of those appliances?	7	3

4.3.3 Limitation of the Result

The Result of the SHC system was limited to the following functions:

i. To determine if the use and control electrical home appliances wirelessly was easy and more convenient than the old system
ii. To determine if there was help and support in the use and control of home appliances
iii. To determine if there was introduction of advanced technology in the use and control of home appliances

4.4 System Security

In the development of this system, various steps taken for the protection of information and property from theft, corruption and other types of damage, while allowing the information and property to remain accessible and productive. System security includes the development and implementation of security countermeasures.

System Password is the security used for this system to prevent control and use of home appliances by unwanted users.

4.5 System Integration

This is the combination of all the components or subsystems into one functional system and ensuring that the subsystems function as required.

It involves the combining the various sub modules involved in the system to make up a functional system.

5.1 Summary

In the past, the manual use and control system of home appliances brought displeasing stress and discomfort to home appliance users. As a result of this displeasing stress and discomfort, the design and implementation of a smart home control system came into place.

The Smart Home Control System, is a scalable, flexible and user friendly system designed with a structured Software Engineering Methodology to solve problems involving the lack of ease and comfort in the use and control of home appliances, provide help and support for home appliance users and generally bring technology and automation into various home appliances and devices.

The design of the system was done using tools such as the Arduino Uno microcontroller, NodeMCU WIFI Module, Ethernet + WIFI Router, Smartphone running on Android 2.3+ and Arduino IDE platform with C++ programming language. The result of this research has proven that the control of home appliances can be done wirelessly.

The system when implemented, was able to control electrical appliances and devices in the home with a relatively low cost design, user-friendly interface and ease in installation.

5.2 Conclusion

It is clear from this project that the easy and convenient use and control of home appliances such as lights and fan can be done wirelessly using a smart phone and with a low cost design and a user-friendly interface.

The designed SHC system was also tested on other home appliances such as Television, Amplifier/Sound Systems, Heating Systems and many more (as long as the maximum

power rating of the system has not exceeded the power rating of the relay).

5.3 Recommendations

Following the complete design and implementation of this SHC system, it is recommended that all homes adopt the use of the new system as it enhances the use of technology in the home and also:

i. Brings Ease and Comfort in the use and control of home appliances
ii. Provides Help and support to home appliances users in the use and control of electrical home appliances.

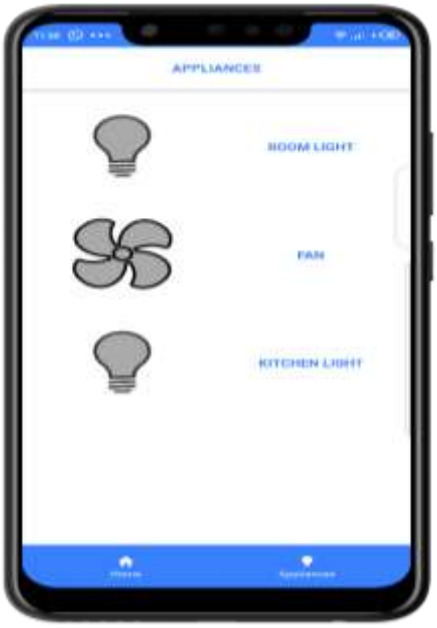

Figure 13: Screen shot of the Sub Menu of the system

Figure 14: Screen shot of the Setup menu of the system

4.2 System Testing

System testing is the testing of a complete and fully integrated software product (guru99, 2019). System testing is split into two categories, they include:

iii. White Box testing
iv. Black Box testing

2) 4.2.1 Test Plan

The testing of the SHCS is done in two forms, White Box testing and Black Box testing.

4.2.1.1 White Box Testing

This has to do with testing the inner workings of the system to determine if there is an accurate and lossless transfer of data

iv. From the Web Client to the NodeMCU module
v. From the NodeMCU module to the Arduino microcontroller
vi. Finally, from the Microcontroller to the relays.

4.2.1.2 Black Box Testing

This has to do with testing the usability and efficiency of the SHCS Smart Home Control System from the users' perspective

III. RESULTS AND DISCUSSION

Result is output realized from the development of a project. **They** are the changes or effects expected to take place after implementing the project. The results are generally positive improvements to the lives of the beneficiaries (Alonzi, 2019).

4.3.1 Actual Test Result versus Expected Test Result

4.3.2 Performance Evaluation

During performance evaluation, the following data were used to determine the efficiency and effectiveness of the system, they include:

iv. Was the time used in controlling the appliances reduced?
v. Was the controlling of those appliances efficient?
vi. Did you experience ease and comfort in the control of those appliances?

The table below shows a record of the response gotten

4.3.3 Limitation of the Result

The Result of the SHC system was limited to the following functions:

iv. To determine if the use and control electrical home appliances wirelessly was easy and more convenient than the old system
v. To determine if there was help and support in the use and control of home appliances
vi. To determine if there was introduction of advanced technology in the use and control of home appliances

4.4 System Security

In the development of this system, various steps taken for the protection of information and property from theft, corruption and other types of damage, while allowing the

information and property to remain accessible and productive. System security includes the development and implementation of security countermeasures.

System Password is the security used for this system to prevent control and use of home appliances by unwanted users.

4.5 System Integration

This is the combination of all the components or subsystems into one functional system and ensuring that the subsystems function as required.
It involves the combining the various sub modules involved in the system to make up a functional system.

5.1 Summary

In the past, the manual use and control system of home appliances brought displeasing stress and discomfort to home appliance users. As a result of this displeasing stress and discomfort, the design and implementation of a smart home control system came into place.

The Smart Home Control System, is a scalable, flexible and user friendly system designed with a structured Software Engineering Methodology to solve problems involving the lack of ease and comfort in the use and control of home appliances, provide help and support for home appliance users and generally bring technology and automation into various home appliances and devices.

The design of the system was done using tools such as the Arduino Uno microcontroller, NodeMCU WIFI Module, Ethernet + WIFI Router, Smartphone running on Android 2.3+ and Arduino IDE platform with C++ programming language. The result of this research has proven that the control of home appliances can be done wirelessly. The system when implemented, was able to control electrical appliances and devices in the home with a relatively low cost design, user-friendly interface and ease in installation

IV. CONCLUSION AND FUTURE SCOPE

It is clear from this project that the easy and convenient use and control of home appliances such as lights and fan can be done wirelessly using a smart phone and with a low cost design and a user-friendly interface.

The designed SHC system was also tested on other home appliances such as Television, Amplifier/Sound Systems, Heating Systems and many more (as long as the maximum power rating of the system has not exceeded the power rating of the relay).

5.3 Recommendations

Following the complete design and implementation of this SHC system, it is recommended that all homes adopt the use of the new system as it enhances the use of technology in the home and also:

Brings Ease and Comfort in the use and control of home appliances Provides Help and support to home appliances users in the use and control of electrical home appliances.

REFERENCES

[1] S. Kumar, "Ubiquitous Smart Home System Using Android app," International Journal of Computer Networks & Communications, **vol. 6, pp. 33-43, January 2014.**

[2] Li Yueheng, Duan Zhiqiang, Yang Dongwei. “Design of smart home system based on Android and Cloud services,” Microcomputer & Its Applications, **2016, vol. 14, pp. 79-82.**

[3] A. McEwen, Designing the Internet of Things, London: John Wiley & Sons, **2013**

[4] S. K. S. L. U. B. Sabin Adhikari, Android Controlled Home Automation, Sabin Adhikari, **2014.**

[5]] R. Piyare, "Ubiquitous Home Control and Monitoring System using Android-based Smart Phone," International Journal of Internet of Things, **vol. 2, pp. 5-11, 2013.**

[6] M. S. H. Khiyal, A. Khan, and E. Shehzadi, "SMS Based Wireless Home Appliance Control System (HACS) for Automating Appliances and Security," Issues in Informing Science and Information Technology, **vol. 6, pp. 887-894, 2009**.

[7] R. Piyare and M. Tazil, "Bluetooth based home automation system using cell phone," in IEEE 15th International Symposium on Consumer Electronics, Singapore, **2011, pp. 192 – 195.**

[8] A. Alonzi, "Project Results," 2019. Available: https://proposalsforngos.com/project-results-outputs-outcomes-impact/.

[9] Zhang, Y., Zhao, G., & Zhang, Y. A smart home security system based on 3G. In Computer Science-Technology and Applications, 2009. IFCSTA'09. International Forum on **(Vol. 2, pp. 291-294).**

[10] B. C. Limited, First Steps with Embedded Systems, Canada, **2002.**

[11] S Kumar Ubiquitous Smart Home System using Android Application, *International Journal of Computer Networks & Communications* **vol. 6, no. 1 pp. 33-43, 2014**

[12] V Pimente and B G Nickerson “Communicating and Displaying Real-Time Data with WebSocket in IEEE Internet Computing” **2012**

AUTHORS PROFILE

Mr. H. A. Okemiri pursed Bachelor of Science from Ebonyi state university, Abakaliki, Nigeria, in 2012 and Master of Science from the same university in year 2018. He is currently pursuing Ph.D. and currently working as Assistant Lecurer in Department of Computer Science/Informatics, Alex Ekwueme Federal University Ndufu Alike Ebonyi State, Nigeria since 2019. He is a member Nigeria Computer Society since 2018, He has published more than 15 research papers in reputed international journals and it’s also available online. His main research work focuses on Machine Learning, Internet of Things, Cloud Security and Privacy, Big Data Analytics, Data Mining. He has 6 years of teaching experience and 3 years of Research Experience.

S. C. Chukwu pursed B.Sc in Computer Science from Alex Ekwueme Federal University Ndufu Alike, Nigeria in year 2019. He is currently pursuing M.Sc in Computer Science at University of Bedfordshire, Luton England. He is a Software Engineer, hardware professional and technician, well-versed in technology and writing computer softwares with passion for developing innovative systems that expedite the efficiency and effectiveness of organizational success. His main research work focuses on Algorithms, Computational Intelligence, IoT and Data Mining. He has 4 years of software development experience using several programming technologies.

Mr. E.O. Uche-Nwachi pursued Bachelor of Science (Computer Science and Management) and Master of Science (Geoinformatics) from University of the West Indies, Trinidad and Tobago. He is currently pursuing Ph.D and is a lecturer at the Department of Computer Science and Informatics at Alex Ekwueme Federal University Ndufu Alike Ikwo, Ebonyi State, Nigeria. He worked previously at Republic Bank of Trinidad as a Data Analyst and Programmer. He is a member of Association of Computer Professionals (UK) and Nigeria Computer Society. He has published more than four research papers in a reputed international journals. His research work focus on Online voting, Computer Based Forecasting, Using Object Orientation Programming(OOP) to Model Geographic Information System (GIS), IOT, Data Mining and Data Analytics. He has 4 years of teaching experience and 5 years of research experience.

