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A GUIDE TO BLUETOOTH LOW ENERGY TECHNOLOGY

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ABSTRACT

Bluetooth Low Energy (BLE) is used as a wireless technology for machine to machine communications and industrial automation. It is also being used in biomedical and sports products. This paper explains the software and hardware needed for implementing Bluetooth low energy technology. An android app has been developed for communication with the designed hardware. This paper serves as a guide to anyone involved in development with Bluetooth low energy. BLE technology is implemented and demonstrated with the help of an example. A high gain differential antenna is used in hardware for better range.

Keywords: bluetooth, ble, low power, wireless.

1. INTRODUCTION

Bluetooth low energy (BLE) is used for wireless communication over a short range. It has advantage of operating on coin cell batteries and providing longer battery lives. It can be used for biomedical applications, sports products, machine to machine communications and industrial automation. A BLE based approach for monitoring electrocardiography and respiration is presented in [1]. A BLE based implantable glucose monitoring system is given in [2]. A BLE based wireless battery charger for implantable medical devices is given in [3]. BLE can also be used for heart rate monitoring while doing exercise [4]. BLE has also been used in reconfigurable wireless health monitoring system [5]. BLE is also used in wireless biomedical sensors [6]. BLE used in Blood Pressure monitoring system is presented in [7]. BLE has been justified as a suitable technology for industrial automation [8]. BLE can also be utilized in Renewable energy sector [9]. This paper can be used as a reference by anyone who wishes to indulge with BLE. The paper is organized as follows: Section II explains the hardware required for implementing BLE technology, Section III explains the software part, Section IV considers the android app development, and Section V integrates all with the help of an example. Conclusions are drawn in Section VI.

2. HARDWARE

Figure-1 shows the factors which determine the device selection for BLE. A comparison of different available devices used for implementing BLE has been already been done in [8]. Following points list the important aspects of BLE devices

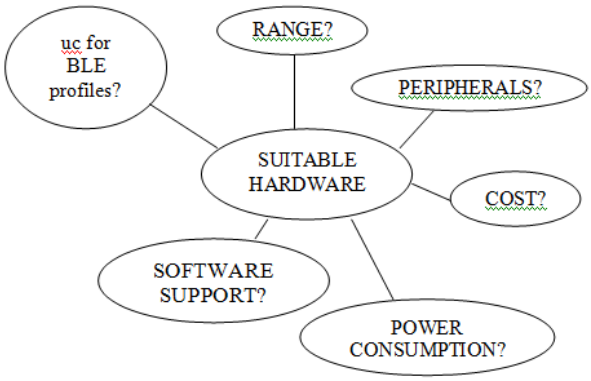

Figure-1. Hardware requirements for BLE device.

- Some devices such as ST BlueNrg implement Bluetooth stack in the BLE IC and external microcontroller is required for implementing BLE profiles. On the other hand Texas CC2540 does not need external microcontroller to implement BLE profiles [10].
- Power Consumption is a key factor for devices running on coin cell batteries. Power consumption of BLE device depends on Transmit Power, hardware and software design.
- Range of a BLE device depends upon transmits power, antenna gain and environmental conditions. Transmit Power and Receiver Sensitivity of different devices has been compared in [8]. Different Kind of industrial environments has been studied in [11].
- Cost of a BLE device depends upon available peripherals and features. A comparison of various devices on the basis of available peripherals and cost has been done in [8].
- The choice of BLE device depends upon the peripherals required if using standalone solution. A comparison of devices on the basis of number of peripherals has been done in [8].
- Software support can be a deciding factor for choosing the BLE device. Before designing one must ensure that the adequate and affordable software support is available for the chosen device.

Antenna design and selection is very critical for hardware. Different types of antenna includes chip antenna, pcb antenna and whip antenna. PCB antennas are the most cost effective and preferred way. The type of antenna chosen depends upon range requirements. For higher range, antennas with more gain are to be used. Table-1 lists some pcb antennas with their respective gain [12] [13] [14] [15] [16] [17].

Table-1. Gain values of different pcb antennas.

Antenna	Type	Average gain (dbi)
Meandered inverted f antenna	Single-ended	5.033
Inverted f antenna	Single ended	2
Half wave dipole antenna	Differential	7.16
Folded Dipole Antenna	Differential	6.5
Yagi PCB antenna	Directional	7.22
W3008	Chip	1.7

3. SOFTWARE

For a standalone BLE device the software that is flashed include the BLE protocol stack and BLE application which includes BLE profiles while other devices have protocol stack in BLE controller and the application is implemented in the external microcontroller. The BLE protocol stack is provided by the device manufacturer. Following terms should be clearly understood for software development of a BLE device.

- **Attributes:** These are basic elements used by servers to send/receive data.
- **Characteristics:** Attributes are grouped together in characteristics. It includes declaration, value and descriptors fields.
- **Services:** Characteristics are grouped together to form a service. Each service serves a specific purpose. Some standard services include Link Loss Service, Immediate Alert Service.
- **Profiles:** Services are grouped together to form a profile. Heart rate profile is one such standard profile.

For Software development for a BLE device one must have control over advertising, device discovery, device connection, device disconnection, services discovery, characteristics and descriptors read and write.

4. ANDROID APPLICATION DEVEOPMENT

Android application is needed if one needs to communicate with a smart phone. Smart Phone can be used to send commands and data to remote BLE device. Android Studio is needed for android app development or Eclipse IDE with android ADT bundle serves the purpose. Layout is designed in XML while dynamic actions are programmed in JAVA. One should be familiar with XML and JAVA for android app development. A basic guide for BLE application is given at [18]. Android is providing BLE APIs for android version 4.3 and above. A flowchart outlining the process of android app development is shown in Figure-2.

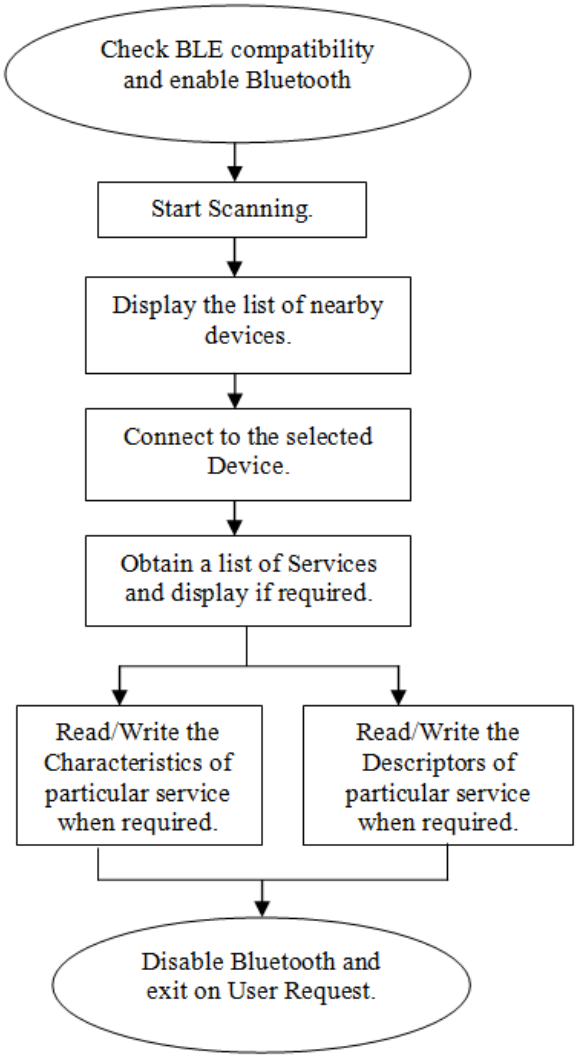

Figure-2. Flowchart depicting android app development.

5. EXAMPLE

This section considers an example for hardware, software and android app development. A pcb is designed for Texas instrument (TI) CC2540 with half wave dipole antenna and Inverted F antenna as shown in Figure-3. The pcb has two CC2540. One CC2540 is connected with half wave dipole antenna while the other CC2540 can be connected to either of the two antennas. Differential antennas do not require baluns while single ended antennas require 50 ohm impedance matching circuit. For this purpose a balun is used with Meandered Inverted F antenna. The two antennas provided different Gain and thus different Range. A comparison of RSSI values and estimated range with different antennas is given in Table-2. Transmit power is 2.5 mW while taking these readings.

Transmit power is software configurable in CC2540. It is seen that Range with half wave dipole antenna is 100 meters while with Meandered Inverted F antenna it is just 61 meters. Hardware design for cc2540 has been elaborated in [8].

Figure-3. PCB for TI CC2540 showing meandered inverted F antenna and half wave dipole antenna.

Table-2. Estimated range with two different antennas.

Antenna	Meandered inverted F	Half wave dipole
Available Average Gain	4 dbi	7 dbi
RSSI (0.5 m)	-43.22 dbm	-39.25 dbm
Estimated Range	61.985m	97.901m

TI provides operating system architecture for software development. A BLE profile is implemented in the software of CC2540 with the following parameters:

- Number of services equal 5
- UART DATA TRANSFER Service is 5th service with UUID F000FFE0-0451-4000-B000-000000000000
- This service has one characteristic. The characteristic have two descriptors.
- The characteristic value is 5 bytes.

CC2540 board is interfaced with a desktop computer through UART. Data entered in hyper terminal goes to CC2540 through UART which is transmitted Over the Air to Android Smart Phone. Block Diagram of the Setup is shown in Figure-4. Actual test setup is shown in Figure-5. Android App is shown in Figure-6. Whatever we type in hyper terminal program of desktop, the same is being displayed on the mobile phone. Data from Computer goes to CC2540 through UART. This data is transmitted over the air by CC2540 to android Smart Phone with BLE compatibility. This example demonstrates the successful implementation of BLE hardware, Software and related android app. This approach can be applied to any domain where short range wireless communication is desired.

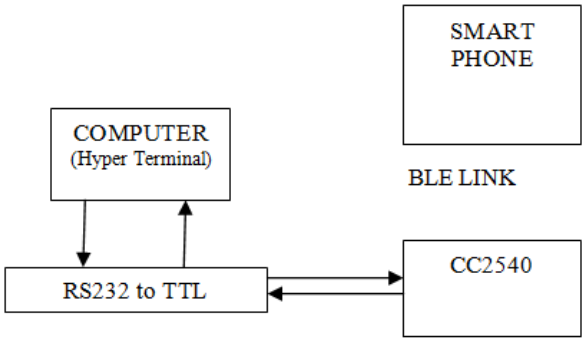

Figure-4. Block diagram of test setup.

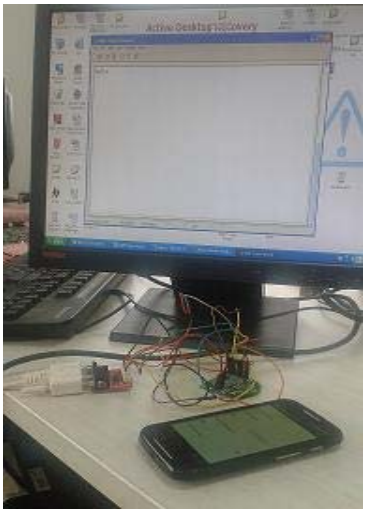

Figure-5. Actual test setup.

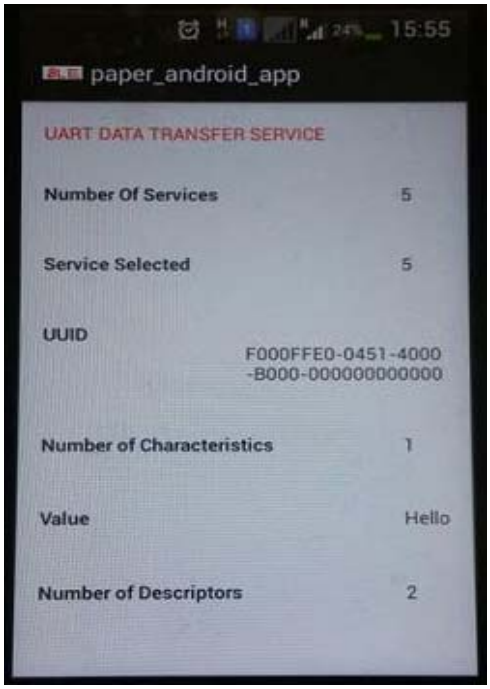

Figure-6. Android app developed for test application.

6. CONCLUSIONS

A complete solution for extending BLE support to an existing product or including BLE in a new product has been provided. BLE hardware, software and an android app has been developed, tested and demonstrated with the help of an example. Considering uses of BLE in different domains, this paper can be very helpful to anyone involved in developing with Bluetooth low energy.

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