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EFFECTIVE REMOTE CONTROL OF SEVERAL OUTDOOR SECURITY LIGHTS BY SMS AND WiFi TECHNOLOGY

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Abstract
The aim of this study was to design and develop a control system using Short Message Service (SMS) and wireless networking (WiFi) technology to remotely control outdoor security lights in large organisations. The device comprises four main units, namely: the mobile phone or a computer system, the Global System for Mobile communication (GSM) modem, the switching unit and the WiFi module. One feature that makes the developed system better than other related existing works is its ability to use two means of control. It makes use of WiFi when the operator is within the coverage area of the network of about 100 m to the device, at no cost, otherwise it uses SMS containing certain codes to control the lights. A Subscriber Identity Module (SIM) card is placed in the GSM modem and SMS from the transmitter are sent to that mobile number. The module is also constantly checked by the microcontroller unit, processes the information, extracts the message and command from the GSM modem and WiFi module respectively and then acts accordingly. Owing to its simplicity, C programming is used to programme the microcontroller. The developed device when tested with three lighting points operating on 230 V power supply, gives an impressive performance in terms of accuracy and promptness with both SMS and WiFi technology.

Keywords: Microcontroller, GSM modem, module, SMS, mobile phone, WiFi technology

1. Introduction

Nowadays home and building automation systems are used almost everywhere, as they provide increased comfort especially when employed in a private home, offices, manufacturing industries (Hsu *et al.*, 2010). On the other hand, automation systems installed in commercial buildings do not only increase comfort, but also allow centralized control of heating, ventilation, air conditioner and lighting. Hence, they contribute to overall cost reduction and energy savings which is certainly a main issue today.

The present age of information and computer technology (ICT) has redefined communication. With mobile phones, one could communicate with friends, family members, business associates, etc. from a distant location. However, the application of mobile phones cannot be restricted to sending SMS, calling friends or connecting to a hotspot for internet browsing. It could be deployed to use in areas that involves controlling of remote appliances. Managing of several home and outdoor appliances remotely is a subject of growing interest, which has seen many developments over the years. However, there is still the need for lots of improvement to make to a breakthrough into future, especially in smart grid applications.

An excellent application of remote control is the controlling of security lights in a big higher institution, such as a university. The system allows the operator to remotely control the security or street lights via a mobile phone by sending SMS containing commands to be implemented or connected to its module. The message when received is processed and the required operation is performed accordingly. SMS messages, also known as instant messages, allow quick transmission of short messages at an economic rate. Combined with this is the ability to still control the security or

street lighting system without spending a dime when one is within a few metres to the device. This gives a great degree of freedom to the operator who can decide to stay in the control room and put on/off the security or street light at ease.

The conventional method employed by most higher institutions and big manufacturing industries in Nigeria is the use of security personnel who move from one point to another to switch on and off the security lights. This approach is obviously very tedious and difficult to do on daily basis. Aside this, it is not efficient enough as the person in charge of the duty may fail to perform it at the right time, which could result in energy wastage, which should be discouraged in strong terms, especially in Nigeria where the available electric energy is grossly inadequate (Akorede *et al*, 2017).

To address this problem, a number of researchers have devised different approaches to remotely control security lights. For example, Sriskanthan and Karand (2002) proposed a system that could control electrical appliances using Bluetooth. The setback of this system is that it is unable to control systems remotely from a far distance. Similarly, Ramli *et al*. (2006) developed a remotely control system of devices through spoken commands. The commands are sent in form of SMS but the cost of sending a voice SMS is quite expensive.

In the same vein, Al-Ali and Al-Rousan (2004) presented a design and implementation of a Java-based automation system through World Wide Web. The design focused on the use of internet to control the switching of home appliances. With this, the switching could be done anywhere in the world provided there is access to the internet. The limitation of this method is that the internet is not readily available and it is prone to hacking. Sakhare and Angal (2015) demonstrated the use of Zigbee network in proffering solution to the problem.

Pan *et al.* (2008) presented a WSN-based intelligent lighting system which acts in accordance withthe user's profiles and activities. Bellido-Outeirino *et al.* (2012) proposed a system focusing on automation of building lighting. The project was accomplished by integrating Digital Addressable Lighting Interface (DALI) devices and wireless sensor networks. Furthermore, Parise *et al.* (2013) presented a lighting system that optimizes the characteristics of the room to determine the switching signal to be sent to appropriate relays. Byun *et al.* (2013) proposed LED lighting system which considers energy efficiency and user satisfaction for indoor environments. This system uses multiple sensors and wireless technology to control the LED light according to the user state and surroundings.

Looking critically at the aforementioned approaches, one observes that their service may not be reliable and cost effective in operation since they used only one control method. To address this deficiency, this study considers two means of controlling the system – use of SMS and WiFi. The WiFi technology is used when the operator on his handset or laptop computer is a few metres away from the control system. This is done at no cost. However, the operator could explore another way of controlling the security lights by simply sending certain codes to a registered mobile number. This option is chosen when the operator is outside the coverage area of the WiFi network provided by the system. This offers more reliability and less operation cost especially when WiFi technology is used. Meanwhile, this paper is an expanded version of the paper presented at the IEEE PES Power Africa Conference held in Accra, Ghana in June 2017.

2. Review of Major Components used in the Project

2.1 Microcontroller

A microcontroller is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications consisting of various discrete chips. Generally, microcontrollers accept input variables, compute them and make decisions to generate outputs in response (Toulson and Wilmshurst, 2016). It does this in a timely manner. Shown in Figure 1 is the snapshot of the microcontroller circuit as employed in this study. The microcontroller programming is done in the traditional 'C' language even though its variants such as C++, Visual C++, Java, could be used for certain applications (Raj *et al.*, 2016).

Figure 1: The Microcontroller on Board.

2.2 Bipolar Junction Transistors

These transistors are used in two broad areas; as a linear amplifier to boost an electrical signal and as an electronic switch commonly used in digital circuits (Theraja and Theraja, 2005). The switches which can either be in an "on" or "off" state, both for high-power applications such as switched-mode power supplies and for low-power applications such as logic gates. Important parameters for this application include the current switched, the voltage handled, and the switching speed, characterized by the rise and fall times.

2.3 Relays

A relay is an electrically controlled switch, typically incorporating an electromagnet, which is activated by a current or signal in one circuit to open or close another circuit. Relays are used wherever it is necessary to control a high power or high voltage circuit with a low power circuit. The first application of relays was in long telegraph lines, where the weak signal received at an intermediate station could control a contact, regenerating the signal for further transmission. A simple electromagnetic relay consists of a coil of wire wrapped around a soft iron core, an iron yoke which provides a low reluctance path for magnetic flux.

2.4 GSM Modem

Modem stands for "modulator/demodulator" and it encodes and decodes signals sent to and from the network servers. A wireless modem is a device which connects to wireless network. A GSM modem is a specialized type of modem which accepts a SIM card, and operates over a subscription to a mobile operator. From the mobile operator perspective, a GSM modem looks just like a mobile phone.

2.5 The WiFi Module

Wi-Fi is a popular technology that allows electronic devices to connect to the internet or exchange data wirelessly using RF radio waves. Many devices can use Wi-Fi, and these devices can also connect to a network resource via a wireless network access point. Wireless LAN module can only be achieved within a local wireless transmission range of a short distance, usually within 100 to 200 m distance, which cannot be used for remote applications. Figure 2 shows the snapshot of the module on board.

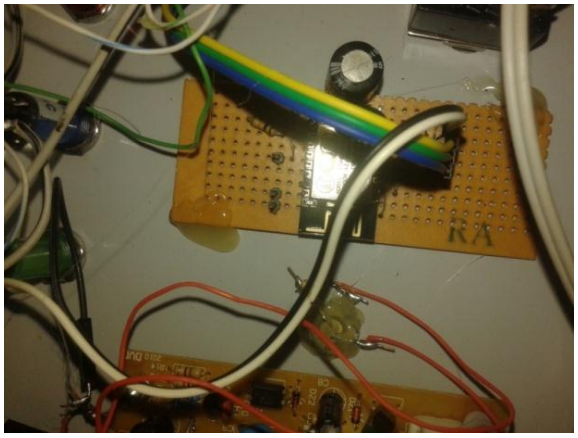

Figure 2: The Module as used in the Study.

3. System Design and Implementation

The system consists of a microcontroller which serves as the brain of the system, a GSM modem, a switching unit, and one WiFi module, which serve as the client and server modules respectively. Both modules are physically connected to the microcontroller. The server side consists of a cell phone that is WiFi enabled, used to control the device from the Web interface. The client module receives the messages/commands and the microcontroller extracts the necessary information therein. This is processed by the microcontroller and the necessary operation is performed. Figure 3 shows the schematic overview of the system developed in this study while Figure 4 is the snapshot of the WiFi interface of the control system.

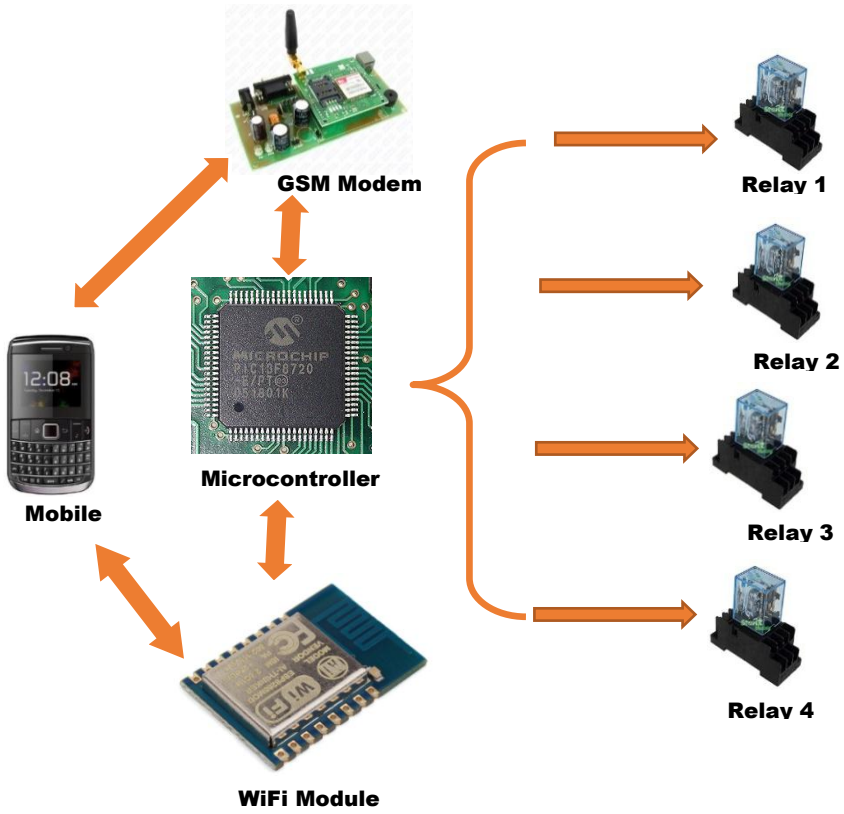

Figure 3: The Layout of Main Components.

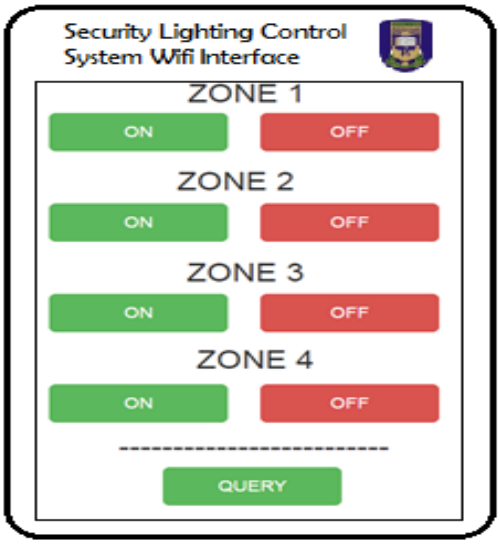

Figure 4: The WiFi Interface of the System.

3.1 The Switching Section

An electromagnetic relay is a type of electrical switch controlled by an electromagnet. To make a relay operate, you have to pass a suitable pull-in and holding current (DC) through its energizing coil. The relay circuit consists of a single relay of 12 V supply. The one employed in this project is 30 A, DC 12 V. External loads may be connected to the relay contacts in two possible ways. If an

initial switch ON of the load is required, it may be energized through the normally close (N/C) contact. On the other hand, if the load needs to be switched ON after the relay toggles, then it is powered through the normally open (N/O) contact.

3.2 The Microcontroller Unit

A microcontroller is a single computer chip or integrated circuit that has the ability toexecute written user programs. The MCU is normally used for the purpose of controlling some devices – this actually gives it its name microcontroller. The user program can be stored within the microcontroller unit (MCU) or on an external chip called an Erasable Programmable Read Only Memory (EPROM). MCU are normally integrated into small devices like the microwave ovens, keyboards and cell phones. The microprocessor that is universally accepted is not the same as a microcontroller. An MCU requires a small amount of computing power, less memory and very little attachment accessories. MCU-based systems are far more reliable and cheaper. Their small size also makes them desirable for circuit designers. The choice of MCU used in this system is STM32 and runs on a DC voltage of 5 V.

STM32 is a family of 32-bit microcontroller integrated circuits by STMicroelectronics. The STM32 chips are grouped into related series that are based around the same 32-bit ARM processor core, such as the Cortex-M7, or Cortex-M0. Internally, each microcontroller consists of the processor core, static RAM memory, flash memory, debugging interface, and various peripherals.

The microcontroller used in this study has the following features:

Connection via: 802.11b/g networks. Encryption types: WEP and WPA2 Personal on-board micro SD slot FTDI-style connection for serial debugging of WiFi shield Mini-USB for updating the Wi-Fi shield firmware open source firmware. This makes it possible to add new protocols directly on the shield. If you are familiar with C and the AVR32 family, you could even use this shield as a standalone WiFi connected microcontroller. Figure 5 shows the complete system circuit diagram designed and used for the study.

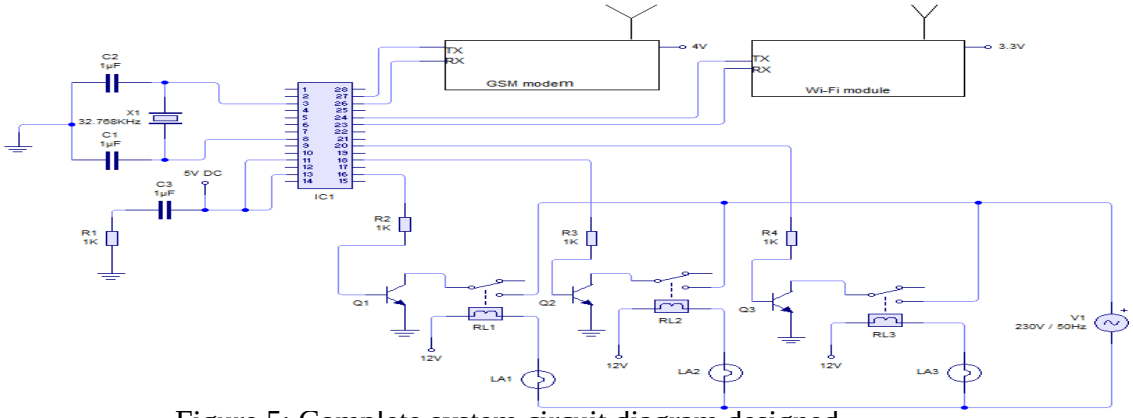

Figure 5: Complete system circuit diagram designed.

3.3 Microcontroller Programming

The microcontroller executes the program loaded on its flash memory. This is the so called executable code, comprised of seemingly meaningless sequence of zeros and ones. The C programming language is used because of its simplicity of program writing. It is also very possible to use the C++ programming language. The flowchart for the programming of the microcontroller is shown in Figure 6 to send appropriate signals to control the relays connected to its output ports.

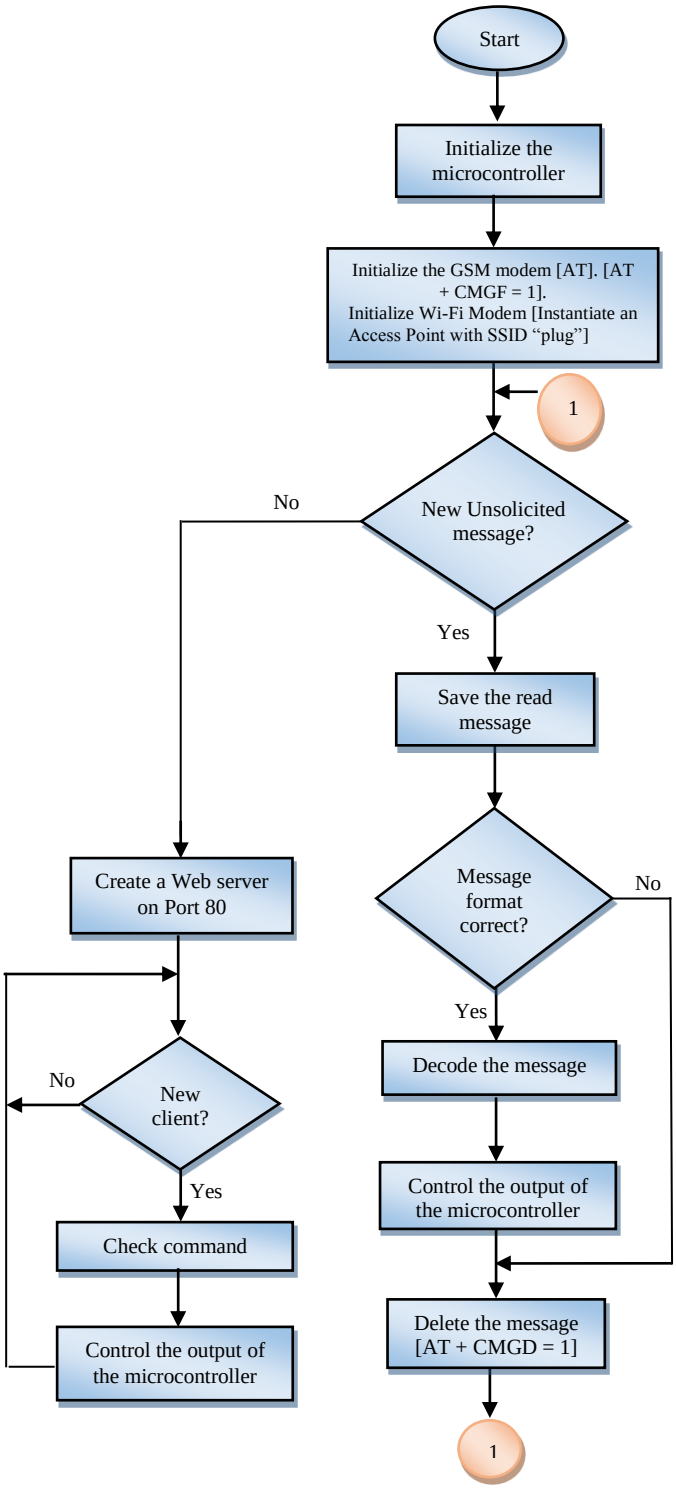

Figure 6: The Flowchart of the Control System.

4. Testing and Performance Evaluation of the System

To test the performance of the developed device, three bulbs were connected to the appliance interface connector of the controller. The microcontroller is programmed to receive a message and translate it to switching of the bulbs. The GSM modem and WiFi module receive the message and

each sends it to the microcontroller needed to activate the bulb. The code "#e01" was sent to the mobile number 08124051785 which made the bulbs to be switched ON after like 10seconds. Thereafter, the message "#e00" meant to switch off all the bulbs was sent to the same mobile number, and the bulbs were OFF. The status of the device was queried with the command "#f01" and an SMS was sent to the GSM handset from the device. Shown in Figure 7 is the status reply sent when the device was queried to know its state. The cache of the GSM modem needs to be cleared after about 50 SMS communications to save memory space.

Specific SMS commands that can be sent and the operation they will perform are enumerated in Table 1.

Table 1: SMS commands and switching operations.

COMMAND	OPERATION
#a01	Switch ON ZONE 1
#a00	Switch OFF ZONE 1
#b01	Switch ON ZONE 2
#b01	Switch OFF ZONE 2
#c01	Switch ON ZONE 3
#c00	Switch OFF ZONE 3
#e01	Switch ON ALL ZONES
#e00	Switch OFF ALL ZONES
#f01	QUARY STATUS
#f00	CLEAR CACHE

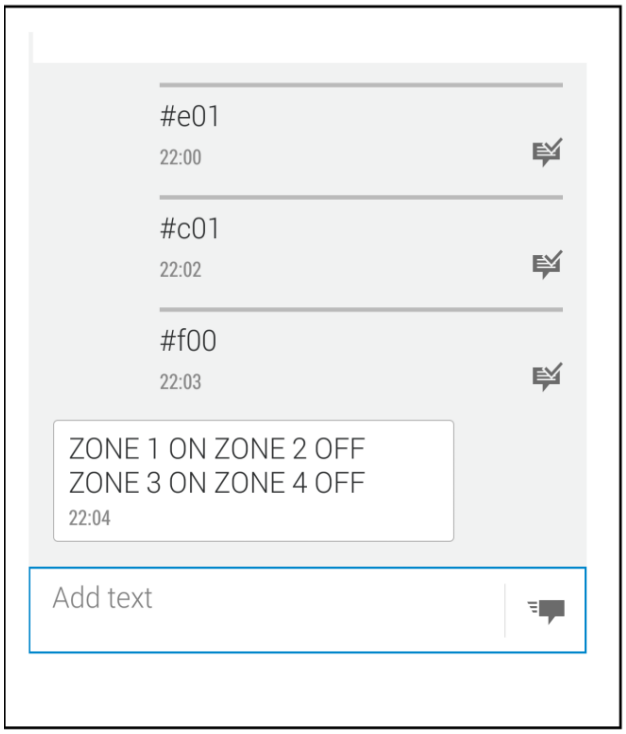

Figure 7: Output Message to SMS Query.

The mobile phone's WiFi was switched on, and after about 2 seconds it discovered an available network named "plug". Connection was made to it and after obtaining the IP address, a password was required. When the password was entered, the connection was then established. From the phone browser, a web address was entered in this form "www.plug.com". The control page with the heading "INTERFACE" as shown in Figure 4 appeared and ON was pressed for ZONE1 light which came on after about half a second (please note that the time taken for the light to respond to the command is a function of the distance between the mobile phone and the device, the closer the faster and vice versa).

Thereafter the OFF button was pressed for ZONE1 light and it went OFF. This was also applicable to all other options pressed as shown in Figures 8, 9 and 10. The status of the device can also be queried from the interface by clicking on the "QUERY" button. When ZONE 2 was OFF, the status of the device was queried and the snapshot of the reply is shown in Figure 11.

Figure 8: Response to ON All ZONEs

Figure 9: Response to ON ZONEs 1 and 2

Figure 10: Response to ON ZONEs 1 and 3. Bulbs.

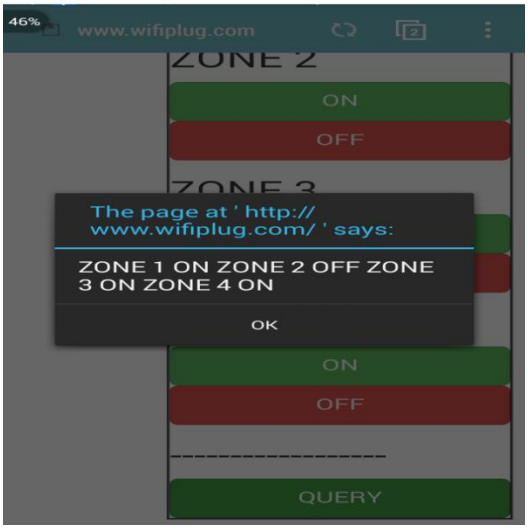

Figure 11: Output Message to the Query on the WiFi Interface.

5. Conclusion

A remote control system using SMS and WiFi technology for control of security and street lighting applications has been successfully developed in this study. The project was achieved using a GSM modem, a WiFi module, a microcontroller, and relays, as major components. The performance of the developed device was evaluated and found to be very effective in line with the design specifications. The major benefit of the system over most existing projects is that it is very reliable in operation and cost effective. This was possible with the use of two means of controlling the system via SMS and WiFi technology independently. The skills acquired in this work could be extended to other engineering applications requiring remote control.

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