The Development of a Remotely Controlled Home Automation System for Energy Saving

KH Mukendi and M Adonis

Abstract - The purpose of this study is to showcase the design and development of a web-enabled home automation system prototype. The unit was developed using low-cost components such as the ubiquitous Arduino microcontroller. One of the features of the developed unit is the ability to monitor the power consumed by electrical loads. The unit also has the ability to control the status of individual loads through the internet using a web-enabled mobile application. This feature enables load management that could contribute to energy saving.

1. INTRODUCTION

The aim of this project is focused on the development of a prototype for an internet based home automation system. The focus is to establish a platform that allows communication between the web-enabled mobile application and the microcontroller situated at a remote location anywhere in the world.

1.1 BACKGROUND

Over the year's humans have learned to rely on technology, the use of technology has thus developed tremendously over the years. This is evident in the telecommunication stream, previously communication was done face to face or through the postcard or letter. In some cultures, it was tradition to play the drum as a form of communication to warn, invite or express a celebration in the neighboring villages. However, today communication takes place relatively fast, easier and without a lot of hassles through the usage of cell phones. A cell phone's function is not limited to calling and texting; it can be used for various functions. Cell phones have become a necessity in people lives, communication and entertainment are all possible with the smartphones.

Automation is the backbone of modern industries, it is the key to global economic growth as it allows for increasing productivity and accuracy by cutting out the human intervention while reducing costs.

Home automation is the extension of industrial process automation to households' appliances. Among others home automation may include the remote control of lights (Centralized or individual), air conditioning, security

K. H. Mukendi, Cape Peninsula University of Technology, P O Box 1906, Bellville 7535, South Africa (e-mail: mukendikalalahubert @gmail.com).
M. Adonis, Cape Peninsula University of Technology, P O Box 1906, Bellville 7535, South Africa (e-mail: adonism@cput.ac.za).

system (remote power monitoring) and other systems such as those used for entertainment. Home automation provides improved comfort and security, increases energy efficiency and convenience for users.

Today automation is introduced in homes through the connectivity of house appliances and smartphones, tablets, and PCs.

1.3 PROBLEM STATEMENT

Energy consumption can be measured through its environmental impact and usage; the measure of the amount of power consumed by the load side of an electrical circuit is termed energy consumption. The maximum power that a load can consume is equal to the total power generated by the source minus the power lost in the transmission line. When the load requires more energy than what the source can provide, this becomes a major issue, which results in load shedding and blackouts. Energy consumption is a major issue in the modern world. Inefficient power monitoring and controlling techniques in the households, businesses, and institutions are the main cause of power consumption.

1.2 LITERATURE REVIEW

A home automation system is a channel by which homeowners and occupants have remote control over different types of electrical and electronics appliances in their home.

The home automation system is the use of robotics and computer technologies to household appliances by defining the home automation as domestics. Energy saving is the advantage that a home automation system gives to all its clients and especially forgetful ones, in that they can now track energy usage at home or while being away to ensure that unnecessary appliances are turned off as needed to reduce energy consumption [1, 2, 3].

Convenience is what makes the internet based home automation interesting in that one does not have to go home and turn ON the geyser and wait for the water to get warm, while still at work one can turn ON the geyser to ensure that once they're home the water is warm enough and ready to be used. This saves time and it is very convenient. While security issues arise, the emphasis is that through surveillance cameras a user can remotely monitor the house. This should monitor incidents of property intrusion. With the home entertainment section, a user can control the distribution of sound throughout the house depending on the room occupancy or control light

intensity from the couch while watching an interesting movie.

With an increase in energy consumption and population, there is an inevitable need to conserve energy with the means possible. The major cause of energy consumption is the inability to remotely monitor and control appliances.

Remote energy monitoring and control is the focus of this study. The literature found that all authors agree that a web-enabled mobile application used to monitor and control appliances remotely can greatly increase efficient energy usage. While [4] mentioned only two communication protocols (Z-Wave and ZigBee), [5] and [6] speaks about ZigBee, Bluetooth, GSM, and Wi-Fi as possible communication methods that a home automation system can host. To implement the home automation system, [6] in their study present interesting methods that could be used. These methods include phone-based home automation system, Bluetooth-based home automation system, GSM based home automation system, Mixed type home automation system, a wireless control system and ZigBee-based home automation system. The GSM based home automation presented by [4] consists of User with an APP inventor user interface, a GSM network, a GSM modem, an Arduino microcontroller, peripheral devices, relay logics and the appliances to be controlled. The system presented here can be controlled by means of a GSM network, internet, or speech control. Then internet being the best of choice as it enables the system to be controlled from anywhere in the world, then GSM uses SMS-based commands to control the appliances. The user sends text commands to the server which might be a PC, the server then passes the commands to the Control Unit which in turn controls the appliances. The GSM is used for communication where there is no internet connectivity. The AT (Attention) command are use used by the server to communicate with the GSM modem. The server consists of a web server, database, main control program and speech recognition says the Satish et al. Every appliance node consists of a transmitter, a receiver an I/O device and a controlling unit (Microcontroller). The GSM is used for its high availability, coverage, and security, but it suffers from the SMS costs and the relative dependency of the SMS on the network. Another drawback of GSM based system is that no user interface is given to the user to control the device. The system cannot be customized on devices as it comes preprogramed.

The study of [4] described different technologies and home automation systems, the authors focused on describing home automation system based on a security point of view in their study. [7] elaborates on various security weaknesses in existing home automation systems. The challenges in the home automation systems were examined. In their study, [5] considered mobile based home automation, Bluetooth-based home automation system, Dual Tone Multi-Frequency based home automation systems, and internet based home automation system, Short Messaging Service based home automation system. Since the goals of this project aimed an internet-based system, the focus was more on the internet based home automation system and a mobile based home automation system.

Figure 1 presents the diagram of how the sensors, mechanical and electrical devices communicate using the home network through GSM module using a subscriber identity module (SIM). This uses a transducer to convert machine's function into an electrical signal readable by a microcontroller. The signals sent to the microcontroller are analysed, and based on this analysis the microcontroller commands the GSM module to select between one of the three communication methods mentioned above (SMS, GPRS or DTMF) [4].
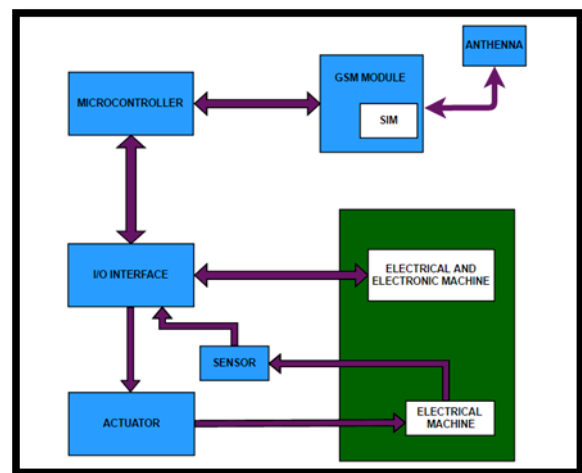

Figure 1: Mobile-based home automation

In this study, the focus was on developing the application to interact with the home automation system, the security issues were only flashlights to consider before marketing the product. Given the time constraints, the focus was first on the minimum deliverables and as time went on, more features were added to the system to make it more interesting that includes a security feature which prompts the users to authenticate themselves before loading the application.

As the literature reveals, a microcontroller is the most popular and most flexible controlling unit used for home automation system. In this project, Microcontroller Systems Design IV was the main subject that helped with implementation. There are currently many challenges that home automation systems have to address. Some of these are reviewed in [7]. In [8] a life cycle assessment is provided for by considering both the benefits and environmental impacts of home automation systems.

2. SYSTEM DESIGN

Home automation can be implemented in several ways, there are many possible approaches towards the development of the mobile application and the home automation. In this section, some pertinent approaches were presented together with their advantages and

disadvantages. Many factors affect the advantage and disadvantage of a home automation system such as the security, implementation, timeline, cost, the complexity of the system, availability of the component, documentation, and support offered by the manufacturers to list a few. In this section, the focus will be on the security, implementation, and cost while evaluating different approaches. Decentralized home automation system, DTMF Based, GPRS Based, Central controller Based, Mixed Type Home Automation, Internet Based Home Automation System, Wireless Control System, Phone-Based Home Automation, Bluetooth Based Home Automation, ZigBee Based Home Automation, and GSM Based Home Automation. From this list of home automation system implementation methods, the internet based on a microcontroller as a controlling unit were the choice and the focus of this project.

2.1 INTERNET BASED HOME AUTOMATION SYSTEM

A microcontroller is a self-contained system with peripherals, memory and a processor that can be used as an embedded system. Most programmable microcontrollers used today are embedded in other consumer products or machinery including phones, automobiles and household appliances or computer systems. Due to that, another name for a microcontroller is "embedded controller." Some embedded systems are more sophisticated, while others have minimal requirements for memory and programming length and a low software complexity. Input and output devices include solenoids, LCD displays, relays, switches, and sensors for data like humidity, temperature or light intensity or power usage.
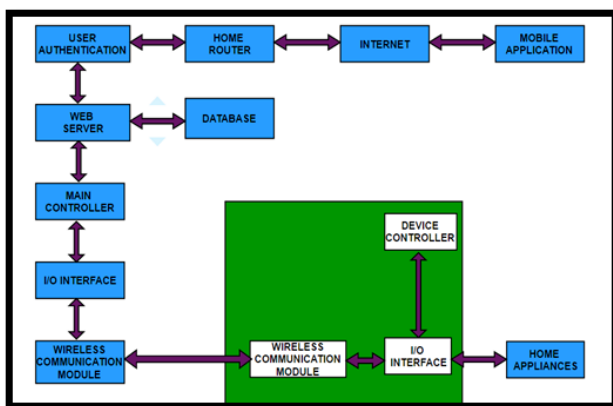

Figure 2: An Internet-based home automation system [4]

Figure 3 below shows a microcontroller based home automation system. The user mobile application interacts with the microcontroller via the web server using the internet protocol. The microcontroller receives commands from the user interface and performs the required tasks based on a controlling algorithm governing the controller. The controller reads devices status and updates this data

into the server for the user mobile application. Also, refer to figure 4 in the literature review for a typical internet based home automation system.

The server handles the users and ensures secure communication between the user mobile application and the controlling unit. Once a user is identified, he will then be allowed access to the controlling interface (Web page).

The advantages of using a microcontroller have reduced the size of circuitry, affordability, and increased flexibility. A microcontroller can be used as a substitute for other integrated circuits (ICs). It can also be easily reprogrammed to modify its functionality. The Microcontroller that was used for this project is the Arduino MEGA 2560 R3.
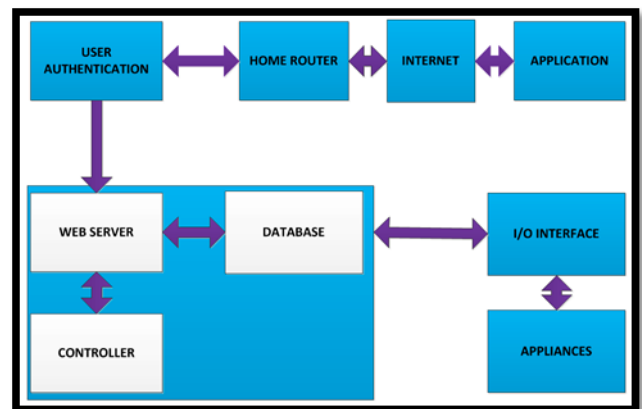

Figure 3: Proposed Home automation (Internet Based home automation with microcontroller)

The downside of this system is its dependency on the mobile connectivity to the internet, if the mobile connectivity is compromised, the user will be unable to remotely monitor and control the home automation system and the limited number of devices depends on the I/O limit of the microcontroller used. A PLC could also be used as a controller for such a system, the PLC is more robust than the microcontroller. The choice of microcontroller controller over the PLC is the cost, and the PLC is not open source, thus making the Arduino microcontroller even the best choice for the system prototyping.

3. DESIGN METHODOLOGY

3.1 THE WEBSITE

When related web pages are collected (Including picture and video contents), and if they can be accessed through the same domain name or IP address, and they are published on at least one web server, then the collection is called website. A website as mentioned can be accessed through the World Wide Web (Internet), or on a local area network (LAN) by referencing a Uniform Resource Locator (URL) which is the ID of the website.
Web sites are created for many reasons, ranging from entertainment to education, and today websites can be used to control household appliances. An Arduino web server was used to serve as the user interface where the

client is presented with user clickable buttons to control the house appliances and monitor the power consumption. The web page as shown in the figure 9 below is made of two important sections, the energy monitoring section, and the control section. The power gauge was designed using java scripts when the "read power" button is clicked, an http request is generated and sent to the web server requiring the power consumption. The server then responds to the request by supplying the web client with the raw reading on the current sensor.

The controlling section of the user interface consists of buttons, and once clicked they each send a corresponding request to the server, then the server in return turns ON/OFF the appliances associated with the request. The server also updates the web client with corresponding images of the appliance status.

The website was created using HTML, XML, and Java Scripts. When access is granted to a user, the user interface is now available to turn on or off devices, check power consumption, change camera position, adjust light brightness, and check the status of entrances.
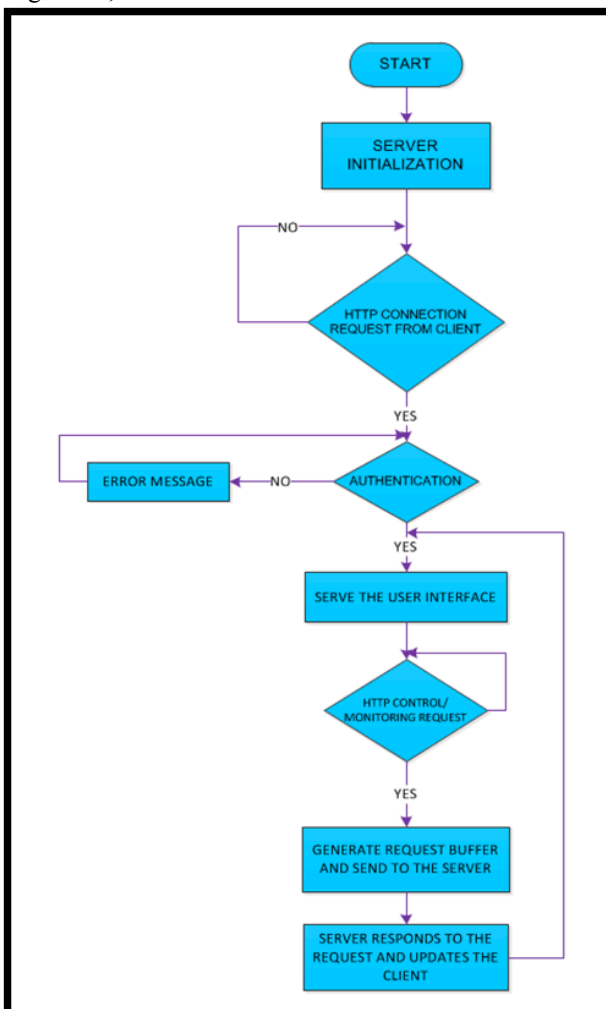

Figure 4: Program Flow-chart

Specific functions are used to generate and send a specific http request to the server depending on the user's request, for instance when the "Read Power" button is clicked, a function called PowerControl is called. This function generates a random number every time is called, it sends a request buffer to the server using the "GET" method. The request buffer consists of a "Get" method, a specific command "Power" and a random number. The random number is used to avoid the browser caching.

To understand the website design, a study of the HTML, XML, CSS, and JS is required.

3.3.1 THE HYPERTEXT MARKUP LANGUAGE (HTML)

The Hypertext Markup Language is a standard used to design the look of the web page. It focuses on the graphic, font, color, and hyperlink effects on web pages, and has for building blocks, elements. HTML describes the structure of web pages using markup, tags representing its elements. The web browsers do not display HTML tags, but instead, tags are used to determine how the web page should be displayed.

3.3.2 THE EXTENSIBLE MARKUP LANGUAGE (XML)

XML stands for Extensible Markup Language. It is a text-based markup language derived from Standard Generalized Markup Language (SGML). XML tags identify the data and are used to store and organize the data, rather than specifying how to display it like HTML tags, which are used to display the data.

3.4 USER INTERFACE (UI)

The user interface interacts a human with a hardware or software, it is the means by which a person controls a hardware device or software application.

a. THE WATTMETER

The Wattmeter as shown in figure 5 below, was created using the HTML canvas and Java Scripts, the meter was designed to measure up to 30 kW of power. The green color represents a smiling face on the gauge, meaning that the power consumption is good. The yellow color on the gauge represents increased power consumption. The red color represents excessive power consumption.
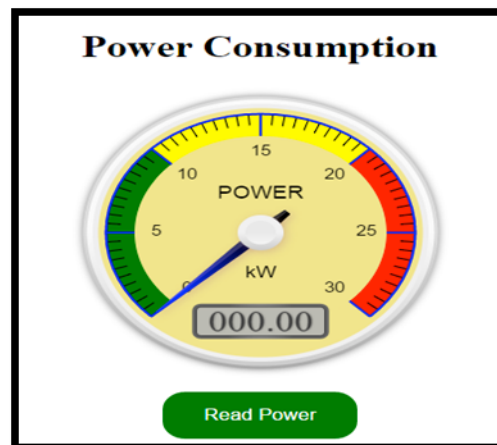

Figure 5: The wattmeter

b. APPLIANCE CONTROL

Appliance control as shown in figure 6 below enables a person to turn ON/OFF appliances; a light bulb, a stove, a heater and a tv respectively. The system is designed in such a way that a picture representing the current state of the appliance is updated on the user interface.
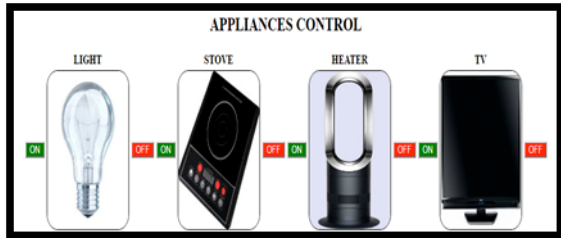

Figure 6: Appliance ON/OFF Control

c. CAMERA POSITION AND LIGHT BRIGHTNESS CONTROL

This section of the user interface as shown in figure 7 below presents the user with means to adjust the position of a camera as well as adjust the brightness of a light. The adjustment is accomplished through two sliders.
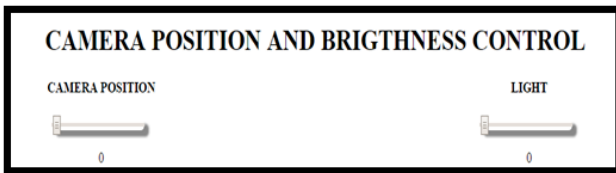

Figure 7: Camera Position and Light Brightness Control

d. INTRUSION DETECTION

The intrusion detection section of the user interface as shown in figure 8 consists of a "CheckEntrance" button, the entrance names, and the entrance status fields.
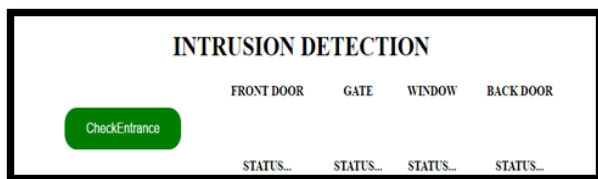

Figure 8: Intrusion Detection

Finally, the complete user interface is a web page that can be accessed via a web browser or using the android web-enabled mobile application created using App Inventor. The android app will be discussed in the next section

3.5 THE WEB SERVER

The web server is a dedicated device or computer or program that uses the Hypertext Transfer Protocol (HTTP) to serve a website to the web client as a response to their request.

In this project, the microcontroller was used to serve the website using HTTP on port 25, and it is also the main controller of the system. The web server and controller is made of an Arduino Mega 2560 R3 (controller which is programmed and manages the overall system), Arduino WiFi R3 shield (Allows the controller to have internet connectivity through WiFi modules), and an SD card (Found the WiFi shield and gives the controller the ability to save files and use them when needed) from which the controller serves the system's user interface.

The microcontroller hosts the website saved in an SD card, the web server when launched, it serves the website to the internet client requesting for it. Once the website which is a user interface is made available to the user, there are now capable of entering their username and password to have access to the overall system.

4. USER INTERFACE

At the completion of this project, the following results were found to be satisfactory and above the minimum deliverables.

It was found in this research that the Arduino UNO does not behave expectedly when the program size is above 56% of its full memory. For this reason, this project's controller was changed to ATmega 2560 to solve the memory issue.

4.1 THE WEB USER INTERFACE

Figure 9 below represent the complete user interface, and as explained in the design procedure.

It was found that the calling a function using the "OnLoad" attribute in the HTML code causes the rest of the functions in the code to not execute, for this reason the power gauge does not update automatically and a button was used for its "OnClick" property.
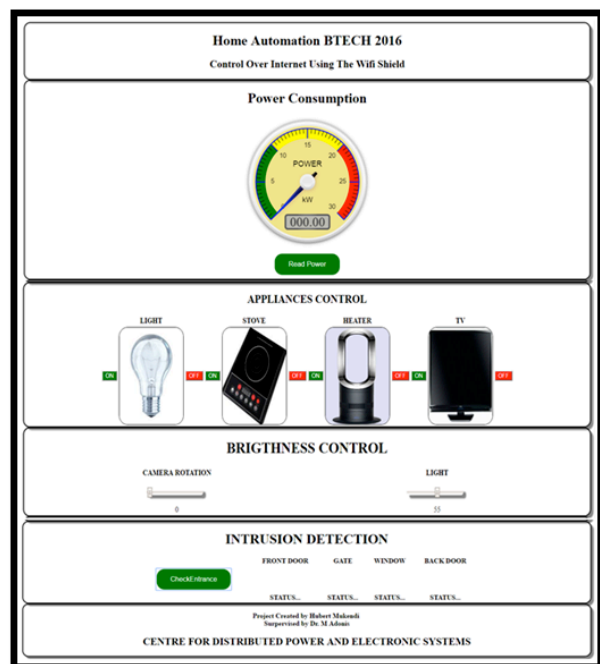

Figure 9: The Complete Web User Interface

4.2 THE ANDROID APP

The Android app as shown in figure 10 below loads the web interface shown above and provides the user with a means to remotely control home appliances and monitor the power consumption thereof.
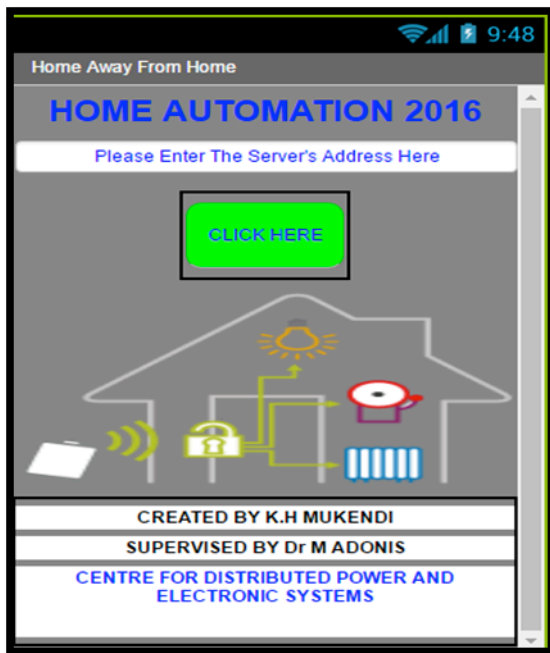

Figure 10: The Mobile Application interface

5. CONCLUSION

The paper summarised the design and development of a web-enabled home automation system. A comprehensive literature review was presented that chronicles the impact and technologies used in home automation systems. The system design methodology is also presented. The mobile application design elements are shown. These highlight the user interface and its monitoring and control features.

Field trials are to be implemented in the next phase. These trials will involve the gathering of experimental data. The results should show what impact the developed unit operation has on reducing energy consumption through load management strategies. The additional features of: camera positioning; light brightness control and intrusion detection, have been evaluated in real-time.

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7. AUTHORS

Principal Author: Hubert Mukendi holds a BTech degree in Electrical Engineering from the Cape Peninsula University of Technology. At present, he is registered for Masters of Engineering.

Co-author: Marco Adonis holds a Doctorate degree in Electrical Engineering from the Cape Peninsula University of Technology. He is presently a senior lecturer and the Deputy Head: Operations for the Center for Distributed Power and Electronics Systems (CDPES).

Presenter:
The paper is presented by Hubert Mukendi