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Indoor Localization and Distance Estimation using Bluetooth Technology

ANUP DAS

Department of Computer Science and Engineering, Jadavpur University.

KOLKATA,WEST BENGAL,INDIA

Abstract: The thesis focuses on solving the problem of indoor localization using Bluetooth technology. This work shows how to build localization system using Bluetooth 4 standard. It offers practical solution for indoor localization with detailed description of developed algorithms. Based on Bluetooth RSSI (Received Signal Strength Indication) strength, position of nearby smart phones is identified. A process to generate more test points is proposed here. These test points are then exploited to choose the near points and to determine the target final location. Implementation of such localization scheme is done for an indoor setting and the presence of obstacles on signal propagation is investigated. The distance calculated on the basis of RSSI is compared with actual distance to show the effect of RSSI variation on localization.

Chapter 1

I. Introduction

Indoor localization systems are motivated by Global Positioning System (GPS)[7]. The traditional approach to positioning is based on GPS[8]. GPS is also known as satellite navigation because positioning is based on a network of satellites. In informational technologies, the problem of indoor localization aims to determine location of objects, assets or persons in an indoor environment. While this problem is easy to formulate, it is hard to solve. In the last few years, there was a lot of development in indoor localization systems with Wi-Fi Access Points and Bluetooth. There is a great demand for indoor localization systems in fields such as a set of industry, marketing and also schools. With the rise of Internet of Things, there is a growing need for precise localization system.

The use of Bluetooth in the distance calculation and location determination it not only improves the accuracy in the positioning but also could be used in the disaster environments such as tsunami, earthquake etc. when there are no base stations are available but in this situation the rescuers still can use Bluetooth to carry out their rescue mission.

According to the intensity of this signal, the known node can have an estimate of the distance between Bluetooth known node and the all neighboring beacon nodes. After performing a certain number of such measurements for different beacons, the known node has to combine all this information for RSSI (Received Signal Strength Indicator), this information is the power of each individual signal and the coordinates of the corresponding transmitter) in order to estimate its distance. This method computes distances based on the transmitted and received signal strengths between known node and unknown nodes. As the prototype has been designed and constructed, the objective behind this work is to improve the accuracy of the system.

Indoor positioning

The GPS technology has made outdoor positioning highly successful and it is now applied in a wide variety of products. Due to the signal attenuation caused by the construction materials of buildings, indoor positioning systems cannot rely on this technology and as a result, has not been equally successful. Several indoor positioning systems have been developed over the last decade, relying on a wide variety of technologies, including WLAN, infrared and ultra-sound among others, but there are still few commercial solutions available, and the ones that do exists are often costly and complex to install [13].

In wide range of positioning techniques the most commonly used techniques is being trilateration, triangulation and fingerprinting, [12]. Currently, the choice of technology and positioning technique depends on the requirements of the system. For instance, radio frequency based technologies such as IEEE 802.11 are inexpensive to deploy but has lower precision other than many other kinds of technologies.

1.1 Global Positioning Module

In this project the main objective is to develop an indoor positioning system based on Bluetooth technology. This system will be integrated into the Global Positioning Module (GPM), which provides the user with a geographical position by transparently selecting the technology, or position provider, that is the most appropriate in any context. GPM is developed for the Android platform, which places certain restrictions on the system architecture since the positioning must take place on the Smartphone itself. In other words, it is the Smartphone that is responsible for detecting Bluetooth signals and estimating a position.

Research Motivation

Generally, a user who is unable to locate his location to other by the help of other Smart phone mobile device it can easily know and locate his position by the help of some Smart devices.

Till today research in this area [36] includes various technological approaches such as Infrared (IR), Ultra wide-band (UWB) [37], Wi-Fi [38], Bluetooth low energy (BLE) [39], Zig-Bee [40], Near field communication (NFC) [41], Radio-frequency identification (RFID), Wireless sensor networks (WSN), magnetic field fingerprinting, image processing.

All these protocols use the same model, where some nodes *know* their location and some other node whose location is not known by known node, estimate their location using the information they receive from the beacons. This information consists of the beacons' coordinates and of features of the beacon signal, such as the *received signal strength indicator* (RSSI) or the *time difference of arrival* (TDoA).

There are many approaches for distance estimation using Wi-Fi.

Scope of work

In this thesis Bluetooth based indoor localization technique is presented, where a Bluetooth enabled node can sense its nearby devices and check their proximity. Effect of obstacles on the accuracy of localization is also investigated here. The technique does not require supporting common infrastructure but can detect the list of neighboring nodes based on the RSSI values.

In this thesis distance of neighboring node can be measured by third party and is stored in database and after running apps to measure RSSI of received signals, using RSSI, distance can be estimated and accuracy can be measured by comparing actual distance with calculated distance.

Application

The application and features of smart phones are increasing day by day because the usage of these feature rich phones is increasing. People are replacing their laptops and personal computers with these smart phones thus the demand for processing. These phones use a battery as their power source which has a limited capacity as compared to plug in devices like personal computers.

In case of smart phones device is portable, the batteries provided are lightweight and hence has limited capacity. In that case android device can communicate with other android device and data exchange. On other hand most important Case is in case of any types of natural disaster (like water flooded ,heavy rain, tsunami, Hurricanes, Earthquakes and Tornadoes but Floods, Droughts and Bush Fires, Snow & Hail Storms, Landslides etc) where mobile network place is unavailable it is difficult task to communicate with mobile devices and also data exchanging with other android Smartphone devices. Here anybody can easily exchange information with other by using android Smartphone devices.

In above situation where mobile network is unavailable in the case of battle field for a solider it is difficult task to exchange information and communicate with head quarter. Or any battalion in do or die situation or who face some disaster (like Avalanches or Snow & Hail Storms) and in a critical situation need to exchange information or data to neighbor battalion or commander. He can easily exchange information with other by using android Smartphone devices.

Organization of thesis

In this thesis Chapter 2 sets the background by providing a brief overview of Bluetooth technology advantages, connection establishment in Bluetooth by Android and related work on Bluetooth base indoor localization system.
Chapter 3 presents proposed methodology of Bluetooth based indoor localization techniques, here system architecture, work flow and RSSI details are given.
Chapter 4 presents implementation of the system where setup details for Android Studio 1.5 library implementation and details of implementation of proposed Bluetooth base indoor localization system..
Chapter 5 presents the results and performance of the proposed Bluetooth based indoor localization system.
Finally, Chapter 6 presents the conclusion and future work of this Bluetooth based indoor localization techniques.

Chapter 2

Background

This chapter presents a background of the Bluetooth based indoor localization system.

BLUETOOTH TECHNOLOGY

Bluetooth is a wireless technology widely used to connect two or more devices and then allow communication between these devices. Nowadays, Bluetooth can be found in all sorts of devices and areas of consumer goods from mobile phones, cars, speakers to light bulbs etc. It is becoming more and more popular in modern technologies. Especially, Bluetooth has gained a lot of attention in Internet of Things concept. Internet of Things is a network of diverse physical objects and serves the purpose of control and awareness of these objects. Bluetooth technology comprises of hardware and software solution. It means that a Bluetooth devices is not only a small Bluetooth antenna but also the software for connecting to this antenna.

Bluetooth was originally designed to replace physical cables which send wireless wave only on a short distance with ranges up to 100 meters especially when there are barriers and obstacles, Bluetooth waves lose their range dramatically. In most countries Bluetooth use from 2.4GHz [3] to 2.485 GHz. It uses full-duplex signal.

Advantages of using Bluetooth

Bluetooth have some advantages over other technologies, which are:

• Bluetooth is pervasively available. Most mobile devices, like cell phones, laptops are already equipped with a Bluetooth module. People carrying such a device already 'wear' all the hardware which is required to localize them. Many other indoor localization systems, however, require the person or object being localized to wear a special badge. This badge contains the hardware which interacts with other parts of the localization system to estimate the location of the target. Using Bluetooth instead of specialized localization technology thus has the advantage that the person being localized does not need to be equipped with additional hardware.

• Bluetooth is relatively cheap. The widespread adoption of Bluetooth in a large variety of devices has resulted in the availability of Bluetooth chips at low prices. Building a localization system using Bluetooth technology can thus be done using low price, off the shelf hardware. Also, since the system does not need to use tracking badges the only hardware costs stem from the Bluetooth sensor network. Commercial localization systems are rather expensive compared to the costs of building a Bluetooth localization system.

• The power consumption of Bluetooth modules is relatively low. The main purpose of Bluetooth is to be a replacement for short distance wired data transfer. Hence, it does not require a large transmission range and the Bluetooth signals are transmitted at low power levels. Since Bluetooth is used in a lot of mobile devices, manufacturers have also put effort in producing Bluetooth chips with even lower power consumption. As a result Bluetooth puts less of a penalty on battery life compared to other wireless technologies, like Wi-Fi for example.

Bluetooth 4.0 Low Energy

In 2010 on 30th of June Bluetooth SIG released Bluetooth Core Specification 4.0 [5] also called Bluetooth Low Energy (LE). This version is commonly known as Bluetooth Smart Ready for host devices and as Bluetooth Smart for transmitting devices such as sensors. It was introduced with low energy technology. Bluetooth devices can now be small with a battery of the size of a coin because of power efficiency of Bluetooth Smart. This allows Bluetooth technology to be implemented into small devices like watches, bracelets and toothbrushes. Bluetooth Smart specification consists of Classic Bluetooth, which includes protocols from older specifications and Bluetooth has High Speed specification which was introduced in Bluetooth Core Specification 3.0. This version also includes increased range of waves. In Classic Bluetooth, the typical range of signal waves was 10 meters, but if needed the signal strength can be optimized to about 100 meters. Bluetooth Smart also promises to be inter-operable with devices made by different vendors.

Bluetooth Smart technology was introduced to the market with two options of implementation on devices [6]. The first option is to implement the new technology and Bluetooth Low Energy functions on Classic Bluetooth existing radio. This implementations means that updating to new version of Bluetooth costs manufacturers less than changing manufacturing process all together. This first option is called dual-mode implementation and contains radio from Classic Bluetooth with the newest functionality. Second option is called single-mode implementation.

In this mode only Link layer of low energy technology is implemented. This link layer provides low power idle mode operations and also provides reliable transportation of data from single-mode to multiple hosts. This data are safely encrypted. Single-mode solution brings extremely low power consumption on these devices meaning long running life on small batteries. Dual-mode also benefits from low energy technology with enhanced battery life. Bluetooth LE contains changes necessary for implementation of

Generic Attribute Profile (GATT). This profile is closely related to Attribute Protocol (ATT) and represents wire application. With this application, clients are able to read or write attributes exposed by server.

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The Bluetooth connection establishment protocol

There are two types of Bluetooth base connection in an Adhoc mode 1) Asymmetric point to point connection establishment protocol and 2) Another is ad hoc symmetric point to point connection establishment protocol**.** Connection establishment in Bluetooth is an asymmetric process.

In asymmetric point to point connection establishment protocol [30] both sender and receiver use inquiry hopping sequence. Receiver starts scanning with enquiry scan state with listening frequency carrier in every 1.28 second. This phase broadcasts Inquiry Access Code (IAC) packet rapidly. After Random Back off Delay (RB) connection establishment delay (R) can be measured by R=2FS+RB. Where FS is frequency synchronization delay.

In an ad hoc symmetric point to point connection establishment protocol is simple to execute by the user like pressing a button and expect to connect. The merged schedule is produced by merging the state switching times of the two units into a single one, which can be seen as an "on off" process. Starting at each "on" interval of the merged process, the two units will connect after a random interval R = 2FS + RB, given that they both remain fixed at their states for an amount of time greater than R. where FS is frequency synchronization delay and RB is the random back off delay. Otherwise, they have to wait for the next "on" interval.

Android Bluetooth architecture

Android Bluetooth system contains Bluetooth driver, Linux Kernel, Bluetooth protocol Layer BlueZ, Bluetooth user Library, BluZ application. In Figure 1 the android. Bluetooth are class Package, Bluetooth application. Bluetooth can transmit asynchronous data and synchronous language at a same time, with protocol layer include a number of agreement such as L2CAP, SDP, RFCOMM and so on, which provide support for upper layer transmission.

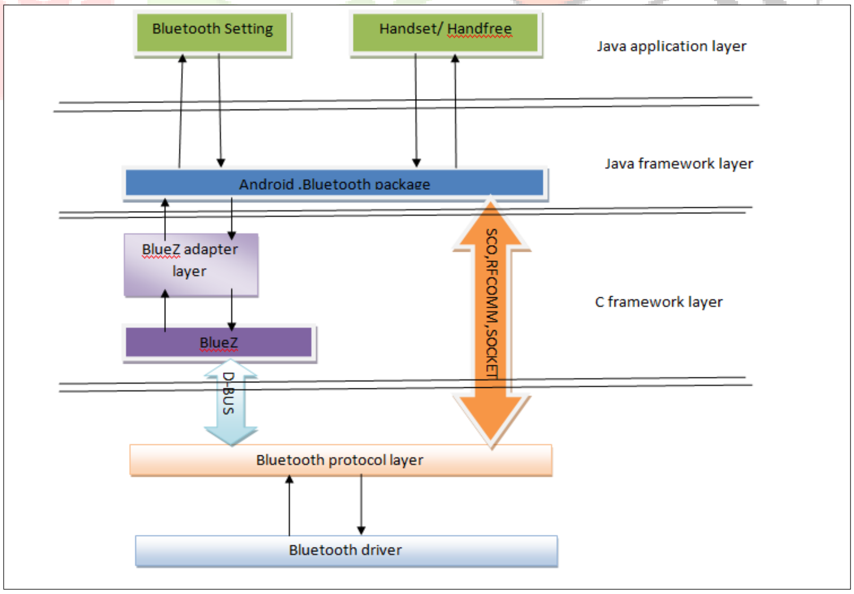

Figure 1 : Structure of Android Bluetooth Architecture [44]

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Bluetooth sensors and iBeacons

Bluetooth sensors and transmitters are small devices with long period of energy. Bluetooth sensors can be placed anywhere. These sensors and beacons are used across all mobile platforms such as Android, iOS or Windows. These sensors are used in applications for wide spectrum of scenarios. IBeacon was originally introduced by Apple Inc.

Integration of iBeacons into mobile devices

Currently, platforms such as iOS provide full support for iBeacons whereas other mobile platforms such as Android, BlackBerry in the form of partial support or support with external libraries. In mobile world which is constantly changing and generations are changed in a course of years, these support differences for iBeacons can vanish within a year or two and iBeacons can easily become natively supported on all mobile devices.

iOS and Windows Phone

Apple Inc. devices run on the operating system iOS which support input through direct manipulation. Based on ability range in region it behave as a ibeacon and perform the specific operation. Windows Phone support GATT profile and its version 8.1 allows to scan only for connectable Bluetooth devices.

Android

In this work, the focus is on utilizing iBeacons in indoor localization with Android. Android version 4.3 supports iBeacons making implementation of iBeacons possible for more than 50% [14] of all Android devices. Even more implementation options for iBeacons are provided in the current version of Android operating system, version 5.1. Some of the main improvements also mentioned here [13] are:

• Scanning - from Android version 5.0 there has been a lot of improvement in scanning for Bluetooth peripherals, including improved scanning for iBeacons. Scanning is optimized for low power consumption.

• Peripheral mode - another improvement is that the devices can transmit advertisement and act as iBeacons.

The use of iBeacons with Android devices is naturally connected with the necessity of having a device with Bluetooth 4.0. Since the beginning of 2015 almost all new devices have Bluetooth Smart Ready function implemented. An Android application itself needs a permission from the user to manipulate with Bluetooth. This permission allows the application to use and access Bluetooth devices in the near-by area. Library functions are provided for iBeacon advertisement for instance, Android AltBeacon Library.

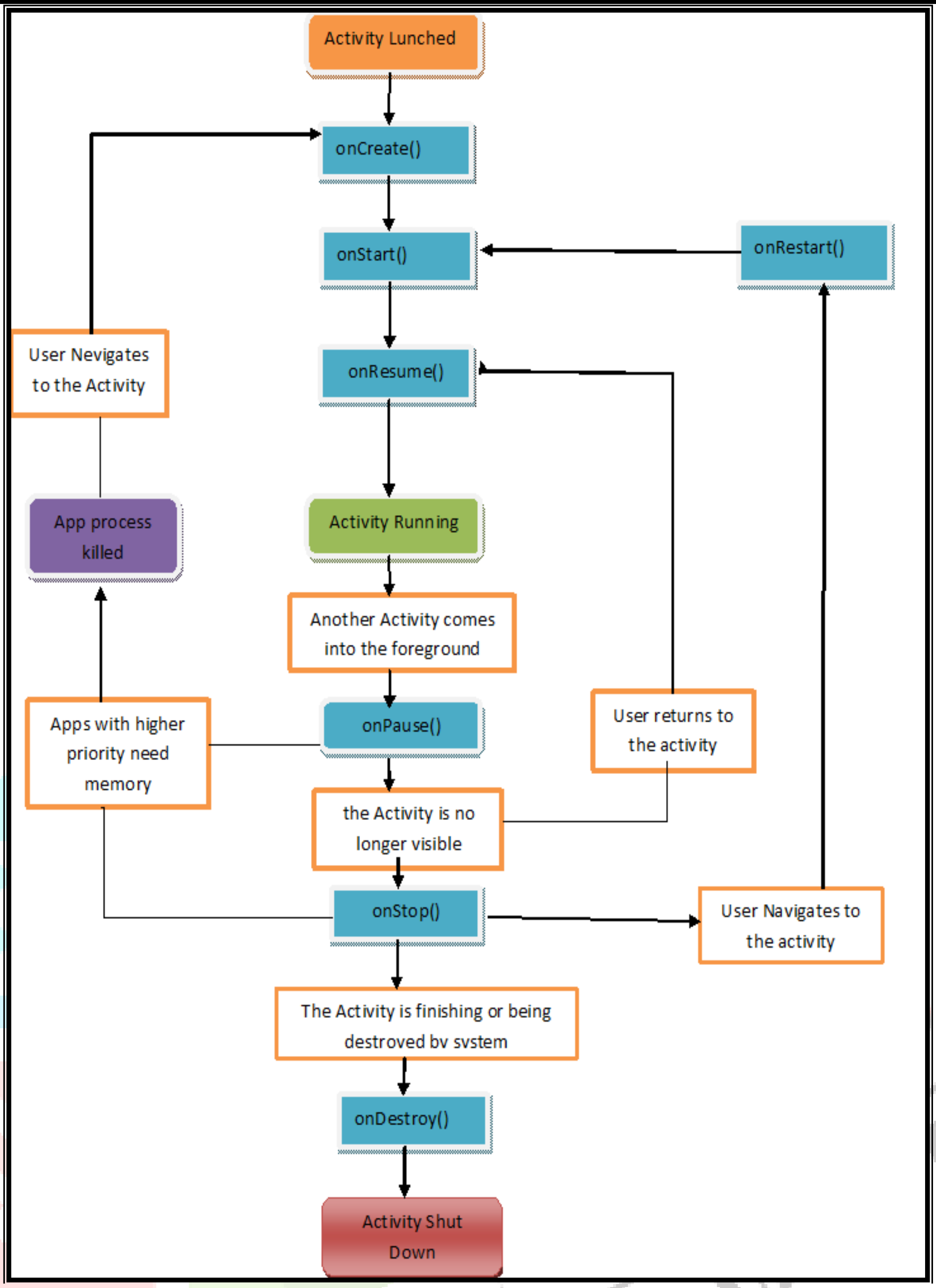


Figure 2 : Android Activity Life Cycle[35]

Android activity life cycle are shown in Figure 4 where activity is launched with some function (onCreate(), onStart() ,onPuse(), OnDestroy() and onStop()). After successfully running activity another activity comes into foreground.

Related work

There are lots of work in Bluetooth based indoor localization techniques using RSSI for distance estimation and determine positioning of unknown node. Some related works are

In indoor Localization Based on Response Rate of Bluetooth Inquiries[47], using context management frame based on inquiry response in infrastructure and network based localization, solutions are presented for mobile users at room level. According to this approach, every location is fingerprinted by inquiry Response Rate. Author's system uses relative entropy measure (Kullback-Leibler function) and its extension (Jensen-Shannon distance measure) to estimate the location of the target device. Bluetooth sources run inquiries periodically, and send the results to their subscriber. Here the estimation performance is evaluated based on estimation accuracy. The solution achieved by author using CMF at top-1 [47] estimation accuracy of 98% and 75%. In this Bluetooth based localization work, solution works well when there is a high spatial density of Bluetooth sensors.

For adaptive distance estimation using on Bluetooth technology [45], node position can be estimated by using RSSI value but the problem is that RSSI based system is that as RSSI varies correct calibration is needed. In this work author uses two calibration methods, firstly static calibration method of LNSM (log-normal shadowing radio propagation model) parameters for distance estimation. The second proposed method uses dynamic calibration performed during the measurement where environment can change its properties. It is not suitable for distance estimation with high precision. Inaccuracy may be changed for environment itself and where human being is present.

A Bluetooth signal strength based Indoor localization method [46], in this work, localization method is proposed which uses calculated values to estimate the positions of unknown transmitters using an error function based on a modified Root-Mean-Square-Error (RMSE) metric. Here three B1uetooth receivers are placed in the room randomly at discrete points and they function as base stations. An Error Function is defined to estimate the positions of unknown transmitters. In this method accuracy need to be improved for practical implementation.

Enhancing Bluetooth based indoor positioning with dead reckoning[50] presents an approach that can be implemented on the smart handheld devices and by introducing the concept of dead reckoning inside a channel, it can enhance the performance of positioning system and phone devices. Also it can use to perform inquiry module which used to find out the RSSI value. In this work author explained the indoor positioning system based on Bluetooth technology which uses a fingerprinting method to estimate a user position in the indoor environment and dead reckoning to increases accuracy. The strength of received Bluetooth signals has non uniform shadowing when the signals are reflected or penetrated by obstacle, So objects accuracy may be limited. In dead reckoning, standard framework is divided into small tiles and the current position of a person is estimated based on assumed speed determined and considering variation is built in sensors in mobile phones. Besides the Bluetooth phone author also use sensors to track the movement of the user using magnetometer, accelerometer and gyroscope and combines Bluetooth based positioning with sensors .The sensor information data gives additional way to determine the location.

In Bluetooth based indoor localization system for measuring distance accuracy [48],the used techniques is ToA (Time of Arrival) The time difference is measured by sending a data packet containing a correlation code including a receiver, correlation IC and microcontroller. In this work one of the stationary are installed Bluetooth stations (master) which initiates the connection to the mobile and starts the time difference measurement by sending a data packet containing a correlation code. Here measurement accuracy is only affected by the clock accuracy of the different base stations. Here additional custom correlation ICs are designed at each base station to determine the time differences with an accuracy of only few nanoseconds. It shows the ability of a system to localize Bluetooth devices with an accuracy of ±1 meter.

In experimenting an indoor Bluetooth based positioning service[32],effectiveness is critically analyzed by connecting Bluetooth and Ethernet LAN as names BIPS. In BIPS, the role of master is always from a fixed workstation which is also connected to the wired network, and the role of slave is always from a portable device. The process of establishing a communication channel is performed by executing two sequential phases first inquiry phase. The second final phase is named paging, corresponds to the initial connection. In this work logical master is compound in two card. One card for discovering new mobile user and another for exchanging data who is connected with BIPS and those user who connected with system.

In Inquiry-based Bluetooth RSSI Probability Distributions for Indoor Positioning[49], by using Weibull function (shift, shape and scale parameter over entire RSSI domain) for approximating the Bluetooth signal strength distribution, reliability and accuracy of the fingerprint database is improved. This work is done by the two phases. First phase is a data training phase in which a radio map for the targeted area is generated in advance, while the second phase is the real-time location determination phase using the radio map. Using Weibull function based fingerprint database, the probability for any arbitrary RSSI can be measured. In this work as a result the reliability and accuracy of the fingerprint database is improved with the Weibull function than the occurrence-based fingerprint approach.

In this thesis chapter, background of Bluetooth technology, advantages of Bluetooth technology, connection details with Android studio 1.5 in Bluetooth based indoor localization system are presented.

Chapter 3

PROPOSED METHODOLOGY

This chapter presents an extensive overview of the Bluetooth based indoor localization system we developed as part of the thesis work. First the system architecture is detailed followed by description of the system workflow.

System Architecture

In order to track a mobile device, a fixed architecture of Bluetooth beacons is necessary. This architecture often consists of inexpensive commodity devices and is generally easy to deploy. The system reads the Received Signal Strength Indicator (RSSI) from Bluetooth-enabled Device. Another option is to have the beacons scan for mobile devices in adhoc mode. This requires a distributed architecture where the beacons report information about the detected mobile devices to a server. The advantage is that there is no need for specialized software on the mobile devices and it does not require active participation from the users.

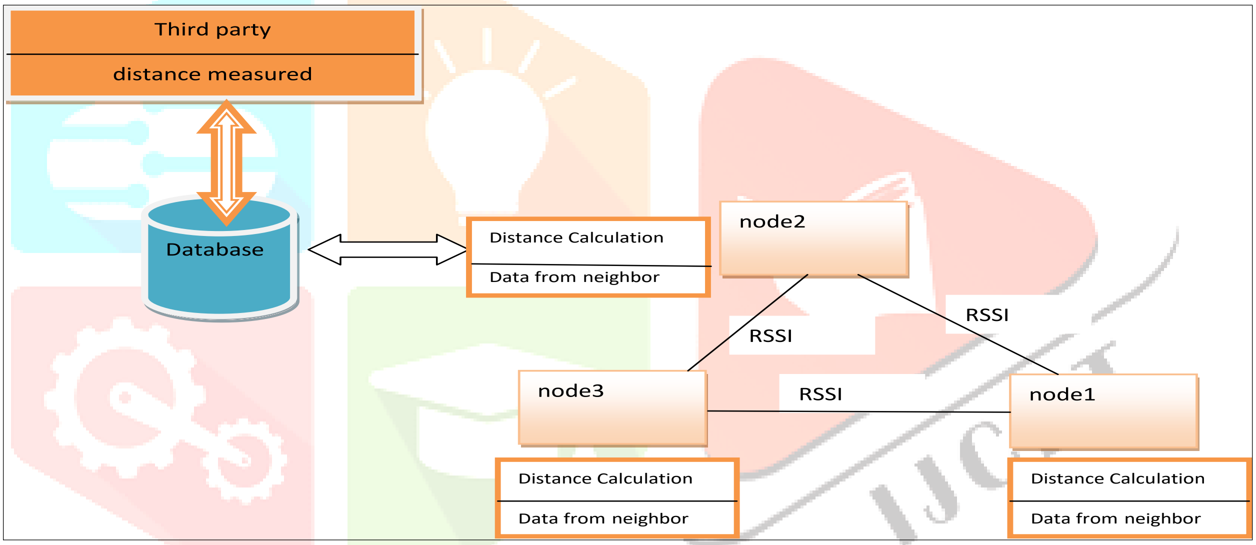


Figure 3: Architecture of the proposed Bluetooth based Indoor Localization System

In Figure 3, the Bluetooth fixed device powers on and it searches for all other neighboring mobile devices in adhoc mode. It can be able to get all the beacon mobile device's RSSI value and MAC address. Here distance can be measured physically by third party and stored in database like laptop or desktop.

In Figure 3 Node1, Node2, Node3 all are beacon nodes. Node1, Node 2 and Node 3 also can be able to get RSSI both from neighbor nodes according to Figure 3 in adhoc mode. The fixed Bluetooth device can able to collect data from neighbor and also calculate the distance with respect to RSSI. The corresponding workflow is explained in the following section.

Work Flow

In this Bluetooth based indoor localization framework, firstly Bluetooth device switches on its transceiver and searches for all the neighboring nodes and get the RSSI value. Hence it is not necessary for two devices to actually be connected. After getting RSSI, distance can be measured by the third party manually and stored in data base. As shown in Figure 4 after running the Apps the first known device would be able to get the RSSI value of all the neighbors and calculate the distance from the known node to unknown node using proximity in Adhoc mode. Distance Accuracy can be measured by comparing with actual distance measured by third party sand derived distance from the distance calculation. The distance calculation from RSSI is detailed in the following section.

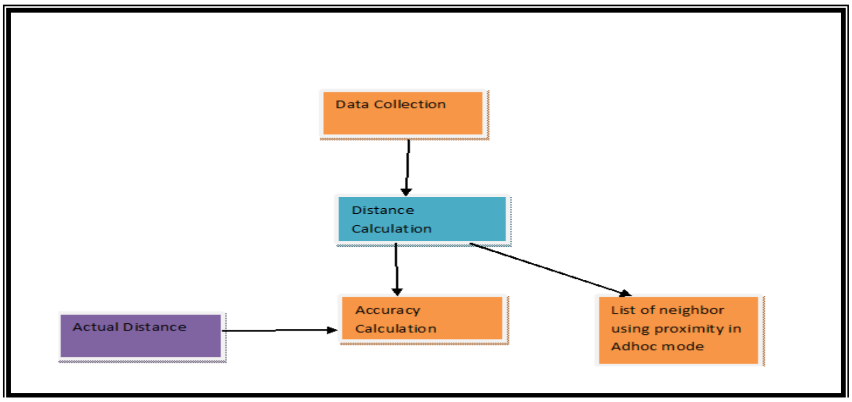


Figure 4 : Work flow of the proposed Bluetooth based Indoor Localization System

Received Signal Strength Indicator (RSSI)

RSSI is a measurement of the strength of an incoming signal. It is a relative indicator and its values change due to a no of factors like environmental factors, node positions, transmission power. Theoretically, the signal strength is inversely proportional to squared distance, and there is a known radio propagation model that is used to convert the signal strength into distance.

Distance estimation identifies the distance between both Bluetooth server and other Bluetooth node using RSSI. Such estimates are an important component of systems localization, because these are used by the position computation and localization algorithm components.

The RSSI value can be calculated by the following equation [28]

$$RSSI = -(10n \log d + A)$$

where d = distance from the sender, A = txPower or received Signal Strength at 1meter distance, n = signal propagation constant or exponent and [RSSI] = dBm.

Also distance can be measured by Distance = 10^ ((RSSI-A)/(10*n))

RSSI value Measurement

dBm and RSSI are different units of measurement that both represent the same thing in signal strength. The difference is that RSSI is a relative index, while dBm is an absolute number representing power levels in mW (milliwatts). RSSI is a term used to measure the relative **quality** of a received signal to a client device, but has no absolute value.

In this chapter our framework of Bluetooth based indoor localization is detailed along with description of the architecture using RSSI and workflow are represented.

Chapter 4

IMPLEMENTATION

This chapter describes the implementation steps toward implementation of the framework described in earlier chapter.

Installation procedure

For complete the installation of Android studio 1.5 on personal notebook some specific hardware are required. It is suitable for both Windows 8.1 version and Linux environment. Before installing Android Studio 1.5, Java Development kit(JDK)1.7.0_79 or JDK 8 version is required. Some environmental variables are needed to be set like JAVA_HOME = C:\Program Files\Java\jdk1.7.0_79 and PATH= C:\Program Files\Java\jdk1.7.0_79\bin;".".

System Required

For Windows Platform

- Microsoft® Windows® 7/8/10 (32- or 64-bit)
- 2 GB RAM minimum, 8 GB RAM recommended
- 2 GB of available disk space minimum,
  4 GB Recommended (500 MB for IDE + 1.5 GB for Android SDK and emulator system image)
- 1280 x 800 minimum screen resolution
- Java Development Kit (JDK) 8
- For accelerated emulator: 64-bit operating system and Intel® processor with support for Intel® VT-x, Intel® EM64T (Intel® 64), and Execute Disable (XD) Bit functionality

The SDK Manager needs to be updated and necessary APIs needs to be downloaded as shown in Figure 5.

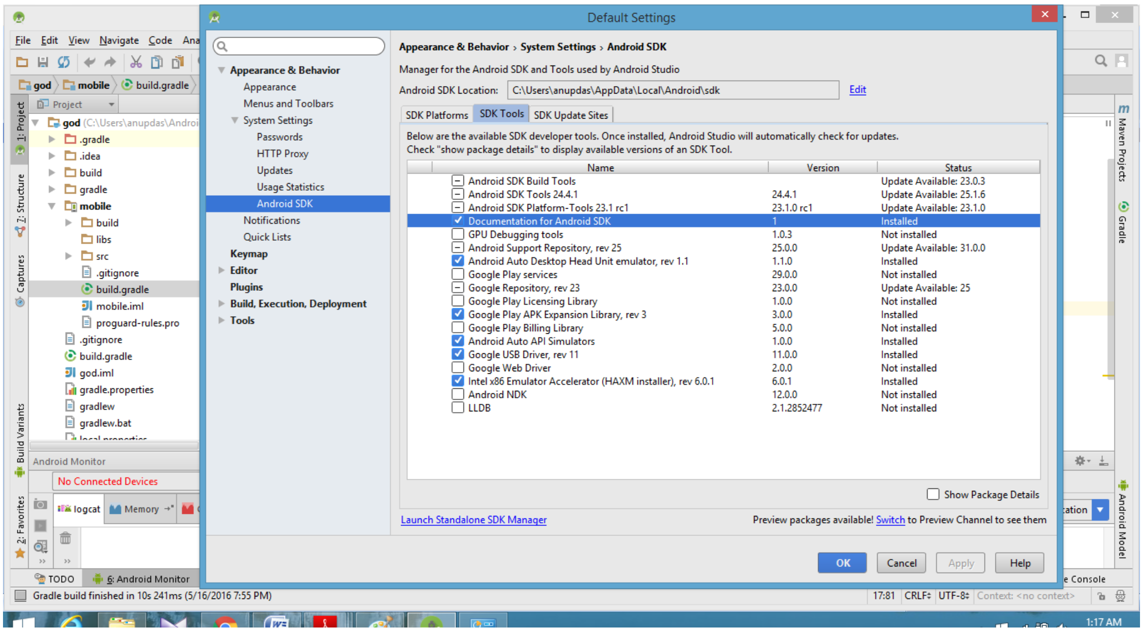


Figure 5: Update SDK tools and different library

Library Implementation

The implementation uses Android APIs level 23 and BluetoothAdapter from Android Altbeacon Library. This library serves to support iBeacons in the same way as they are supported natively in iOS.

AltBeacon Library implementation

Here Android Studio is used for this thesis development. Android studio uses Gradle, an advanced toolkit for custom build application and administration of dependencies within Android project. Android application is based on Activities which are components that provide user interaction. To allow compilation of Android AltBeacon library within application, needed to edit Module Build File that allows me to edit dependencies of the module under development. In the higher build file called Project Build File, there are main dependencies such as Gradle version. But in this thesis only the module build file is needed to be edited. In this file the library dependencies is added as:

compile 'org.altbeacon:android-beacon-library:2+@aar'

This guarantees that building is with highest possible implementation of AltBeacon Library version 2+. Additionally, variables *minSdkVersion* and *targetSdkVersion* are defined. These two variables restrict versions of Android operating system on which the application can be run.

The variable *targetSdkVersion (here 17)* defines the version which is optimal for the application and *minSdkVersion (here 23)* defines the minimal version of Android system.

Permissions

Besides configuring the module build file, it is necessary to edit AndroidManifest.xml located inside root directory of the application. This file carries all essential information about the application. It is written in XML and a permission is needed here to add for Bluetooth to allow scanning and reading iBeacon advertisement. Two permissions have to be added into file namely:

<uses-permission android:name='android .permission.BLUETOOTH'/>

and

<uses-permission android:name='android.permission.BLUETOOTH_ADMIN'/>

These permissions grant an application the access to Bluetooth and allow to discover and connect to Bluetooth devices. The values of parameters of user-permissions are constant values.

Details of the Implementation

Flow chart

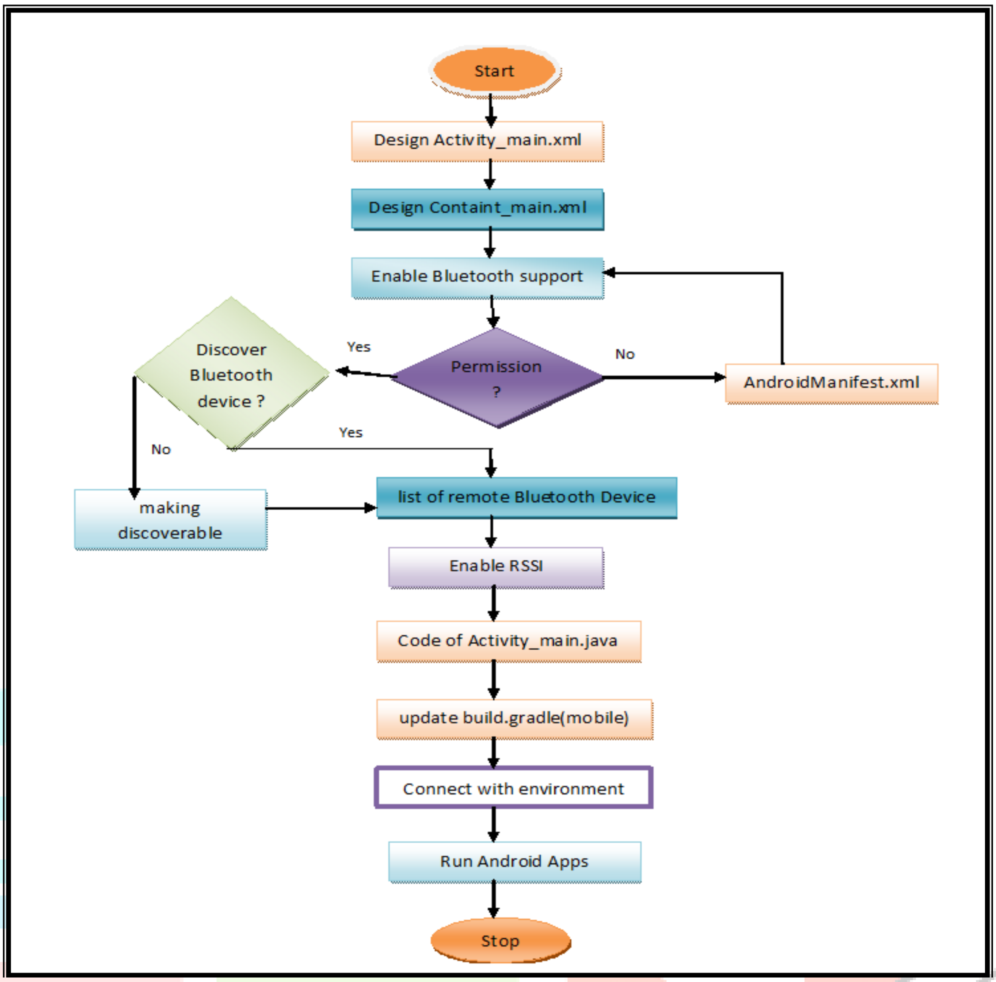


Figure 6 : Flow Chart for Implementation of proposed Bluetooth based indoor localization system

Code and setting process for proposed Bluetooth based indoor localization system in android Studio 1.5

Figure 6 presents the steps for Bluetooth base indoor localization system developed in Android studio 1.5. Firstly Activity_main.xml and content_main.xml are to be designed and permission should be set in Android_Menifest.xml for getting permission to activate the Bluetooth operation. The code is also implemented in java platform as Activity_main.java file. For running apps an Android device is connected as an environment. Following steps are given below.

Step1:

First of all, an Activity which is called as "MainActivity" gets created. This is the home page that provides the buttons to navigate to other pages. The "activity_main.xml" is shown below

```
<?xml version="1.0" encoding="utf-8"?>
<android.support.design.widget.CoordinatorLayout xmlns:android="http://schemas.android.com/apk/res/android"
xmlns:app="http://schemas.android.com/apk/res-auto"
xmlns:tools="http://schemas.android.com/tools"
android:layout_width="match_parent"
android:layout_height="match_parent"
android:fitsSystemWindows="true"
tools:context="com.example.anupdas.myapplication_blutooth_conn.MainActivity">

<android.support.design.widget.AppBarLayout
android:layout_width="match_parent"
android:layout_height="wrap_content"
```

```
android:theme="@style/AppTheme.AppBarOverlay">

<android.support.v7.widget.Toolbar
android:id="@+id/toolbar"
android:layout_width="match_parent"
android:layout_height="?attr/actionBarSize"
android:background="?attr/colorPrimary"
app:popupTheme="@style/AppTheme.PopupOverlay" />

</android.support.design.widget.AppBarLayout>

<include layout="@layout/content_main" />

<android.support.design.widget.FloatingActionButton
android:id="@+id/fab"
android:layout_width="wrap_content"
android:layout_height="wrap_content"
android:layout_gravity="bottom|end"
android:layout_margin="@dimen/fab_margin"
android:onClick="getBluetoothActivity"
android:src="@android:drawable/ic_dialog_email" />

</android.support.design.widget.CoordinatorLayout>
```

The complete Android Bluetooth APIs is available in the android.bluetooth package. Classes from this package are used create an Activity to perform the following Bluetooth functionalities:

- Enable/disable Bluetooth.
- Make Bluetooth device discoverable by other Bluetooth devices.
- Discover other Bluetooth devices.
- List the names and MAC addresses of those found Bluetooth devices in a "ListView".
- Establish connection with one of the Bluetooth devices in the "ListView".

Step2:

Home page , content_main.xml page is designed as given below.

```
<?xml version="1.0" encoding="utf-8"?>
<RelativeLayout xmlns:android="http://schemas.android.com/apk/res/android"
xmlns:app="http://schemas.android.com/apk/res-auto"
xmlns:tools="http://schemas.android.com/tools"
android:layout_width="match_parent"
android:layout_height="match_parent"
android:paddingBottom="@dimen/activity_vertical_margin"
android:paddingLeft="@dimen/activity_horizontal_margin"
android:paddingRight="@dimen/activity_horizontal_margin"
android:paddingTop="@dimen/activity_vertical_margin"
android:onClick="getBluetoothActivity"
app:layout_behavior="@string/appbar_scrolling_view_behavior"
tools:context="com.example.anupdas.myapplication_blutooth_conn.MainActivity"
tools:showIn="@layout/activity_main">


<ToggleButton
android:layout_width="wrap_content"
android:layout_height="wrap_content"
android:id="@+id/toggleButton"
android:textOn="Bluetooth On"
android:textOff="Bluetooth Off"
```

```
android:onClick="onToggleClicked"
android:layout_alignParentTop="true"
android:layout_alignParentLeft="true"
android:layout_alignParentStart="true" />

<ListView
android:layout_width="wrap_content"
android:layout_height="wrap_content"
android:id="@+id/listView"
android:layout_centerHorizontal="true"
android:layout_below="@+id/toggleButton"
android:layout_alignParentBottom="true"

/>

<Button
android:layout_width="match_parent"
android:layout_height="wrap_content"
android:text="Bluetooth"
android:id="@+id/btnBluetooth"
android:layout_above="@+id/listView"
android:layout_toEndOf="@+id/toggleButton" />

</RelativeLayout>
```

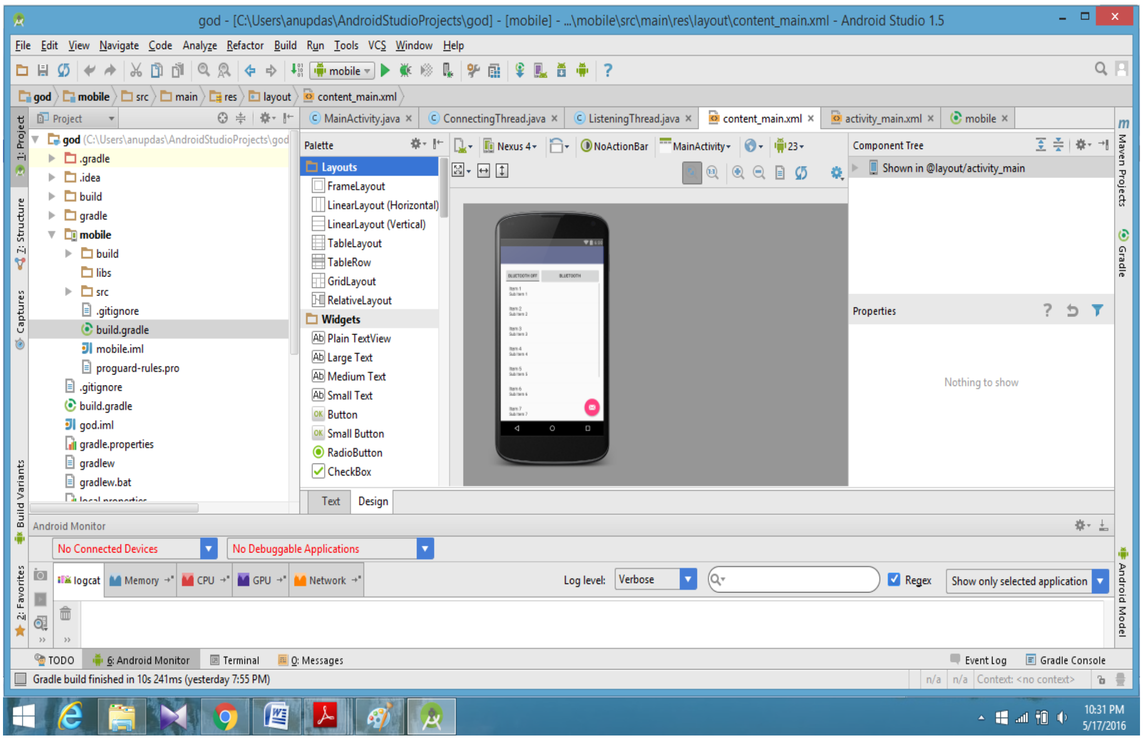


Figure 7 : Designing of Apps home page i.e. content_main.xml

The Designing preview of "BluetoothActivity" should look like that in Figure 7.

step3:

Before any attempt to use Bluetooth functionalities in an app, it must verify whether the device supports Bluetooth. To do that, we have to call upon the "BluetoothAdapter" class of the Android Bluetooth APIs.

"BluetoothAdapter" is the most important class in the Android Bluetooth APIs. It represents the Bluetooth adapter of an Android device. Currently, Android only supports one Bluetooth adapter per device. "BluetoothAdapter" is the starting point for all Bluetooth operations. To begin any Bluetooth operation, the app will have to first call the static method "getDefaultAdapter()"

which returns a handle representing the default local Bluetooth adapter. If "getDefaultAdapter()" returns null, then the device does not support Bluetooth and that is the end of the road. A valid "BluetoothAdapter" handle allows you to scan for other Bluetooth devices.

The code for verifying Bluetooth Support is given below

```
BluetoothAdapter bluetoothAdapter = BluetoothAdapter.getDefaultAdapter();
if (bluetoothAdapter == null) {
// Device does not support Bluetooth
} else {
// Any valid Bluetooth operations
}
```

Enabling Bluetooth

Once the Bluetooth support on the device is affirmed, the next step is to ensure that Bluetooth is enabled. To request that Bluetooth be enabled, "startActivityForResult()" is called with "ACTION_REQUEST_ENABLE" action Intent. The code should be like

```
if (!bluetoothAdapter.isEnabled()) {
Intent enableBluetoothIntent = new Intent(BluetoothAdapter.ACTION_REQUEST_ENABLE);
startActivityForResult(enableBluetoothIntent, ENABLE_BT_REQUEST_CODE);
}
```

Making Bluetooth Discoverable

Once Bluetooth has been enabled, it should be discoverable by other Bluetooth devices. To do this, "startActivityForResult()" is called with "ACTION_REQUEST_DISCOVERABLE" action Intent.

```
protected void makeDiscoverable(){
// Make local device discoverable
Intent discoverableIntent = new Intent(BluetoothAdapter.ACTION_REQUEST_DISCOVERABLE);
discoverableIntent.putExtra(BluetoothAdapter.EXTRA_DISCOVERABLE_DURATION, DISCOVERABLE_DURATION);
startActivityForResult(discoverableIntent, DISCOVERABLE_BT_REQUEST_CODE);
}
```

"DISCOVERABLE_BT_REQUEST_CODE" constant passed to "startActivityForResult()" is a locally defined integer which must be greater than 0 so that the system passes back in "onActivityResult()" implementation as the "requestCode" parameter. By default, the device becomes discoverable for 120 seconds, but in this thesis system have used a local variable called "DISCOVERABLE_DURATION" that takes the value of 300.

Discovering Remote Bluetooth Devices

Next, the app discovers remote Bluetooth devices. Any remote Bluetooth device within the range responds to a discovery request if it has been enabled to be discoverable. To start the discovery process, the app calls the "startDiscovery()" method of the "BluetoothAdapter" handle.

For each device discovered, the Android system will broadcast the "ACTION_FOUND" Intent. This Intent always returns two bundles of data as follows:

- An "EXTRA_DEVICE" containing a "BluetoothDevice" that represents the remote Bluetooth device that is found; and
- An "EXTRA_CLASS" containing a "BluetoothClass" that describes the general characteristics and capabilities of that found device.

In order to capture this broadcast, the app must register a "BroadcastReceiver" for this "ACTION_FOUND" Intent.

```
private final BroadcastReceiver broadcastReceiver = new BroadcastReceiver() {
public void onReceive(Context context, Intent intent) {
String action = intent.getAction();
// Whenever a remote Bluetooth device is found
if (BluetoothDevice.ACTION_FOUND.equals(action)) {
// Get the BluetoothDevice object from the Intent
BluetoothDevice device = intent.getParcelableExtra(BluetoothDevice.EXTRA_DEVICE);
// Add the name and address to an array adapter to show in a ListView
adapter.add(device.getName() + "\n" + device.getAddress());
}
}
};
```

Then this "BroadcastReceiver" class for the "ACTION_FOUND" Intent is registered.

```
IntentFilter filter = new IntentFilter(BluetoothDevice.ACTION_FOUND);
this.registerReceiver(broadcastReceiver, filter);
```

Enabling RSSI

For enabling RSSI(Received Signal Strength Indicator) value which is discussed earlier in Chapter 3.3 the sample code is given below.

```
if (BluetoothDevice.ACTION_FOUND.equals(action)) {
// Get the BluetoothDevice object from the Intent
BluetoothDevice bluetoothDevice = intent.getParcelableExtra(BluetoothDevice.EXTRA_DEVICE);
// Add the name and address to an array adapter to show in a ListView

int rssi = intent.getShortExtra(BluetoothDevice.EXTRA_RSSI, Short.MIN_VALUE);
adapter.add(bluetoothDevice.getName() + "\n"
+ bluetoothDevice.getAddress() + "\n"
+ "RSSI of is this device is :---> " + rssi + "dBm");


Toast.makeText(getApplicationContext(), "  RSSI: " + rssi + "dBm",
Toast.LENGTH_SHORT).show();
bluetoothAdapter.cancelDiscovery();
}
```

To make Bluetooth device discoverable for 15 seconds following needs to be written.

```
if (BluetoothAdapter.ACTION_DISCOVERY_FINISHED.equals(action)) {
Log.v(TAG, "Entered the Finished ");
bluetoothAdapter.startDiscovery();
```

Step4:

Complete code in " MainActivity.java" page needs to be written for running the application. Also all the code should be written in a Class file.

Step5:

build.gradle (mobile) page needs to be set up and minSdkVersion, targetSdkVersion and Sync project needs to be updated with gradle file (Figure 8).

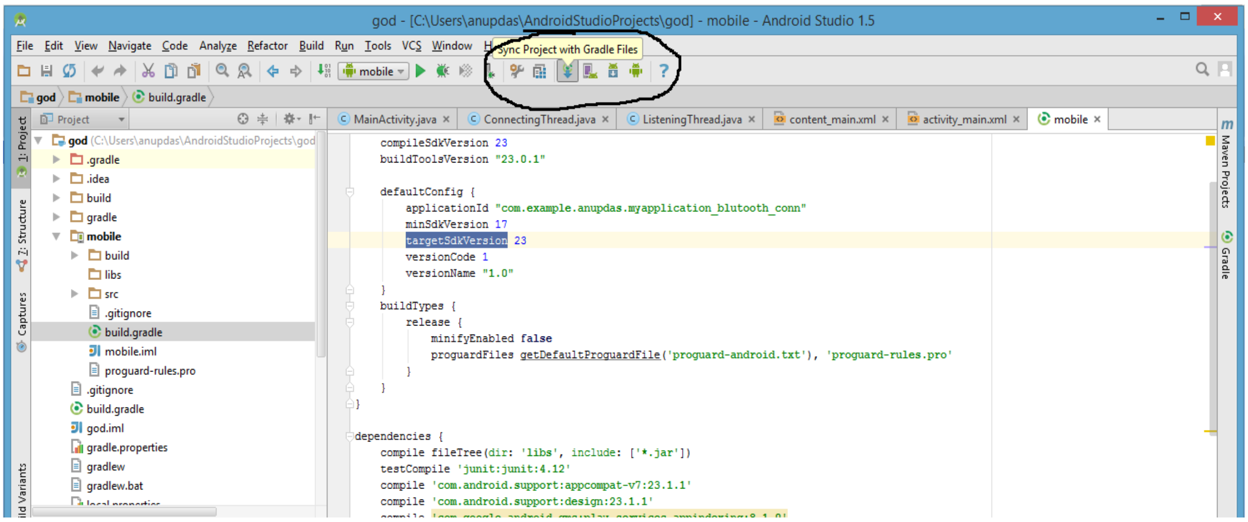


Figure 8: Sync project with gradle files in Bluetooth base indoor localization system

In this thesis distance of beacon node from the Bluetooth device is calculated in Android Studio 1.5 platform. Bluetooth Devices are also paired with another Bluetooth Device. This can be utilized for exchanging data and information for proximity based messaging using Bluetooth technology.

Discovering devices is only the first step to any Bluetooth operations, such as listening for incoming connection, requesting a connection, accepting a connection, and exchanging data. The connection mechanism follows that of the client-server model. In general, to implement a connection between two devices, one of them has to act as the server and the other the client. The server makes itself discoverable and waits for connection request from client. The client on the other hand initiates the connection using the server device's MAC address discovered during a discovery process.

Step6:

For pairing Bluetooth device using BluetoothServerSocket we have to connect with two other class Listening thread and connecting thread from MainActivity.java page

Setting Up a Listening Server

The device that acts as the server must hold an open "BluetoothServerSocket" which is the server socket that listens for incoming connection requests. When the connection request is accepted, the server socket will return a connected "BluetoothSocket" to be used for managing the connection.

1) "listenUsingRfcommWithServiceRecord()" method of the "BluetoothAdapter" handle is called to return a secure RFCOMM (Radio Frequency Communication) "BluetoothServerSocket" with Service Record.

```
BluetoothServerSocket  bluetoothServerSocket =
bluetoothAdapter.listenUsingRfcommWithServiceRecord(getString(R.string.app_name), uuid);
```

The first string parameter is the service name which could be the app name. The second parameter is a Universally Unique Identifier (UUID) which is a standardized 128-bit format for a string ID that is used to uniquely identify the Bluetooth service in the app. The system automatically writes the service name, UUID, and the RFCOMM channel to the Service Discovery Protocol (SDP) database on the device. The string to a UUID like

```
private final static UUID uuid = UUID.fromString("fc5ffc49-00e3-4c8b-9cf1-6b72aad1001a");
```

2) "accept()" method of the "BluetoothServerSocket" is called to start listening for connection requests. The call blocks the current thread until a connection is accepted or an exception has occurred. The "BluetoothServerSocket" only accepts a connection request that has a matching UUID. "BluetoothServerSocket" is closed by calling its "close()" method.

```
BluetoothSocket bluetoothSocket = bluetoothServerSocket.accept();
bluetoothServerSocket.close();
```

As "accept()" blocks any other interaction until a connection is accepted, it should not be run in the main UI thread. Then it is called from the main UI thread like

```
ListeningThread t = new ListeningThread();
t.start();
```

Setting Up a Connecting Server

Once a device is setup as a discoverable server holding an open "BluetoothServerSocket" and listening for connection request, any other Bluetooth device within range can discover and initiate connection request to it as a client.

To find remote Bluetooth devices and display their names and MAC addresses on a "ListView, a "setOnItemClickListener" needs to be set to the "ListView" to listen for any click event performed on this "ListView

```
listview.setOnItemClickListener(new AdapterView.OnItemClickListener() {
@Override
public void onItemClick(AdapterView<?> parent, View view, int position, long id) {
String  itemValue = (String) listview.getItemAtPosition(position);
String MAC = itemValue.substring(itemValue.length() - 17);
BluetoothDevice bluetoothDevice = bluetoothAdapter.getRemoteDevice(MAC);
// Initiate a connection request in a separate thread
ConnectingThread t = new ConnectingThread(bluetoothDevice);
t.start();
}
});
```

1) Using the "BluetoothDevice" object that represents the remove server device, the app calls the "createRfcommSocketToServiceRecord(UUID)" method to create an RFCOMM "BluetoothSocket" ready to start a secure connection to this remote device using SDP lookup on the UUID parameter.

2) "connect()" method of the "BluetoothSocket" is called to initiate the connection request. Upon this call, the system performs an SDP lookup on the remote device to find the service that matches the UUID. This call blocks the current thread until a connection is accepted or an exception has occurred due to a connection error or a time-out after 12 seconds.

In this chapter the setup procedure, enabling library implementation and coding process towards the implementation of the localization framework is presented.

Chapter 5

RESULTS

This chapter presents the methods used to evaluate the performance of the implemented system, and discusses the obtained results.

Description of the indoor location

The environments in the scenarios described above vary mainly by the size of the rooms. Firstly conduct a test in house, where proposed building plan is shown in Figure 9 to see if the size of a room has any effect on the variability of the RSSI. Secondly also conduct the test in Jadavpur University as shown where proposed building plan is shown in Figure 10. Here is the proposed building plan is given below which have been used for doing test and getting proper RSSI value.

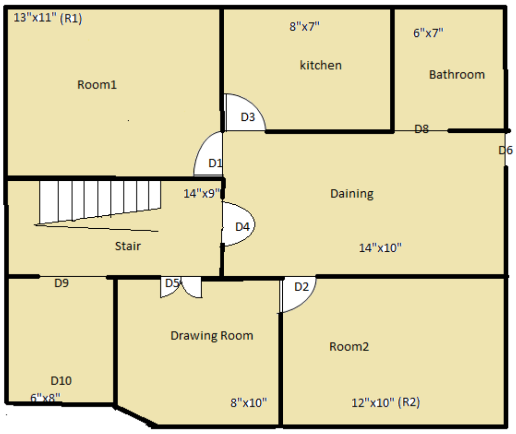


Figure 9 : Proposed Building Plan used in Bluetooth base indoor localization for calculating RSSI in Home

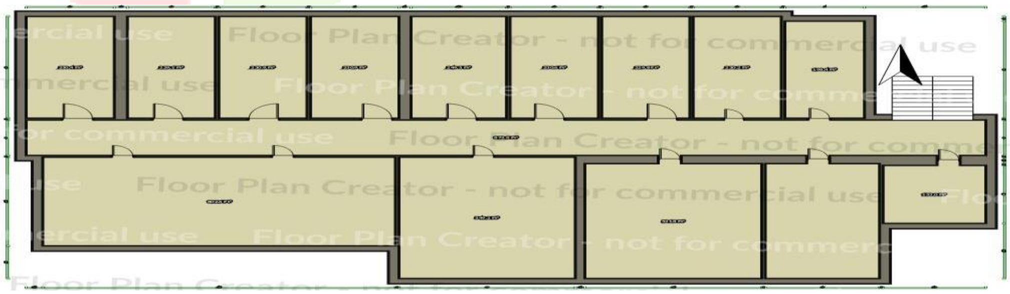


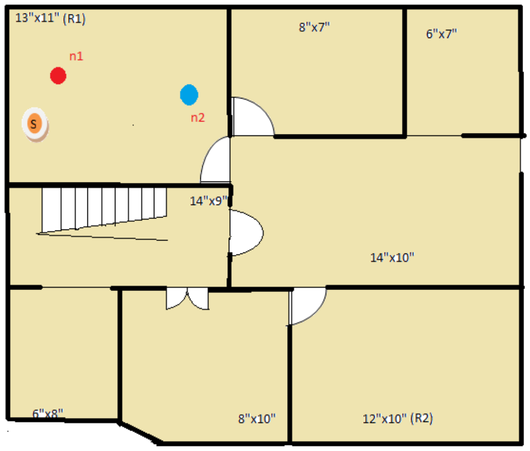
Figure 10 : Proposed Building Plan used in Bluetooth base indoor localization for calculating RSSI in Jadavpur University

In this both proposed building plan two Android phones and one tablet are used in Room1. In this thesis Samsung Grand neo plus naming Bluetooth device GT-601T are used as a server where apps are run and it finds the neighboring Bluetooth devices as a beacon node. Here iball Slide phone and Micromax phone are used as a beacon node. In this thesis, purpose is looking for variability of the RSSI for various types of obstacles.

The adaptive distance estimation method that does not meet the line of sight (LOS) condition is evaluated with this measurement. Therefore, this system could be used in various types of environments, where obstacles and dynamic changes are present.

Experiments are conducted for the home environment and snapshot scenarios are given below from figure 11 to figure 16. Presence and absence of obstacles in signal path and its corresponding effect on the RSSI is also shown.

Here GT-601T is used in fixed position as a Bluetooth known node for finding neighboring Bluetooth device of unknown node as a beacon node. figure 11 and figure 12 as shown below measure line-of-sight conditions



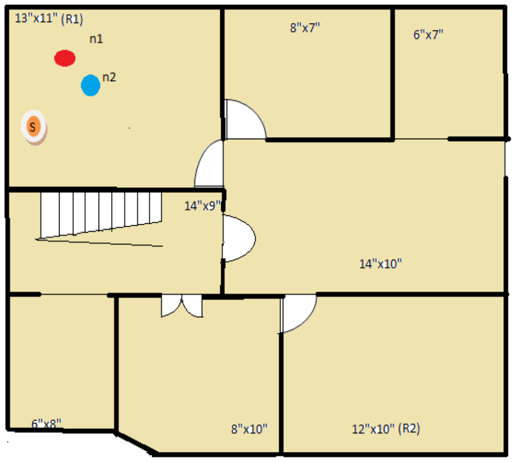
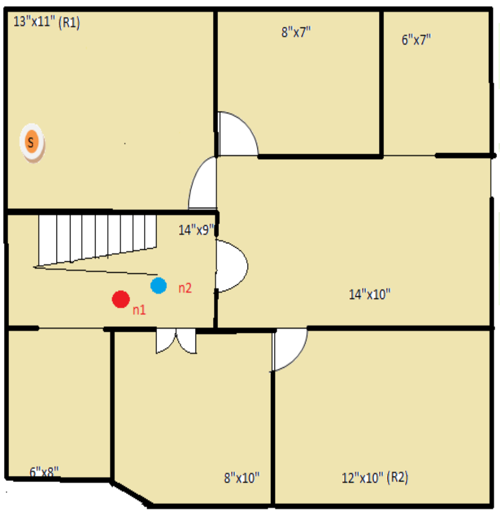
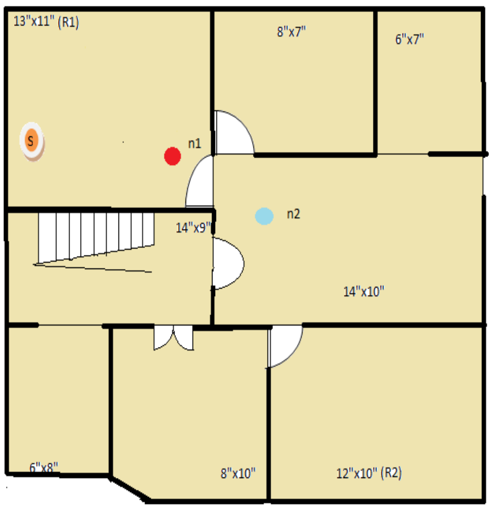


Figure 11 : known and unknown Node position1

Figure 12: known and unknown Node position2

According to proposed Bluetooth base indoor localization system in Figure 11 and Figure 12, S is the known node are in fixed position and n1 and n2 are unknown node in moveable position in room1. The distance is measured in feet and inches unit without obstacle.



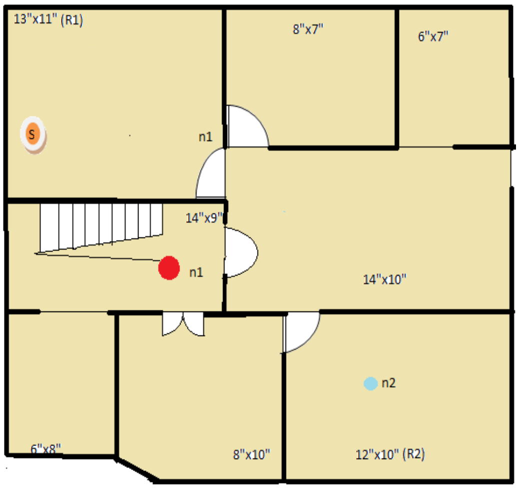


.

Figure 13 : known and unknown Node position3

Figure 14 : known and unknown Node position4

In Figure 13 and Figure 14 , S is the known node and is in fixed position and n1 and n2 are unknown nodes in different moveable position in room1 and room2. Door of both rooms are kept open. The distance are measured in feet and inches unit without obstacle.



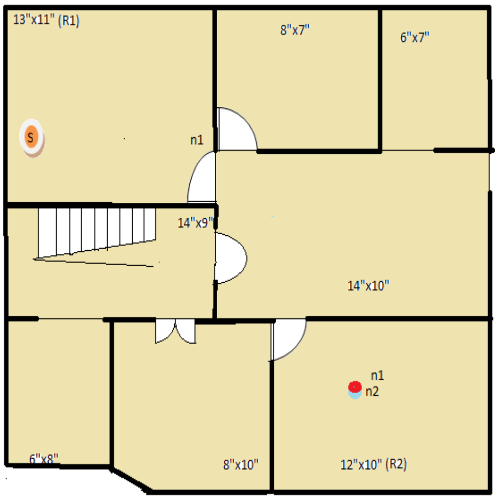


Figure 15 : known and unknown Node position5

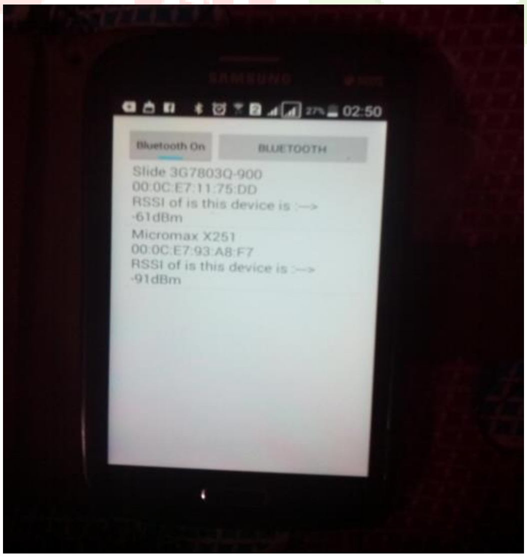
Figure 16 : known and unknown Node position6

According to proposed Bluetooth based indoor localization system, in Figure 15 known node is in fixed position in room1 and unknown node n1 are set in stair room where room1 door is open but wall are present between known and unknown node. In Figure 16, known node is set in fixed position in room1 but both unknown node n1 and n2 are set in room2. RSSI value are measured in both, when door is open of room1 (i.e without obstacle) and door is closed (i. e with obstacle).The RSSI value is measured in both node by moving with device different angle.

In above figure 11 to 16, S is the known node and n1 and n2 are the other two moveable node as a beacon. Node n1 and n2 is both two android Bluetooth device Micromax x251 and Slide3G7803qp-900 respectively.

Results for different condition

Results in home when door of Room1 is open



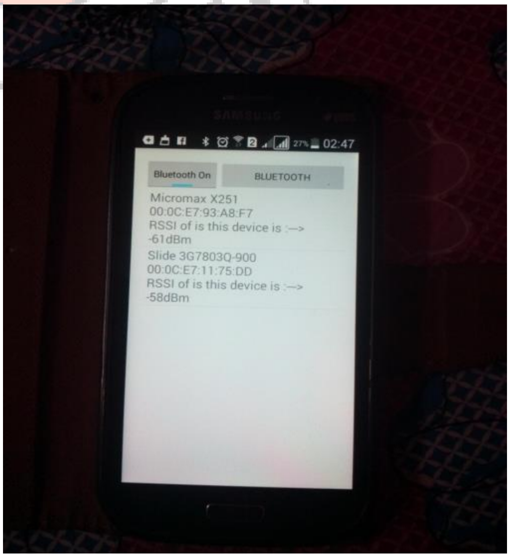


Figure 17 : Results at position 1

Figure 18 : Results at position 2

Results are taken at the rooms under several conditions like door open, close etc. Figure 17 and Figure 18 show the results by Android apps at home when door is open and the known node are in fixed position and unknown nodes are in moveable position. For the configuration shown in Figure 17, the actual distance from GT-601T (known node) is measured by third party for node1 (unknown node) (Slide3G7803qp-900:- At distance 4 feet 8 inches and RSSI value is -61dBm) and node 2 (Micromax x251:- At distance 8 feet 4 inches and RSSI value is -91dBm).

Figure 18 shows the RSSI values received for position 3 described above. For the configuration shown in Figure 18, distance from GT-601T (known node) measured by third party are for node2 (unknown node) (Slide3G7803qp-900:- At distance 4 feet 8 inches and RSSI value is -61dBm) and node 2(unknown node) (Micromax x251:- At distance 4 feet 2 inches and RSSI value is -58dBm).

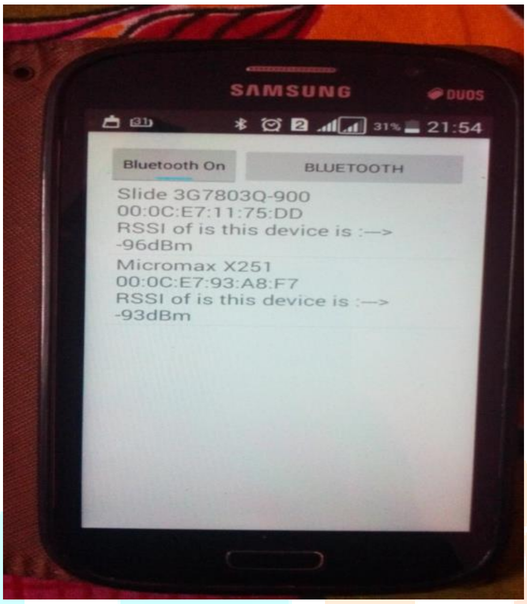


Figure 19 : Results at position 3

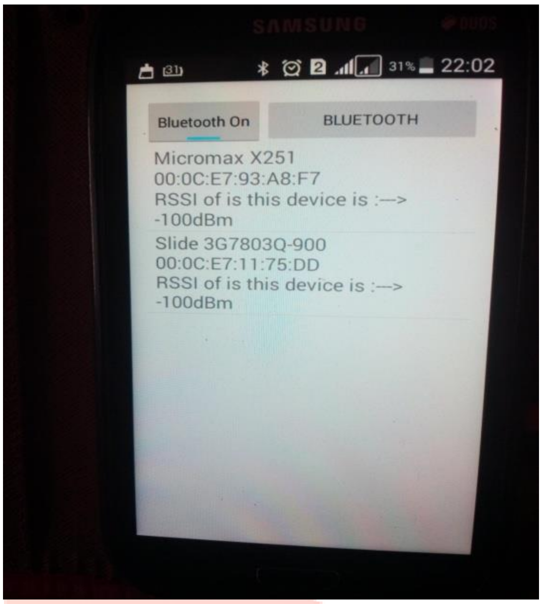


Figure 20 : Results at position 4

Figure 19 shows the results by Android apps from the known node to unknown node without obstacles. Where distance from GT-601T (known node) measured by third party are for node1(unknown node) (Slide3G7803qp-900:- At distance 8 feet 4 inches and RSSI value is -96 dBm) and node 2(unknown node) (Micromax x251:- At distance 10 feet 6 inches and RSSI value is -93 dBm).

Figure 20 shows the results by Android apps from the known node to unknown node without obstacles also distance from GT-601T (known node) measured by third party are for node1 by Android apps from (Slide3G7803qp-900 :- At distance 13 feet and RSSI value is -100 dBm) and node 2 by Android apps from (Micromax x251:- At distance 13 feet 5 inches and RSSI value is -100 dBm).

In this Bluetooth based indoor localization techniques distance estimation of unknown node from known node with obstacle is difficult as the RSSI value is changed. When door is closed then RSSI value is affected rather than when the door is open. In case of measurement by third party when door is closed then node 1 RSSI value is -92 dBm at 7 feet distance and RSSI value -100 at 10 feet distance where calculated distance is 3 feet 52 inches and 8 feet 75 inches respectively. Similarly in case of node 2 when door is open result is shown in Figure 20 but when door is closed then node2 RSSI value is -97dBm at 11 feet 3 inches distance and RSSI value -100 dBm at 12 feet 7 inches distance where calculated distance is 7 feet 87 inches and 8 feet 75 inches respectively.

Result at Jadavpur University Room CC-5-15

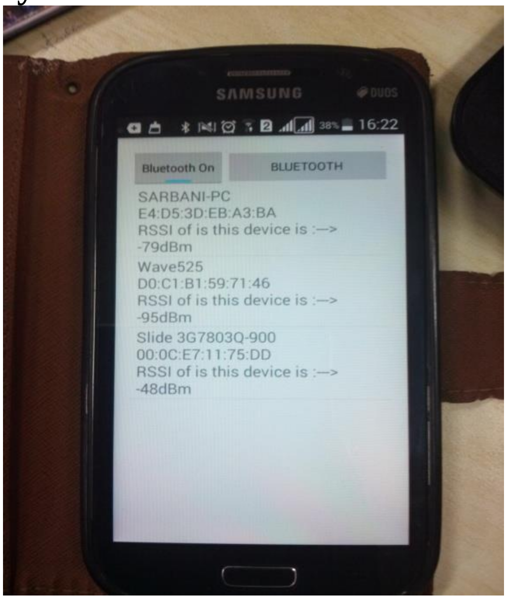


Figure 21 :Data result at Jadavpur University Room CC-5-15

Results are calculated by Android apps at the Jadavpur University room CC-5-15 when door is open and known node are in fixed position and unknown node are in, moveable position and also distance from GT-601T (known node) measured by third party are for node1(Slide3G7803qp-900 :- At distance 2 feet 8 inches and RSSI value is -48 dBm) and node 2 (Wave525:- At distance 8 feet 4 inches and RSSI value is -95 dBm) and node 3 (SARBANI-PC:- At distance 5 feet 2 inches and RSSI value is -79 dBm).

System performance

The results for Node 1 from the known node in Home environment are listed in Table 1 and Table 2.

Name	When door is open						When door is closed		
Distance in feet	4.25	4.66	5.08	8.33	13		7	10	20
RSSI value in dBm unit	-58	-61	-68	-96	-94	-100	-92	-100	NA

Table 1: Client1 result table at different position by measuring third party using proposed Bluetooth base indoor localization system.

Name	When door is open						When door is closed		
RSSI value in dBm unit	-58	-61	-68	-94	-96	-100	-92	-100	NA
Distance in feet	5.41	4.87	4.8	7.08	7.6	8.75	3.52	8.75	

Table 2 : Client1 result table at different position by calculating distance using proposed Bluetooth base indoor localization system.

Variation of actual distance and its corresponding measured RSSI is given in Figure 22.

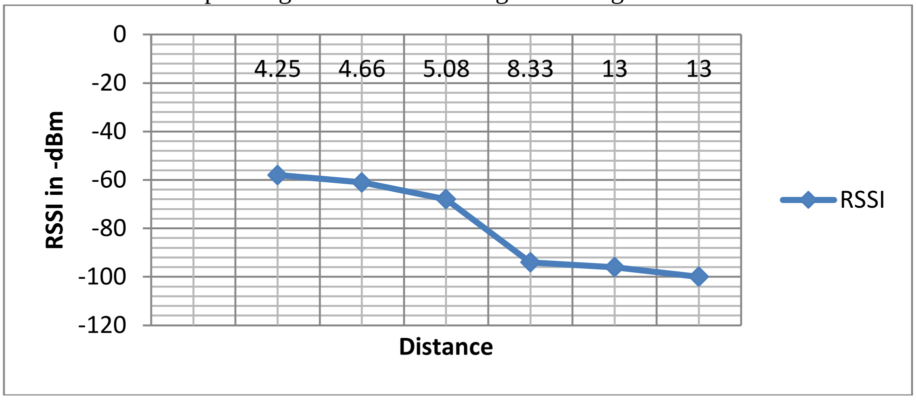


Figure 22: Graph for distance measuring by third party in proposed Bluetooth base indoor localization system (Client1)

The variation of RSSI with respect to measured distance in shown in Figure 23.

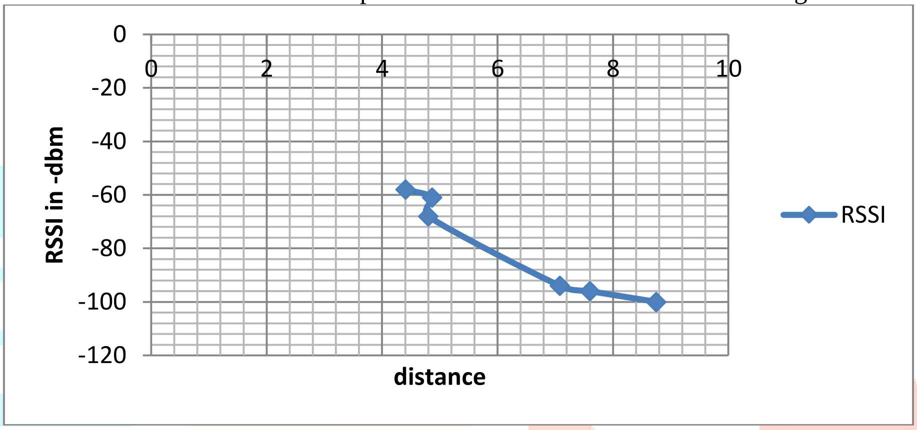


Figure 23 : Graph for distance estimation of unknown node based on RSSI value with respect to distance in proposed Bluetooth base indoor localization system (Client1)

The result table for node 2 from the known node (Client 2) in Home environment is detailed in Table 3 and Table 4. The distance sensitivity of RSSI with respect to measured distance and calculated distance are shown in Figure 24 and Figure 25.

Name	***When door is open***							***When door is closed***		
Distance in feet	3.416	3.33	3.67	8.33	10.5	12.67	13.416	11.25	12.583	27
RSSI value	-70	-73	-81	-91	-93	-98	-100	-97	-100	NA

Table 3: Client2 result table at different position by measuring third party using proposed Bluetooth base indoor localization system.

Name	***When door is open***							***When door is closed***		
RSSI value in dBm unit	-70	-73	-81	-91	-93	-98	-100	-97	-100	NA
Distance in feet	3.54	3.38	4.48	6.38	6.83	8.15	8.75	7.87	8.75	

Table 4: Client2 result table at different position by calculating distance using proposed Bluetooth base indoor localization system.

Variation of actual distance and its corresponding measured RSSI is given in Figure 24

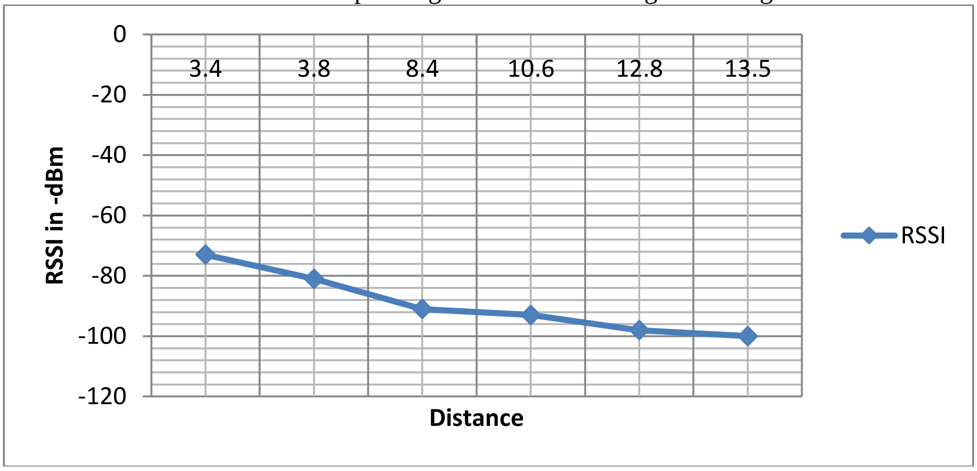


Figure 24 : Graph for distance measuring by third party in proposed Bluetooth base indoor localization system (Client2)

The variation of RSSI with respect to measured distance in shown in Figure 25.

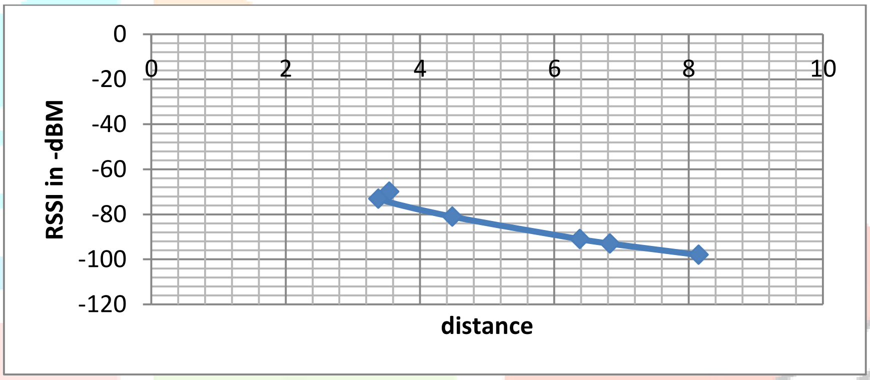


Figure 25 : Graph for Graph for distance estimation of unknown node based on RSSI value in proposed Bluetooth base indoor localization system (Client2)

Here in both the client table for measuring distance of unknown node from the known node the calculated value is measured based on average signal propagation constant is n= 6.35 and A= -72.19 at the most efficient coefficients for Tx = 3.2 dBm [45] in free space without obstacles. Results are converted into unit feet from meter where 1 meter = 3.28084 feet.

In this chapter detailed implementation of the framework is presented, effect of obstacles on Bluetooth based indoor localization is studied and system performance is shown.

Chapter 6

CONCLUSION AND FUTURE WORK

In this thesis, an indoor positioning system is designed that takes RSSIs of Bluetooth signals as input. RSSI could become the most used technology of distance estimation from the cost/precision viewpoint because of low cost. Android devices are used for measuring proximity. The challenges of such Bluetooth based indoor localization are identified. The change of RSSI due to several environmental factors is studied. Line-of-sight and non-line-of-sight signals bear different RSSI values for the same distance. Thus makes distance estimation from RSSI a complicated issue in presence of obstacles. Noisy real life environments are also considered.

Experiments are conducted both in Home and Jadavpur University. Node position and change of RSSI values are taken into account. This is causing some inaccuracies in distance calculations.

Experimental results from this paper indicate that good signal strength estimates can be achieved. However, considerable estimation errors at certain positions remain.

This system can estimate proximity without needing any extra hardware installation and hence can run when all other forms of communication are ceased.

Future work

We plan to implement proximity based messaging and exchange all the data and information with client and server and apply statistical methods to improve distance estimation based on RSSIs.

II. ACKNOWLEDGMENT

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REFERENCES

[1] History of the Bluetooth Special Interest Group. Bluetooth SIG. Bluetooth [online]. Available from: http://www.bluetooth.com/Pages/History-of-Bluetooth.aspx. [Accessed: 15-05-2016]

[2] History of Bluetooth technology & Bluetooth SIG[online].Available from : [Accessed: 18-05-2016]
   a. http://www.radio-electronics.com/info/wireless/bluetooth/bluetooth_overview.php

[3] A Look at the Basics of Bluetooth Technology. [online] Available from: http://www.bluetooth.com/Pages/Basics.aspx. [Accessed: 18-05-2016].

[4] About the Bluetooth SIG. [online] Available from: https://www.bluetooth.org/en-us/members/about-sig. [Accessed: 20-05-2016]

[5] Specification Adopted Documents: Adopted Bluetooth Core Specifications. Bluetooth SIG. Bluetooth [online]. Available from:https://www.bluetooth.org/en-us/specification/adopted-specifications.[18.5.16]

[6] The Low Energy Technology Behind Bluetooth Smart. [online].Available from: http://www.bluetooth.com/Pages/low-energy-tech-info.aspx .[Accessed: 20-05-2016]

[7] M. S. Grewal, L. R. Weill, and A. P. Andrews, "Introduction," in *Global positioning systems, inertial navigation, and integration*, John Wiley & Sons, Inc., 2007, pp. 1–17. http://saba.kntu.ac.ir/eecd/taghirad/E%20books/TOC/GPS-INS%20Integration.pdf.[Accessed: 15-5-2016]

[8] "Global positioning system," *Wikipedia, the free encyclopedia*. 22-Jan-2015.

[9] "Ten things you need to know about indoor positioning. Directions magazine." [Online].Available: http://www.directionsmag.com/entry/10-things-you-need-to-know-about-indoor-positioning/324602. [Accessed: 24-Sep-2015].

[10] Region Monitoring and iBeacon. Apple Inc. [online]. Available from: https://developer.apple.com/library/ios/documentation/UserExperience/Conceptual/LocationAwarenessPG/RegionMonitoring/RegionMonitoring.html.[Accessed: 15-5-2016]

[11] Getting Started with iBeacon: Version 1.0. Apple Inc. [online].Available from: https://developer.apple.com/ibeacon/Getting-Started-with-iBeacon.pdf.[Accessed: 10-5-2016]

[12] App Store Distribution. [online]. Available from: https://developer.apple.com/support/appstore/[Accessed: 15-5-2016]

[13] Android 5.0 APIs: Wireless & Connectivity. [online] Available from: https://developer.android.com/about/versions/android-5.0.html[Accessed: 13-5-2016]

[14] Dashboards: Platform Versions. [online]. Available from: https://developer.android.com/about/dashboards/index.html?utm_source=suzunone.[Accessed: 15-5-2016]

[15] B. Hofmann-Wellenho, H. Lichtenegger, and J. Collins, "Global Positioning System: Theory and Practice," Springer-Verlag, 1997. [Accessed: 15-5-2016]

[16] K. Whitehouse and D. Culler, "Calibration as Parameter Estimation in Sensor Networks," Wireless Sensor Networks and Apps., 2002, pp.59-67.

[17] N. B. Priyantha, A. K. L. Miu, H. Balakrishnan, and S. Teller, "The Cricket Compass for Context-Aware Mobile Applications," 7th ACM Int'l. Conf. Mobile Computing and Networking, Jul. 2001, pp. 1-14.

[18] Savvides, C.-C. Han, and M. B. Strivastava, "Dynamic Fine-Grained Localization in Ad-Hoc Networks of Sensors," 7thACM/IEEE Int'l. Conf. Mobile Computing and Networking, Rome,Italy, 2001, pp. 166–179.

[19] J. Haartsen, "Bluetooth-The universal radio interface for ad hoc wireless connectivity", Ericsson Review, no3, 1998.

[20] J. Proakis, "Digital Communications" http://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-450-principles-of-digital-communications-i-fall-2006/lecture-notes/book_1.pdf

[21] J. Haartsen, "Bluetooth Baseband Specification, version 1.0", available at www.Bluetooth.com.

[22] Overview and Evaluation of Bluetooth Low Energy: An Emerging Low-Power Wireless Technology [online] available from "http://www.mdpi.com/1424-8220/12/9/11734.htm" [Accessed :18/5/2016]

[23] S.S. Chawathe. Low-latency indoor localization using Bluetooth beacons. In Intelligent Transportation Systems, 2009. ITSC '09. 12th International IEEE Conference on, pages 1 -7, oct. 2009.

[24] S.S. Chawathe. Beacon placement for indoor localization using Bluetooth. In Intelligent Transportation Systems, 2008. ITSC 2008. 11th International IEEE Conference on, pages 980 - 985, oct. 2008.

[25] Mortaza S. Bargh and Robert de Groote. Indoor localization based on response rate of Bluetooth inquiries.In Proceedings of the _rst ACM international work- shop on Mobile entity localization and tracking in PS-less environments, MELT '08, pages 49-54, New York, NY, USA, 2008. ACM.

[26] A. Awad, T. Frunzke, and F. Dressler, "Adaptive Distance Estimation and Localization in WSN using RSSI Measures," 10th Euromicro Conference on Digital System Design Architectures, Methods and Tools, Aug. 2007, pp. 471-478.

[27] M.Z. Barahim, M.R. Doomun, and N. Joomun. Low-cost bluetooth mobile positioning for location-based application. In Internet, 2007. ICI 2007. 3rd IEEE/IFIP International Conference in Central Asia on, pages 1 -4, sept. 2007.

[28] ENHANCED RSSI-BASED HIGH ACCURACY REAL-TIME USER LOCATION TRACKING SYSTEM FOR INDOOR AND OUTDOOR ENVIRONMENTS , INTERNATIONAL JOURNAL ON SMART SENSING AND INTELLIGENT SYSTEMS, VOL. 1, NO. 2, JUNE 2008

[29] E. Husni and S. Purwantoro, “Shopping application system with Near Field Communication (NFC) based on android,” in 2012 international conference on system engineering and technology (ICSET), 2012, pp. 1–6.

[30] Theodoros Salonidis, Pravin Bhagwat, and Leandros Tassiulas. 2000. Proximity awareness and fast connection establishment in Bluetooth. In Proceedings of the 1st ACM international symposium on Mobile ad hoc networking & computing (MobiHoc '00). IEEE Press, Piscataway, NJ, USA, 141-142.

[31] Javier J. M. Diaz, Rodrigo de A. Maues, Rodrigo B. Soares, Eduardo F. Nakamura, and Carlos M. S. Figueiredo. Bluepass: An indoor bluetooth-based localization system for mobile applications. In Computers and Communications (ISCC), 2010 IEEE Symposium on, pages 778 -783, june 2010.

[32] G. Anastasi, R. Bandelloni, M. Conti, F. Delmastro, E. Gregori, and G. Mainetto. Experimenting an indoor bluetooth-based positioning service. In Distributed Computing Systems Workshops, 2003. Proceedings. 23rd Inter-national Conference on, pages 480 - 483, may 2003.

[33] M.Z. Barahim, M.R. Doomun, and N. Joomun. Low-cost bluetooth mobile positioning for location-based application. In Internet, 2007. ICI 2007. 3rd IEEE/IFIP International Conference in Central Asia on, pages 1 -4, sept. 2007.

[34] GENERIC ATTRIBUTE PROFILE [online]:Available from [Accessed: 20-5-2016] https://developer.bluetooth.org/TechnologyOverview/Pages/GATT.aspx

[35] “Android developers.” [Online]. Available: http://developer.android.com/index.html.[Accessed: 20-5-2016].

[36] K. Al Nuaimi and H. Kamel, “A survey of indoor positioning systems and algorithms,” in *Innovations information technology (IIT), 2011 international conference on*, 2011, pp.185–190.

[37] R. Want, A. Hopper, V. Falcão, and J. Gibbons, “The active badge location system,” *ACM Trans Inf Syst*, vol. 10, no. 1, pp. 91–102, Jan. 1992.

[38] S. Zirari, P. Canalda, and F. Spies, “WiFi GPS based combined positioning algorithm,” in *Wireless communications, networking and information security (WCNIS), 2010 IEEE international conference on*, 2010, pp. 684–688.

[39] O. Hammadi, A. Hebsi, M. Zemerly, and J. Ng, “Indoor localization and guidance using portable smartphones,” in *2012 IEEE/WIC/ACM international conferences on web intelligence and intelligent agent technology (WI-IAT)*, 2012, vol. 3, pp. 337–341.

[40] F. Salim, M. Williams, N. Sony, M. Dela Pena, Y. Petrov, A. A. Saad, and B. Wu, “Visualization of Wireless Sensor Networks using ZigBee’s Received Signal Strengthindicator (RSSI) for indoor localization and tracking,” in *Pervasive computing and communications workshops (PERCOM workshops), 2014 IEEE international conference on*, 2014, pp. 575–580.

[41] E. Husni and S. Purwantoro, “Shopping application system with Near Field Communication (NFC) based on android,” in *2012 international conference on system engineering and technology (ICSET)*, 2012, pp. 1–6.

[42] Bulusu, N., Heidemann, J., Estrin, D.: GPS-less low cost outdoor localization for very small devices. IEEE Personal Communications Magazine 7(5), 28–34 (2000).

[43] Dil, B., Dulman, S., Havinga, P.: Range-based localization in mobile sensor networks. In: R¨omer, K., Karl, H., Mattern, F. (eds.) EWSN 2006. LNCS, vol. 3868, pp. 164–179. Springer, Heidelberg (2006).

[44] Weihua Pan,Fucai Luo,lei Xu : 32 Research and design of chatting room system based on Android Bluetooth

[45] Adaptive Distance Estimation Based on RSSI in 802.15.4 Network http://www.radioeng.cz/fulltexts/2013/13_04_1162_1168.pdf [Accessed 20.5.2016]

[46] A Bluetooth Signal Strength Based Indoor Localization Method: Published in: IWSSIP 2014 Proceedings, date 12-15 May 2014, pages 251 - 254.

[47] Mortaza S. Bargh and Robert de Groote. 2008. Indoor localization based on response rate of bluetooth inquiries. In *Proceedings of the first ACM international workshop on Mobile entity localization and tracking in GPS-less environments* (MELT '08). ACM, New York, NY, USA, 49-54.

[48] G Fischer, B Dietrich, F Winkler: Bluetooth Indoor Localization System.[online] PROCEEDINGS OF THE 1st WORKSHOP ON POSITIONING, NAVIGATION AND COMMUNICATION [Accessed:18.5.16]

[49] Ling Pei, Ruizhi Chen, Jingbin Liu, Heidi Kuusniemi, Tomi Tenhunen, Yuwei Chen: Using Inquiry-based Bluetooth RSSI Probability Distributions for Indoor Positioning[online][accessed 18.05.2016]

[50] Dr. Farzil Kidwai, Gaurav Saraswat, Prashant Joshi: ENHANCING BLUETOOTH BASED INDOOR POSITIONING WITH DEAD RECKONING: International Journal of Computer and Electronics Research [Volume 4, Issue 5, October 2015]