GSM-Based Home Appliances Control System for Domestic Power Users in Ghana*

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Abstract

With the rising increase in population and its attendant increase in the consumption of energy, there is a great need to conserve energy in every way possible. The inability to access and control the appliances from remote locations is one of the major reasons for energy wastage in Ghana. This project presents the development and implementation of a Global System for Mobile Communication (GSM) based remote control system for electrical appliances and lighting that enables complete control of the interface on which it is based. GSM Shield was used for receiving Short Message Service (SMS) from the homeowner's mobile phone that automatically enables an Arduino microcontroller to take the necessary actions like switching OFF and ON electrical appliances such as fan, light, air-conditioner, supply mains and so on. Basically, it reads the SMS and acts according to the message. Similar products commercially available are Internet dependent and so lack the true sense of real mobility and security. However, the present GSM-based remote control system allows the homeowner to control household appliances from anywhere using the mobile phone and also prevents unauthorised access to these appliances. Crucial to the present system is the provision of security on detection of intrusion via SMS using GSM technology. This GSM-based home appliances control system is recommended for implementation in every home to tackle the rampant energy wastage in Ghana.

Keywords: Global System, Short Messages Service, Home Appliances, Communication, Power

1 Introduction

The development of digital information has led to the rapid change in human lifestyle. The use of electricity is very important as one of the main sources of energy that is vital in modern lives. As the years go by, technology has been ever evolving, and as a result, new means are being developed for easier and safer control of electrical devices for more efficient power management at homes and workplaces.

Most people inevitably tend to leave their lights, fans and other appliances on when leaving their homes resulting in energy wastages and inefficiencies. It is not always feasible to be physically present or near the vicinity of the home environment but whatever be the case, much effort should be done to moderate energy wastage. In Ghana, these wastages are very detrimental to industrial development. Consequently, available technologies need to be widened to eliminate or reduce these wastages in electricity usage. Negligence with regards to leaving lights and other electrical appliances on can lead to outrageous electricity bills, wastage of much needed power (electrical energy) and shorter life span of electrical devices or appliances.

This paper presents the design and implementation of a centralised remote lighting and appliances control system for smart home applications using GSM technology that generally reduces the cost of power consumption appreciably. This system is implemented using a customised user friendly mobile application. This same system implements intrusion detection, notification alerts and alarm functions.

Recent energy crisis in Ghana and the entire West African sub-region justifies the need for the present system because electrical energy is a limited resource that is not readily available. Therefore, we cannot afford to abuse the very little we have available. If we unintentionally leave any of the home electrical appliances (TVs, fan, bulbs) on, we should be able to access them remotely. Therefore, the remote controlling takes the control of the home beyond the home and directly to the hands of the home owners. Basically, if a simple mobile phone takes on the added responsibility to control the electrical appliances of any home, then the control has no geographical boundaries. The ever-increasing incline towards mobile services among Ghanaians makes it the logical choice when developing a system which can control home appliances and lighting from anywhere.

1.1 Home Automation

Home automation or Intelligent/Smart Home (SH) means automating daily tasks of electrical devices used in homes (Rahman *et al*., 2015). Automated

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homes are equipped with special facilities to enable occupants to control or program an array of electronic devices. For example, a homeowner on vacation can arm a home security system, control temperature gauges, switch appliances on or off, control lighting, program a home theater or entertainment system, and perform many other tasks. Generally, SHs are designed with the aim of building an environment that is aware of the things happening with the people in it.

Previously, automated devices were independent or, grouped in small independent systems. But the idea of giving them interoperability using a common "language" keeps growing. Consequently, the first Home Automation Systems (HASs) originated from the concept of home networking, full of possibilities, but this also included new factors to bear in mind. Some of these factors include interoperability, scalability, acceptability, security and limited services.

Home automation becomes smarter if the controlling can be done effectively from any remote place. The available technologies for this remote communication are the Internet, Mobile Telephony, Zigbee, and Bluetooth (Moraes *et al*., 2000).

1.2 Existing Home Automation Technologies

The introduction of Internet of Things (IoT) and other wireless technologies fueled many researches in HAS. Several wireless communication technologies that can support some form of remote sensing and control, remote data transfer and monitoring such as Wireless Fidelity (Wi-Fi), Radio Frequency Identification (RFID), Bluetooth, mobile telephony (GSM) have been used to actualize various unending levels of intelligence in homes.

Yan and Shi (2013) examined the feasibility of Bluetooth technology in HASs using Android smartphones without internet control. Devices were connected to a Bluetooth sub-controller, accessed and controlled by the smartphone via a mobile application using built-in Bluetooth connectivity but this technology is geographically limited in application.

Park (2012) proposed a mobile Internet Protocol (IP) based architecture and succeeded in the design of a smart home security and automation without any actual building and testing. Recent researchers have also used Web services, Simple Object Access Protocol (SOAP) and Representational State Transfer (REST) as an interoperable application layer to remotely access home automation systems.

Ciubotaru-Petrescu, *et al.* (2006) designed and implemented SMS-based control for monitoring systems. This system has three modules, viz; sensing unit for monitoring the complex applications, processing unit (microcontroller), and a communication module that uses a General Packet Radio Service (GPRS) modem or cell phone via serial port RS-232. The SMS is used for status reporting such as power failure. If the system can be used for industrial purposes, then surely, it also has domestic applications. Conte and Scaradozzi (2003) have again viewed HASs as Multiple Agent Systems (MAS).

Though the HACS technology seem promising, the major task of improving performance has attracted least research attention. Alkar and Buhur (2005) propose an Internet-Based Wireless HACS for Multifunctional Devices. Murthy (2008) explored Primary Health-care (PHC) Management for the rural population. His solution proposed the use of the mobile web-technologies providing the PHC services to the rural population. The system involves the use of SMS and cell phone technology for information management, transactional exchange and personal communication. Potamitis *et al.* (2003) and Jawarkar *et al.* (2008) proposed remote monitoring through mobile phone involving the use of spoken commands. The spoken commands are generated and sent in the form of text SMS to the control system and then the microcontroller based on the SMS received takes a decision to complete a particular task. Other systems include the introduction of a smart home management system over the Ethernet network based on Extensible Markup Language (XML) SOAP standards (Piyare and Lee, 2013).

HACSs till now have been based on data transmission via the internet which is not ubiquitous in Ghana and the entire sub region. The usage of spoken commands or speeches requires training of one's voice. However, most Africans are accent dominated. The uniqueness of this paper manifests in the use of GSM technology with an independent application which is user friendly and deployable on non-smart phones.

1.3 GSM and Communication Systems (Mobile Telephony)

GSM is a digital mobile telephony system that is widely used around the world. It uses a variation of Time Division Multiple Access (TDMA) and it is the most widely used of the three digital wireless telephony technologies (TDMA, GSM and CDMA). GSM digitizes and compresses data, then

sends it down a channel with two other streams of user data, each in its own time slot. In telecommunication, telephony encompasses the general use of equipment to provide voice communication over distances, specifically by connecting telephones to each other. The term mobile telephony is derived from original telephony to denote the communication that facilitates mobility using wireless technology. Mobile telephony offers services like voice and data transfer. Data transfer is done using SMS and some other enhanced data rate services like GPRS and EDGE. This paper harnesses the SMS data transfer service of the GSM.

SMS is a telecommunications protocol that allows the sending of short text messages (160 characters) to and from terminal equipment (Anon, 2016c). An SMS message is sent from a device to a SMS Center (SMSC), which, in turn, communicates with mobile networks to determine the subscriber's location. Then, the message is forwarded as a small data packet to the destination device. Subsequent messages sent by the original source device undergo the same process, also known as store and forward.

SMS is used as a means of monitoring and controlling systems because it is the easiest and the most available technology. The massive growth and poor infrastructure in many countries make voice and IP not feasible and reliable unless there is massive investment to improve upon the existing networks (Jaiswal, 2011). SMS will get through even when the network is busy for a long time. SMS monitoring and control also has its place in industrial systems, car parking systems, weather monitoring and alert systems, market information service, fire detection and security systems, agricultural irrigation system, smart patient communication systems, among others.

2 Resources and Methods Used

2.1 Resources

The design of this system makdes use of the following tools: Arduino IDE, MIT App Inventor 2, Arduino Uno R3, Linksprite SIM900 GSM Modem, 4-channel Relay Module, 20×4 LCD Display, PIR Based Motion Detector, Buzzer and the Desktop/Laptop computer.

2.2 Methods Used

2.2.1 Remote HACS

The design uses an appliance control system through a mobile device via a mobile app which enables the user to control home appliances remotely. The system is based on serial data transmission using SMS over GSM Network in order to facilitate the control of appliances in a global network environment. The system ensures a secured exchange of data on GSM communication. A mobile application enables the mobile phone to offer system connection and control utilities.

2.2.2 System Architecture

The architecture is flexible and can be actualized in different ways to suite different homes with minimum design changes (Fig. 1). The architecture is divided into three components: home environment, home gateway and remote environment as shown in Fig. 1. The home environment consists of sensors and also the appliances that the system will be controlling. The sensor employed is the PIR motion sensor which detects the presence of an intruder and communicates it to the microcontroller. The Home gateway is divided into two parts: GSM network and microcontroller firmware. These two parts fused together allow the capability to send and receive SMS to and from the system. The configuration, sensor and actuator control layers have been implemented on the Arduino to enable successful communication between remote user and the home gateway. The remote environment consists of the HACS mobile application, the SH environment to be controlled and monitored from a remote location using the mobile application.

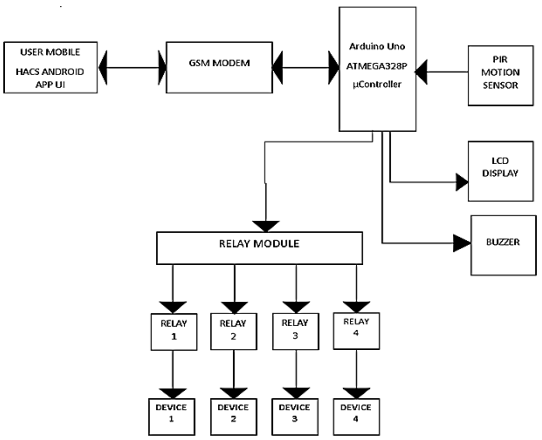

Fig. 1 System Architecture

2.3 System Operating Principles

The HACS is made up of two subsystems namely: appliances control unit, which is responsible for ubiquitous access of appliances, and security alert subsystem, also responsible for security intrusion detection.

In this paper the microcontroller with Universal Asynchronous Receiver/Transmitter (UART)

circuit is interfaced with an AT command supporting GSM modem. The user at a remote place sends SMS through the use of the HACS text-based mobile application to the mobile to control the home appliances. The microcontroller decodes the received message and does the required action. The protocol used for the communication between the two is AT command. The microcontroller pulls the SMS received by phone, decodes it, recognizes the mobile number and then switches on the relays attached to its port to control the appliances. After successful operation, the controller sends status feedback to the user. Fig. 2 shows the Model of the HACS while Fig. 3 shows the flow chart.

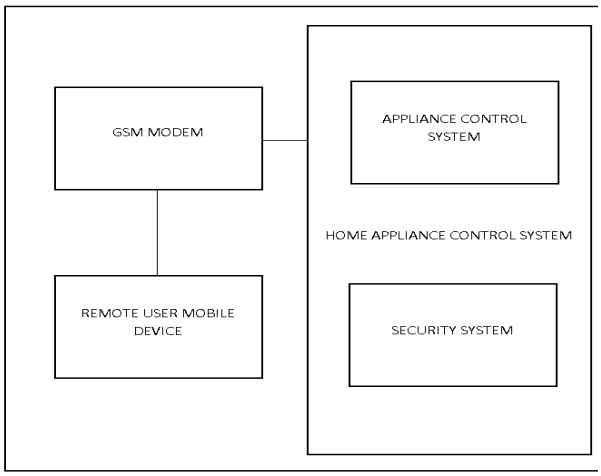

Fig. 2 Model of HACS

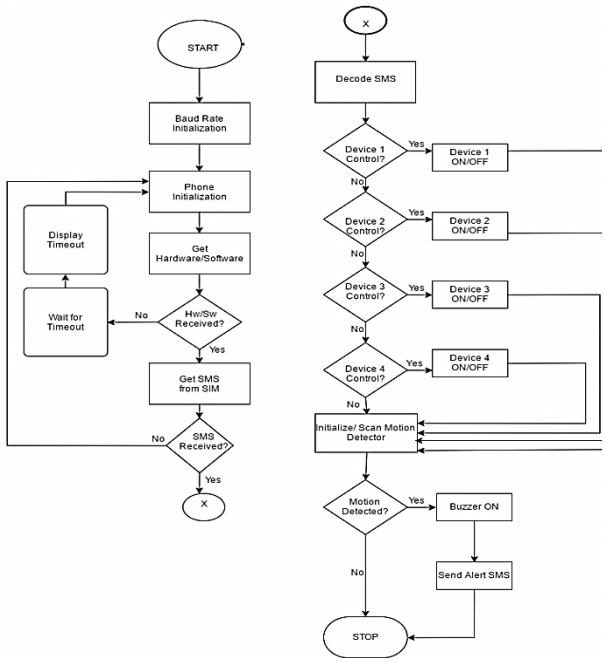

Fig. 3 HACS' Flow Chart

3 Results and Discussion

3.1 Implementation

The whole project and testing is coded in C programming language using the Arduino Sketch IDE software specifically designed for programming the Arduino microcontroller board and its peripherals. To develop the system, the sensor to be deployed, the GSM Shield and the buzzer are independently tested to ensure perfect working condition before integration. Table 1 presents the system's cost analysis.

Table 1 Hardware Cost Analysis

COMPONENT	QUANTITY	PRICE (GHC)
Arduino Uno	1	75
SIM900 GSM Shield	1	200
PIR Motion Sensor	1	15
Relay Module	4	32
Jumper Cables	60	10
Buzzer	1	1
LCD Screen	1	45
AC Adapter	1	20
Total		398

3.2 HACS Mobile Application

The HACS has three user screens; first screen is 'splash screen' which contains information about the App and its developers. Once the user invokes the HACS from the mobile menu, splash screen appears and stays on for ten seconds. It then takes the user to the registration/login screen where the user will have to enter the correct username, password and recipient phone number (phone number of the SIM card embedded in the SIM900 GSM Shield). On entering correct password, Device Control Screen will appear on screen and it prompts the user to enter the mobile number of GSM Modem which is interfaced with device control circuitry and it crosschecks it with the number that was entered on the Register Screen to confirm if there is a match. Once a match is confirmed, all the necessary control buttons are enabled and are available for selection. The HACS Application has the capability to exchange the ASCII data with the HACS circuit through SMS facility of mobile phone when users click the on/off buttons for each appliance option as shown in Fig. 4. The Android platform comprises of SMS stack. This allows device to exchange data in through SMS on GSM Network with other GSM devices.

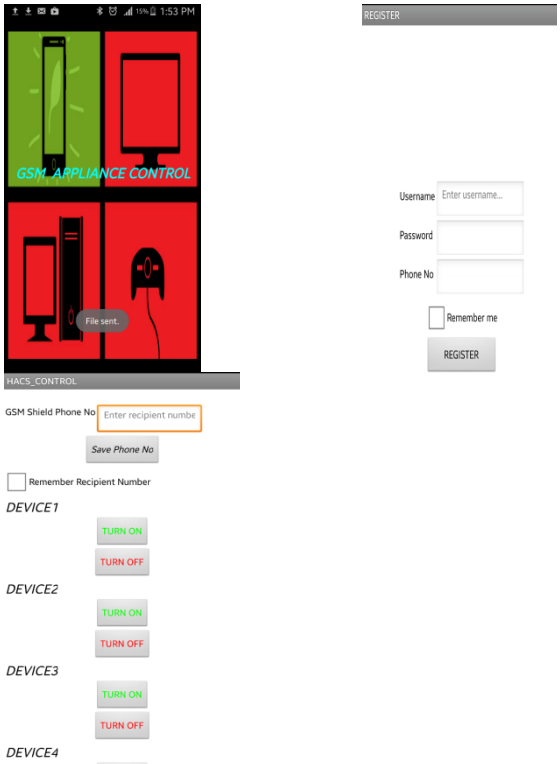

Fig. 4 HACS Splash Screen, Password Screen and HACS Control Screen

3.3 System and its Operations

The GSM module is connected with the Arduino board using the serial communication port. The module has RS232 port and the Arduino pro-mini can communicate using Transistor-Transistor logic (TTL) levels. A max232 IC is used to make a bidirectional conversion between the RS232 and TTL logic levels. The Tx pin of the Arduino board is connected to the Rx pin of the GSM module through the max232 and the Rx pin of the Arduino is connected to the Tx pin of the GSM module using max232 itself. The code written in the Arduino is able to communicate with the GSM module using AT commands. The AT commands are sent or received from the module using the serial communication functions provided by the Arduino library. The functions like Serial.begin() which helps to initialize the serial port with a given baud rate, Serial.write() to send a data to the serial port, Serial.available() and Serial.read() functions to read data from the serial port are used. The GSM module used in this circuit is a SIM900 based module which can communicate with other devices using RS232 serial communication port. It works on 9 V power supply.

GSM modules respond “OK” when it receives the command “AT” and it is the best way to check communication between the module and the microcontroller. To operate Relay1 in ON condition, click on “TURN ON” Device1 grid in the HACS mobile application which sends “#a1b0c0d0” through SMS to GSM Modem and the microcontroller to receive equivalent value in HEX through serial read register which makes ‘digital pin 2’ high and makes Relay1 in OFF condition simply “TURNS ON” Device1 grid in the HACS mobile application.

3.4 Circuit Design

The sensor and the buzzer were assigned to two of the analog pins on the Arduino board while the other actuators and the GSM Shield are assigned to the digital pins of the Arduino Board. The circuit was designed using Fritzing circuit designer. Fig. 5 shows the circuit diagram of the prototype.

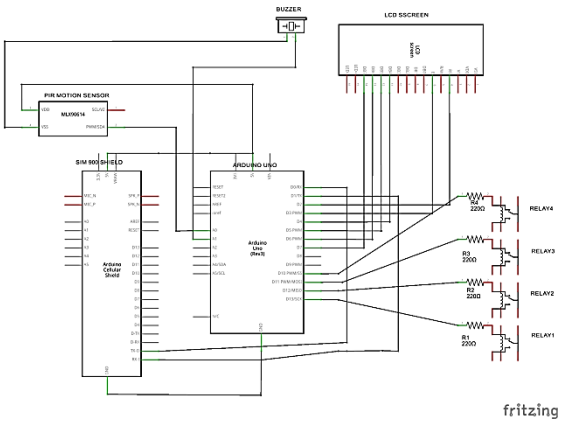

Fig. 5 HACS Circuit Diagram

4 Conclusions

In conclusion, a HACS has been designed and implemented with remote access and control of appliances and intrusion detection functionalities. A prototype of the design has also been developed which presents a mobile controlled and user-friendly approach to the available home automation system which provides solutions to the problems homeowners face concerning energy wastage and appliance control. With other functionalities like intrusion detection alert and alarm systems, light control, and remote control of home appliances, the homeowners will enjoy an improved standard of living.

From the work that has been carried out, the following are recommended:

(i) Device Status Update should be integrated into future designs to enable the home owner monitor which appliances are on or off.

(ii) Connection over Wi-Fi can also be integrated in future designs to cater for delays in mobile networks

(iii) Further research should also be done concerning possible expansions of the scope of this project to offices, and school hostels; and

(iv) The system gets its power from the public power supply system which is well known not to be stable. On this note, we will advise any further work on this control system to have its power supply independent on its own or better still use rechargeable batteries or solar if possible.

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