Bluetooth-Based Home Automation System Using an Android Phone

Amirah 'Aisha Badrul Hisham[a], Mohamad Hafis Izran Ishak[a]*, Chan Kok Teik[a], Zaharuddin Mohamed[a], Nurul Hawani Idris[b]

[a]Control and Mechatronic Engineering Department, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia
[b]Faculty of Geoinformation and Real Estate, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

*Corresponding author: hafis@fke.utm.my

Graphical abstract

Abstract

Implementation of home automation using the latest technology gives us more convenience, security and safety. Smartphone affordability increases every year and smartphones have begun to play important roles in our daily lives due to their size and portability. Google's Android operating system (OS) is one of the leading and most preferred smartphones. Controlling home appliances by using an Android phone gives users the ability to control their home appliances anywhere and at any time while at home and saves time spent in searching for the remote control unit of home automation systems since the user's phone is usually kept close at hand. This project presents the design and implementation of a low cost prototype of a Bluetooth-based home automation system using an Android phone. The design uses an Arduino Mega 2560-R3 board and the home appliances are physically connected to input/output ports of this board via relays. Cytron BlueBee is used to establish wireless communication between them. BluetoothHome, an Android application, is developed to provide a user friendly graphical user interface (GUI) for the remote control of home appliances.

Keywords: Home automation; android; bluetooth

■1.0 INTRODUCTION

Home automation systems are implemented to increase user convenience in the control of home appliances either via wired or wireless communication [1–5]. The word "wired" means that the home appliances are physically connected to a server or central controller to the home automation system, while "wireless" means that home appliances are connected wirelessly to a server or central controller or remote control unit. LightwaveRF is a home automation systems company that utilizes a wireless connection between the remote control unit and home appliances [6]. Figure 1 shows the LightwaveRF "smart" power socket and remote control unit.

Home appliances such as TVs, DVD players, air conditioning and other devices come with their respective remote control units. When a home automation system is installed, there is the addition of at least one more remote control unit [7].

Nowadays, people are inseparable from their smartphones. A total of 5000 people from the US, UK, China, India, South Korea, South Africa, Indonesia and Brazil took a smartphone survey which was organized by Time magazine. This survey found that the majority were highly attached to their phones, whereby 84% claimed that they could not go a single day without their phones [8].

Android [9] has 75% worldwide of the smartphone market share and a total of 136 million Android phones were sold in the third quarter of 2012 [10]. Android has become the top mobile gadget operating system (OS) on the market today. In other

words, the Android phone has become the most popular and commonly used OS in society.

Figure 1 LightwaveRF "smart" power socket and remote control unit [1]

■2.0 LITERATURE REVIEW

2.1 Home Automation Systems

Home automation or domestic robotics (domotics) is a combination of automation technologies and computer science [7]. High affordability and connectivity through smartphones and tablets has increased the popularity of home automation in recent years [10–12]. The life quality of the elderly and disabled can be improved by using home automation. Radio frequency (RF) is one of the techniques used in the home automation network to control and monitor home appliances.

Home automation consists of electronic programmable controls for home appliances using wired or wireless communication. A smart home controller connects the entire

house in a home automation system [1, 11]. This acts like a centralized control of household systems, such as sprinkler units and inside temperature monitors. With this centralized control unit, a person does not need to leave the couch to turn on/off home appliances, which is convenient for users. Home automation is designed to introduce convenience and efficiency to a home [3]. People living with physical handicaps [5] may rely on the features of a home automation system to accomplish mundane tasks that might otherwise be difficult or impossible.

2.2 Android OS

Android OS is open source based on the Linux kernel with a Java programming interface, designed primarily for touchscreen gadgets [12]. The Android phone has been on the market since October 2008. Device manufacturers, wireless carriers and enthusiast developers are allowed to modify and distribute the software under the Apache License [12].

Google Play is Android's primary application store. There were approximately 700,000 applications available for Android in October 2012, developed by a large community of Android application developers [12].

Android architecture consists of several layers as shown in Figure 2. The applications have to be layered in order to access the hardware. Several libraries are available. ARM architecture is the main hardware platform for Android.

2.3 Bluetooth Technology

Bluetooth technology is a low-power-consumption short-range wireless communications technology [13] and operates in the unlicensed industrial, scientific and medical (ISM) band at 2.4 GHz to 2.485 GHz [14]. The 2.4 GHz ISM band is available and unlicensed in most countries. Pairing uses two Bluetooth enabled devices known to each other [2]. Table 1 shows the types of Bluetooth.
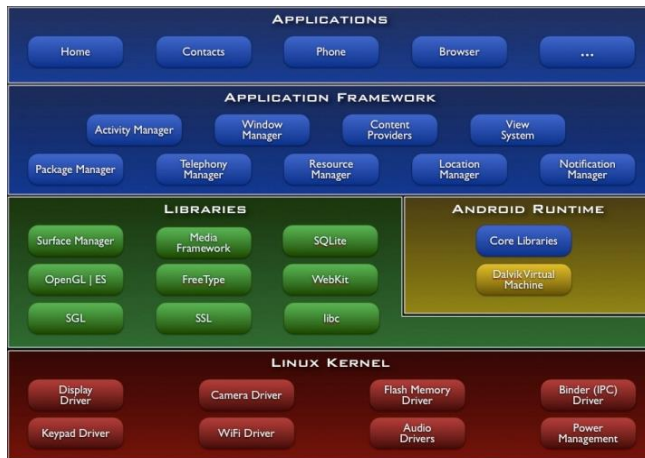

Figure 2 Android architecture [12]

Table 1 Types of bluetooth

Bluetooth Class	Range
Class 1	100 metres
Class 2	10 metres
Class 3	1 metre

2.4 Arduino

Arduino is an open source physical computing platform based on a microcontroller board and an integrated development environment to program the board [15, 16]. Arduino acquires several inputs such as switches or sensors and controls several outputs such as lights, motors and others. Arduino software is compatible with the Windows, Macintosh and Linux OSs unlike most microcontroller systems that are limited to Windows. Arduino programming is simple for beginners. It is good for students to know how to use it since many applications use Arduino [17].

■3.0 RESEARCH METHODOLOGY

This project consists of two parts: hardware implementation and software development.

3.1 System Design

Figure 3 shows the system design of this project. This project utilizes two types of communication: wireless and wired. Cytron BlueBee, which is a Bluetooth module, is used to enable the controller to wirelessly communicate with an Android phone [18]. The home appliances are physically connected to the controller via relays. The Android phone sends a signal to the controller. The signal received is processed and controls the home appliance accordingly. At the same time, the controller sends the status (ON/OFF) of the home appliance to the Android phone.
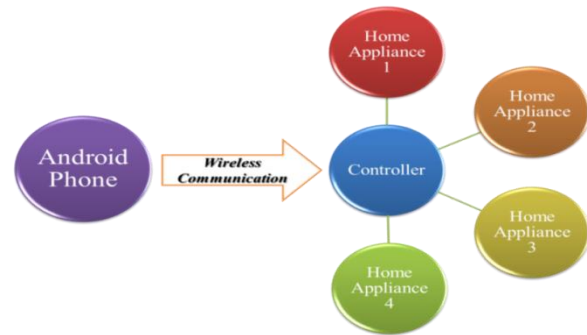

Figure 3 System design

3.2 Hardware Implementation

This section describes the implementation of the controller. The controller is integrated using an Arduino Mega2560-R3, Cytron BlueBee, logic converter, relays and other electronic components. Figure 4 shows the controller design.
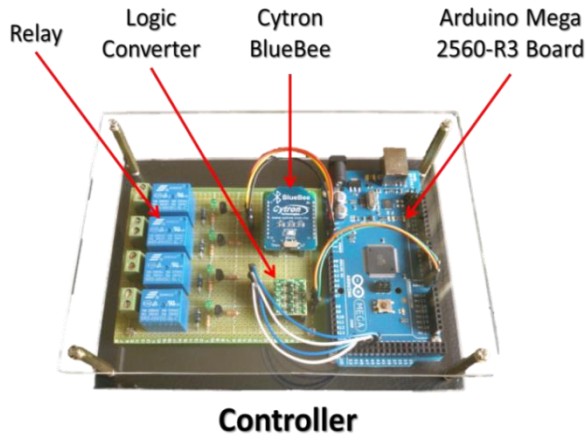
Figure 4 Controller design

The four components used in this project are:
- i.   Arduino Mega2560-R3.
- ii.   Cytron BlueBee.
- iii. Single Pole Double Throw Relay 0-5V.
- iv.   Logic Converter four Channels.

3.3 Electronic Circuitry Design

Electronic circuitry connects all the components together to perform tasks. A controller is designed by integrating several components, such as an Arduino Mega2560-R3, Cytron BlueBee, logic converter, relays and other electronics components. These components need to be well connected to ensure the controller is functioning. Figure 5 shows the connection between the controller and the home appliances. The controller is divided into two parts: input and output.
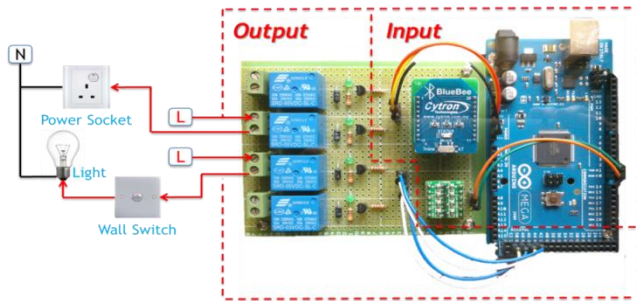

Figure 5 Connection between controller and home appliances

The input part continuously listens to the incoming connection until a Bluetooth connection is established and receives the data sent from the Android phone. The input connection of the controller is shown in Figure 6. Cytron BlueBee is connected to the Arduino Mega2560-R3 via a logic converter. The logic converter is needed because Cytron BlueBee and Arduino Mega2560-R3 operate in different voltages: 3.3V and 5V, respectively.

The output part controls the home appliances once the data from the Android phone has been processed. The output connection of the controller is shown in Figure 7. The home appliances are connected to the Arduino Mega2560-R3 via relays. The relay isolates the low voltage circuit (5V) from the high voltage circuit (240V). It works as an electromechanical switch to

turn on/off the home appliances. The transistor is used to trigger the relay. Green LEDs are used to indicate that the signal has been sent to the output pin after it has been processed.
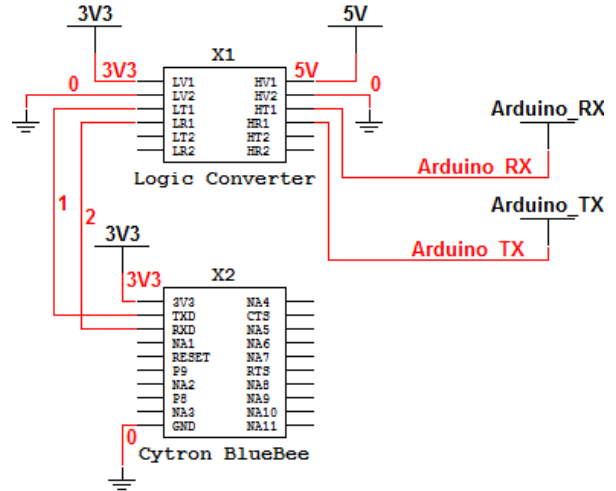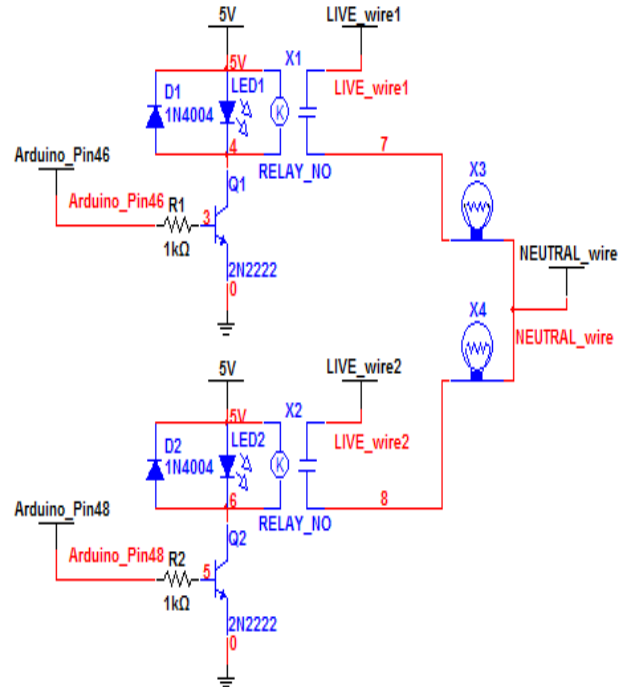

Figure 6 Input connections

Figure 7 Output connection of pins 46 and 48

3.4 Software Development

This section describes Arduino programming and Android application development. The controller is programmed in C using Arduino IDE. The Android application is developed in Java programming using Eclipse IDE.

3.4.1 Andruino Programming

The baud rate of Arduino Mega2560-R3 is set to the baud rate of Cytron BlueBee which is 9600 using the Serial.begin( ) function. Four digital pins (46, 48, 50, 52) are assigned as the output pins using the pinMode( ) function. The Serial.available( ) function is

used to check for any data received. Returning a value greater than zero means that data has been received. This data received is read by the Serial.read( ) function and stored in the incomingByte buffer. The output pin is set to low or high using the digitalWrite( ) function. Data is sent to an Android phone using the Serial.println( ) function. For example, if data received is "a", then the output pin 46 is low and "Home Appliance 1 is OFF!" is sent to the Android phone. Table 2 shows the response on data being received in the Arduino Mega2560-R3.

Table 2 Response on data being received in Arduino Mega2560-R3

Data Received	Output Pin Status	Data Sent
a	Pin 46 is low	Home Appliance 1 is OFF!
q	Pin 46 is high	Home Appliance 1 is ON!
s	Pin 48 is low	Home Appliance 2 is OFF!
w	Pin 48 is high	Home Appliance 2 is ON!
d	Pin 50 is low	Home Appliance 3 is OFF!
e	Pin 50 is high	Home Appliance 3 is ON!
f	Pin 52 is low	Home Appliance 4 is OFF!
r	Pin 52 is high	Home Appliance 4 is ON!

3.4.2 Android Application Development

The Smartphone used throughout this project was a Sony Xperia P with Android OS version 2.3.7 (Ginger Bread). The Android application was developed in Java programming using Eclipse IDE with Android platform API8: Android 2.2 (Froyo), the lowest Android version that the application can support. More devices can be supported with lower API levels but with fewer features. It was important to make this decision before development because the application is unable to run on a platform below the Android 2.2 OS. BluetoothHome is the Android application developed to control home appliances.

3.4.3 Eclipse Me

Eclipse IDE is an integrated development environment which supports several programming languages [11]. It is written mainly in Java, but it is an extensible plugin system which can develop applications in other programming languages such as C, C++, Perl, PHP and Python. Eclipse contains the Eclipse Java development tools (JDT) for Java, Eclipse CDT for C/C++, Eclipse PDT for PHP and others. Eclipse with ADT plugin is the recommended IDE for Android application development.

 Figure 8 shows the *BluetoothHome* developed in Eclipse IDE. Four items are needed to develop an Android application: the Java source file, layout file, strings.xml and AndroidManifest.xml. *BluetoothHome* consists of two activities (MainActivity.java and DeviceListActivity.java) and a service (BluetoothControl Service.java). These three Java source files handle data sent and data received and there are five layout files: activity_device_list.xml, activity_main.xml, custom_title.xml, device_name.xml and message.xml. There are two other files: strings.xml and AndroidManifest.xml.

■4.0 RESULTS AND DISCUSSION

The Bluetooth-based home automation system using an Android phone was successfully implemented. This prototype consists of a controller, power sockets connecting the home appliances to the controller and an Android application (*BluetoothHome*) providing the user interface for remotely controlling the home appliances as shown in Figure 9.
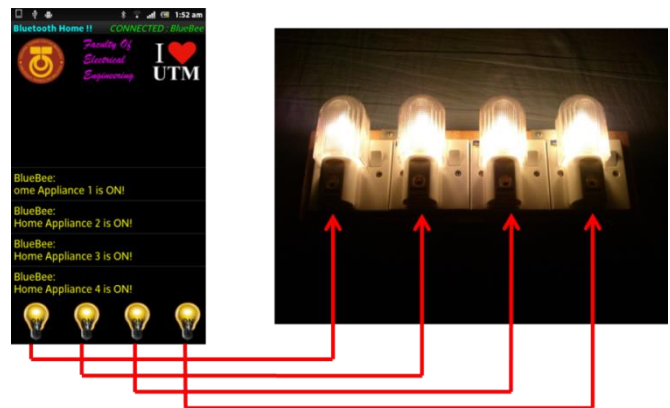
BluetoothHome is able to control home appliances within the area of the house. The home appliance is turned on/off immediately without any delay when the button is pressed as shown in Figure 10.
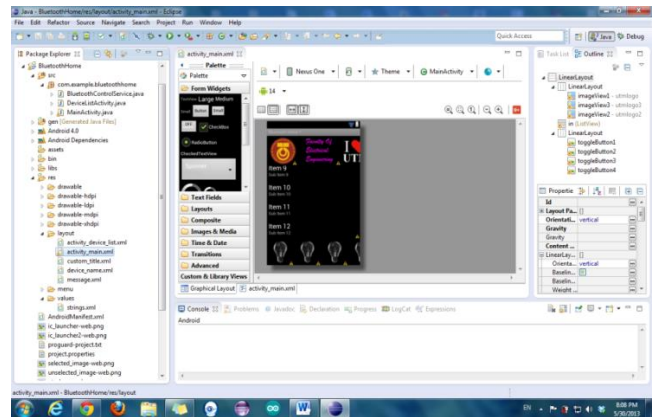
Figure 8 Eclipse IDE

Figure 9 Home automation prototype

Figure 10 Home appliances are controlled accordingly

4.1 Running Using Android Debug Bridge

Android Debug Bridge (adb) allows the application to run on the connected phone via a USB. USB debugging in the phone settings must be selected. The adb driver has to be installed onto a computer before it can be used. Some phones have an adb driver inside them and it can be automatically installed when connected

to a computer. Phones without an adb driver have to download it from the internet. BluetoothHome is run on Sony Xperia P via adb because the emulator does not support Bluetooth based applications.

4.2 Debugging Using Android Debug Bridge

BluetoothHome is debugged on Sony Xperia P via adb. A toggle breakpoint is put in the line statement (byte [] buffer = new byte [256];) to identify the received data in the buffer. A step-over operation is used during debugging and the data received in the buffer is [72, 111, 109, 101, 32, 65, 112, 112, 108, 105, 97, 110, 99, 101, 32, 49, 32, 105, 115, 32, 79, 78, 33] which is ASCII code as shown in Figure 11; 72 is "H" and 111 is "o". This code is automatically translated into the readable sentence (Home Appliance 1 is ON!) and displays in the Main UI.
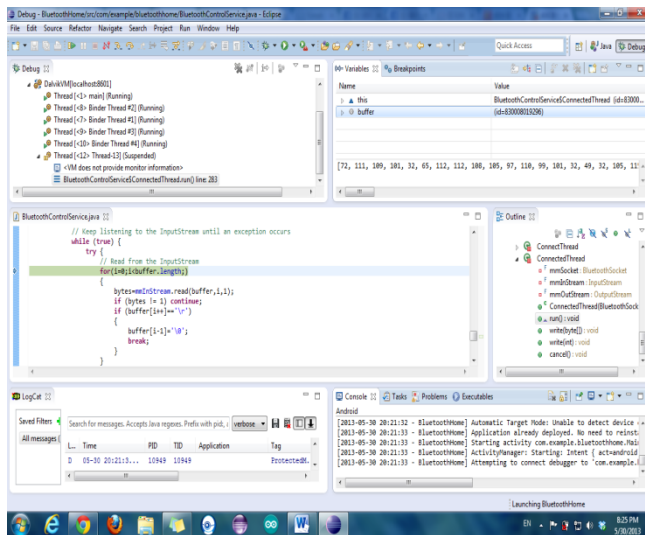

Figure 11 Data received

4.3 Limitations and Problems Encountered

Some problems were encountered during this project. Bluetooth connection of the Android application could not be established in the early stages of this project. This problem was solved after referring to the online solution on Android Bluetooth APIs. In addition, *BluetoothHome* was unable to display the data received correctly. This problem was solved by putting a flag in the data listening loop. However, another issue was that the list view is unable to display the first character ("H") of the first data received. The list view is able to display the following data received correctly.

■5.0 CONCLUSIONS

It can be concluded that the objectives of this project were achieved, ie, to develop a low cost and high reliability home automation system. In addition, a user-friendly Android application as an alternative to the remote control unit of a home automation system has also been established.

Improvements can be made to improve this project. Some recommendations are:

i. The Bluetooth connection between the Android phone and the controller is automatically established when the user starts the BluetoothHome, provided the phone's Bluetooth is turned on.
ii. An LCD display is integrated into the controller to provide the status of the home appliances.
iii. BluetoothHome is able to control TV channels, air conditioning temperatures and so on.

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