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Handover in Bluetooth Networks using Signal Parameters

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Abstract: Bluetooth is an established standard for low cost, low power, wireless personal area network. Currently Bluetooth does not support any handover protocol in which handoff occurs dynamically, when a Bluetooth device is moving out of the piconet. This paper presents Bluetooth handover concept in terms of measuring the signal parameters with respect to localization. These parameters are Received Signal Strength Indicator (RSSI), Link Quality (LQ), Transmitted Power Link (TPL) and Received Power (RX). According to the experimental analysis based on Bluetooth specifications, only Received Power RX is best suited for distance estimation and handover decision. Furthermore this paper discusses location estimation techniques, Bluetooth signal parameters for distance estimation and finally experimental analysis of signal parameters and their comparisons with distance is discussed. The main objective of this paper is to analyze the relation between Signal parameters and Handover. The parameter selected for distance based measurement can be used as threshold value for handover initiation. All the work is being done in BlueZ using Linux kernel 2.6.

Key words: Bluetooth, localization, received power, BlueZ, signal parameter, link quality

INTRODUCTION

Bluetooth is a short range wireless radio technology that enables Bluetooth enabled electrical devices to wirelessly communicate in the 2.45 GHz ISM (license free) frequency band (Bluetooth, 2001). The communication changes the transmitting and receiving frequency 1600 times per second, using 79 different frequencies. The range of Bluetooth network can be 1 to 100 m. It is used to transmit both synchronous as well as asynchronous data. The data rate of the Bluetooth network at physical layer is 24 Mbit sec^{-1} (Bluetooth Specification 3.0, 2010). Bluetooth devices can be classified into three types of power classes. Table 1 presents the classes for Bluetooth devices along with power specifications and effective range.

The basic unit of networking in Bluetooth is a Personal Area Network (PAN) or piconet, consisting of a master and one to seven active slaves. In a piconet, the devices share the same Frequency Hopping Spread Spectrum (FHHS) channel, which is a transmission technology used in Local Area Wireless Network (LAWN) (Bluetooth, 2001). Two or more than two piconets form one scatternet. So, a scatternet is collection of piconets and the connection node which links the two piconets is member of the both piconets.

Table 1: Bluetooth power classes

Type	Power level (dBm)	Range (m)
Class 3	0	0.1 to 10
Class 2	4	Up to 10
Class 1	20	Up to 100

Handover in Bluetooth network is not implemented due to many reasons. One of the reason is that Bluetooth is specially designed for short range communication and its typical purpose is to use piconet profile (Subhan and Hasbullah, 2009). The second and most important reason is to identify the boundaries of Bluetooth networks. It is very difficult to define the roaming boundaries for Bluetooth.

In cellular networks, handover means transferring from one base station area to another base station area without signal loss. However, in Bluetooth networks the problem of service termination occurs. So in order to provide seamless connection the soft handover functionality needs to be implemented in Bluetooth networks so that if a mobile user goes out of range from one base station to another, the connection is already established before the previous breaks. According to the literature survey, different researchers concluded with different techniques, but all the techniques proposed so far were based on RSSI values. In this paper the problem of handover in Bluetooth networks is addressed using RX power level, which is more precisely related to distance. Handover based on RSSI is discussed here.

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George *et al*. (2003) presented three soft handover proposals. In all of the proposals, the base stations can measure the RSSI. In the first proposal, if the value of RSSI becomes less than the threshold value, the Bluetooth device periodically inquires to search for new base station and updates the information of the base station in a stack. When the RSSI of the link between Bluetooth device and current base station becomes less than the threshold value the base station informs Bluetooth device to connect to another base station whose address is kept in stack of the Bluetooth device.

In the second proposal, the author suggests that when the value of RSSI becomes less than the threshold value, the base station sends the information of the Bluetooth device and requests for connection to the Bluetooth device to all nearby base stations through the cable network. In third proposal, the author suggests that Bluetooth device should keep a back link with another base station all the time. When the RSSI value of the connected link becomes less than the threshold value, the current link is disconnected and starts inquiry for building the backup link and also periodic inquiry for connection to the new base station.

Kansal and Desai (2002) presented hard handoff algorithm in which the base station and Bluetooth devices periodically poll each other to check the existence of the link. If the link is disconnected, the base station requests the nearby base station to page the Bluetooth device through a wired network.

Similarly, Baatz and Gopffarth (2000) discussed the handover techniques where the new device is searched at the time of handover. In this technique, the inquiry procedure is avoided at the time of handover. The same hard handover is discussed by Lee (2000) in which a mobile device first breaks the old connection and then starts inquiry for the new master to connect.

An idea based on packet relaying was presented by Steelant (2001) in which masters are fixed nodes while slaves are mobile nodes. If mobile loses its connection with the master a new node is chosen called as relay node, which relay all the packets to the communication partner. In this paper, a new extra layer is inserted called relaying layer, between L2CAP layer and the higher layer that uses the L2CAP layer, this extra layer is used for roaming applications. This kind of communication is best if the communication strongly depends on one special master, while it is not needed when the masters act as a gateway.

Zhen *et al*. (2004), Zhen presented a roaming technique for data transmission using UML diagrams. This technique is suitable only for Bluetooth piconets. This technique is not suitable for data transmission in scatternet, because in scatternet there are many masters and many slaves, so this technique depends on one special master. Similarly Chiao and Ming Huang also presented soft handover algorithm based on RSSI (Chen *et al*., 2005; Chung and Ming, 2008). If the value of RSSI value is less than the threshold value, handover is activated.

RSSI is a parameter used for activating the handover, when a mobile device is moving from one coverage area to another. In order to randomly analyze the effect of RSSI on handover, other parameter for handover needs to be explored. Therefore position estimation in Bluetooth needs to be analyzed.

The relation between handover and position estimation is to define a parameter for distance based measurement in Bluetooth networks. Therefore, in Bluetooth networks various positioning techniques need to be addressed. This paper discusses Bluetooth handover parameter in terms of signal parameter which is one of the techniques used in indoor positioning for short range communication.

The main idea proposed in this paper is to define the handover threshold values for a mobile device when it is going out of range. In Bluetooth networks there are various positioning techniques available. But due to its low cost, only Signal based positioning techniques are applicable. For this purpose various signal parameters have been experimentally tested using HCL layer. These parameters are mainly used for range based estimations, distance measurements and accurate position estimations. The relation between signal based measurements and handover analysis is to define a threshold value for initiating the handover, when a Bluetooth enabled device is moving away from one master to another master device. In Bluetooth specification there is no proper support for handover, therefore, the idea behind this study is to explore the handover and to define the threshold value for initiating the handover. The parameter defined in previous research (George *et al*., 2003; Chung and Ming, 2008), for initiating the handover is RSSI. In this paper it is experimentally verified that RSSI is not an accurate parameter for initiating the handover in Bluetooth networks.

HANDOVER IN BLUETOOTH NETWORKS

Bluetooth specification does not provide any support for handover, when a mobile device is moving out of range from one master device to another master device; the connection termination occurs (Subhan and

Hasbullah, 2009). The main reason for this deficiency is its short range and adhoc network setup. Therefore this problem needs to be addressed. The main contribution of this paper is to address the threshold value required for initiating the handover. The benefit of this threshold value selection is to decide the handover activation.

The algorithm proposed in this study is almost similar to the previous study conducted by George *et al.* (2003) which is based on the RSSI value. However this study proposes handover parameter different than RSSI, which is RX power level. The reason behind RX power level is its relation with distance better than RSSI. The performance of proposed algorithm is yet to be validated using simulation. In the proposed algorithm the mobile device is continuously in periodic state, scanning remote base stations and connecting to them. The addresses of all the nearest base stations are stored in a stack. The latest inquiry address is stored at the top of the stack. When the RSSI values of the Bluetooth device and the current base station become less than the threshold value, it sends a request to the connected base station to increase the transmitted power. If RSSI link value gets greater than the threshold, again the connection is maintained, while if the decrease in the RSSI value occurs again it pages the topmost base station and starts communication with the new base station. Both the links are kept active for future moment of the mobile device. Algorithm 1 depicts the proposed strategy for handover scheme.

The novel idea behind this study is to experimentally address various signal parameters and to correlate its effect with distance in order to propose the threshold value for handover and distance based measurements. The proposed threshold parameter for handover initiation in Bluetooth network is discussed further.

Algorithm 1: Proposed handover algorithm for bluetooth networks

```
BEGIN
    1.  BT(Periodic inquiry on)
        Stack (BT base station address)
While [1]
    if (RSSI (BTm) < threshold (value)
        Send LMP_Request (slave)
          Increment (LMP_Power)
            If (BT(rssi) > threshold value
                Go to step 1
            elseif
            Page (New Base station)
                Exchange Master/slave role
                    Go to step 2
            End
        End
    End
    2.  Connect to the Base station
END
```

Positioning in bluetooth networks: Positioning in Bluetooth networks refers to determine the position of any device with respect to some reference coordinate. Positioning is not only to identify the position of object but also to estimate the distance to the object. According to the survey presented by Pandey and Agrawa (2006), Mao *et al.* (2007) and Roxin *et al.* (2007) various standard techniques are available for positioning which are Global Positioning System (GPS), Angel of Arrival (AOA), Time of Arrival (ToA), Time Difference of Arrival (TDOA), Triangulation and Trilitration are the well know positioning techniques for wireless communications. Each of these techniques have their own benefits and draw backs. For example GPS is a well known navigation technique for object position finding, which is the reliable one but it requires very expensive equipments and also due to its line of sight with the satellite. This requires an open air, inside building and for indoor environment this technique fails.

AOA is also used for positioning. This technique measures the angle arrived at the receiver side from multiple directional antennas. The accuracy of this technique highly depends on the accuracy of antennas. Therefore this technique also requires additional hardware which leads to the heavy cost.

TOA and TDOA measure the timing of the arrival signal from multiple base stations. In the TOA, the time of arrival of signal is compared with the signal transmitted time. In TDOA, the same technique is applied here also but the difference between the arrived signals at different receivers are calculated and compared with the transmitted time from sender. Position accuracy highly depends on the accurate measurement of timings in base stations as well as in transmitter.

Triangulation and Trilitration are both used in GPS, for high position accuracy. Triangulation measures the angle from three stationary points and using trigonometric calculations for accurate angle calculation. The use of triangulation concept is widely used in many navigation systems. The concept of triangulation can be easily implemented using access points for positioning in Bluetooth. The position of access points will be in such a manner that depicts the structure of triangle. To find out the distance, the concept of Trilitration comes out. This technique measures the distance from stationary objects. The diameter of these three stationary objects from the transmitter must be known in advance. In practical situations both Triangulation and Trilitration techniques can be easily implemented.

Distance estimation parameters in bluetooth: In Bluetooth networks indoor positioning is carried out using signal parameters. The main reason behind these signal based measurements is the simplicity and low cost without purchasing expensive hardwares. Aventhi (2006) presented RSSI based localization techniques in detail, he also compared different RSSI based indoor positioning techniques. Hossain and Soh presented Bluetooth signal parameters for indoor positioning and experimentally verified its relation with distance (Hossain and Soh, 2007). This study discusses signal parameters for distance estimation. The parameter which best suits with distance will be selected for handover threshold. Therefore, four different parameters were experimentally investigated. These parameters are RSSI, LQ, TPL and RX. Following are the brief introduction about these parameters.

Link Quality (LQ): It is an 8 bit unsigned integer value, which shows the status of the link. The value ranges from 0 to 255. If the values of the link are greater or near to 255 it means that the link quality is good, if its value is low so the quality of the service will be also low. This parameter is device specific. Some Bluetooth dongles have value 0 and some have different values.

For most Bluetooth devices these values are derived from the average Bit Error Rate (BER) visible at the receiver and these values are automatically updated when packets from the sender are received. According to the Bluetooth specification, the exact mapping of BER to LQ is device and manufacturer specific.

Received Signal Strength Indicator (RSSI): RSSI is an 8-bit integer which denotes whether the received (RX) power level is within or above/below the Golden Receiver Power Range (GRPR), which is regarded as an ideal RX power range. Figure 1 illustrates the relationship between GRPR and RSSI, as defined in Bluetooth specification. According to the Bluetooth specification, positive or negative RSSI (in dB) means the RX power level is above or below GRPR respectively, while zero implies that the RX power level is within the golden range. Therefore RSSI is taken as a parameter for RX power level or power control and not for distance estimation.

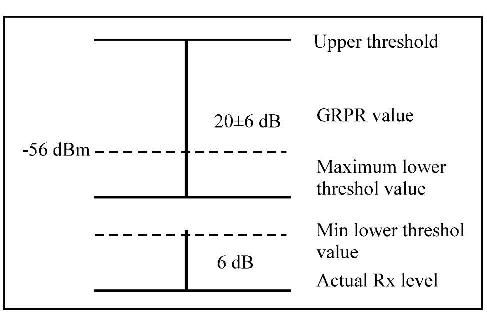

Fig. 1: Bluetooth GRPR

Transmit Power Level (TPL): TPL is an 8 bit signed integer values which specifies the Bluetooth transmit power level (in dBm). For Class 1 devices, which have a maximum output power of +20 dBm, power control is mandatory when the TPL is between +4 and +20 dBm. In Bluetooth specification, power control is optional for TPL under +4 dBm. This parameter is also considered as manufacturer specific, although for class 3 devices the power option is not mandatory to support all devices.

Received Power level (RX): This parameter is obtained indirectly from the measured RSSI values. These values are then converted to RX power level using the radio propagation model. According to the experimental observation, RX power level is best suited with distance. RSSI can be converted to RX power level only if the Upper and Lower threshold values of the GRPR are known.

The RX power level is then converted to distance estimation using the Radio Propagation model.

Bluetooth mobile radio propagation model: This model is used to estimate distance from the known value of RSSI and TX Power level based on Zhou and Pollard (2006) and Kotanen (2003). The parameter required for estimating distance using this model is Received power level, which is obtained indirectly from RSSI values. The receiver power RX power level can be calculated from the following Friis equation.

$$\text{Prx} = \frac{\left(\text{Ptx.Gt.Gr.d}^2\right)}{\left(4\pi \text{d}\right)^2} \tag{1}$$

The above equation has been used for RX power level calculation and distance estimation. The distance formula can be further calculated by simplifying equation, by taking log both sides. The distance equation can be written as follows:

$$\text{Distance (d)} = 10^{\left[\frac{\text{Ptx} - \text{RX(i)} + \text{G} - 20*\log\left(\frac{c}{4\pi f}\right)}{10n}\right]} \tag{2}$$

where, RX is known as the power received by the receiver. Ptx referred above is the transmitted power which is taken in dB. Grx here represents the antennas gain power and Gtx represents the transmitted power of antenna. The unit for both is dBi. The velocity of light is represented by c and the central frequency is referred as f. The values for c and f are c= 3.0×10^8 m sec^{-1} and f = 2.44 GHz. The variable n is used as the attenuation factor which is taken as 1.50 for (free space). Received power level in Bluetooth networks can be measured indirectly from RSSI.

The conversion process of RSSI to RX power level is based on Eq. 1 and 2.

Experiments: This section discusses experimental test bed for Bluetooth signal parameters. The purpose of these experiments is to establish a relationship with distance in order to calculate the threshold value for handover decision. And also to find out which Bluetooth parameter best suits with distance.

Test bed: Experimental setup is located within a wireless research laboratory. The dimensions of the laboratory are 20×40 m, an area of 800 m^2. This wireless lab includes many cubicles for research students. Various Bluetooth dongles of different specifications were used in order to give better results in terms of accuracy. After complete analysis of different Bluetooth dongles using Fedora 10, equipped with latest version of BlueZ, finally class 2 USB Bluetooth devices together with Nokia 5130 were selected, because it gives much better results as compared to other Bluetooth dongles. All the work was done using BlueZ command line utilities, hcitool, hciconfig. These command line utilities provide access to the Bluetooth hardware using HCL layer. The devices used in experiments are listed below. The algorithms are developed in BlueZ programming language under Linux 2.6 shell. Algorithms 2, 3 and 4 are used for device discovery, RSSI measurements and distance calculation respectively using standard radio propagation model.

Data collection: The experiments were conducted using HCL layer of Bluetooth specification which provides connectivity to various Bluetooth devices, using the command line utilities of BlueZ, which is an official Linux protocol stack for Bluetooth networks (BlueZ, programming language).

Multiple sets of each signal parameter were collected to select suitable Bluetooth dongles. After analysis of RSSI readings class 2 specification devices were selected for data collection. The maximum range of class 2 specification Bluetooth dongles is 10 m. In order to collect the RSSI readings, 0.3 m step size was chosen. At each step size 30 readings were taken for each signal parameter; the mean of these readings were taken for distance estimation. The same technique was adopted for all the signal parameters. Table 2 depicts the RSSI readings obtained using hcitool. Each of these signal parameters are discussed in the next section. The specifications of master and slave devices used in experiments are as follows:

Algorithm 2: Bluetooth device discovery and connection

```
BEGIN
    /* Open and initialize Bluetooth devices */
        hciconfig hci0 up
    /* Check for Bluetooth local device */
        hcitool dev
        hcitool scan
    /* scan and automatically connect Bluetooth devices
        While [ 1]
        hcitool scan
        rfcomm connect all
        end
END
```

Algorithm 3: Bluetooth signal parameters

```
BEGIN
/* check if the device are already connected
        If rfcomm connect = 1
While [1]
/* Read RSSI, LQ and TPL of the connected
 Bluetooth device
    HCL_ Read _RSSI (device address)
    HCL_Read_LQ (device address)
    HCL_Read_Transmit_Power –level(device address)
    end
    elseif
        While [ 1]
        hcitool scan
        rfcomm connect all
        end
    END
```

Algorithm 4: Distance estimation in bluetooth network for handover decision

```
BEGIN
/* Step 1: Conversion of RSSI to RX
        for i = 1 : length (rssi)
        if (rssi (i) > 0)
        RX (i) = rssi (i) + GRPR (upper range)
        elseif
        RX (i) = rssi – GRPR (lower range)
        elseif
        if (rssi (i) = 0)
        GPRR(upper) ≤ RX ≥ GPRR (lower)
        end
/* Step 2: Distance calculation using Free space Propagation Model
        for i = 1: length (RX)
        distance (i) = 10 ^ [Ptx - RX (i) + G - 20 * log (c/4πf)] / 10 * n
        end
END
```

Table 2: RSSI readings

Distance (m)	RSSI (dBm)	Distance (m)	RSSI (dBm)
0.0	0.0	3.6	-26.5
0.3	-4.5	3.9	-27.4
0.6	-10.0	4.2	-28.4
0.9	-15.0	4.5	-28.0
1.2	-20.0	4.8	-28.0
1.5	-20.5	5.1	-27.0
1.8	-26.5	5.4	-29.0
2.1	-26.5	5.7	-28.0
2.4	-27.0	6.0	-28.5
2.7	-28.0	6.3	-29.5
3.0	-28.5	6.6	-30.5
3.3	-27.5	6.9	Disconnected

Master device specification

Type	:	USB
Address	:	00:15:83:15:A3:10
Range	:	10 m
Manufacturer	:	Cambridge Silicon Radio (10)

Slave device specification

Type	:	Mobile device (Nokia 5130)
Address	:	D8:75:33:7F: AC: DA
Range	:	10 m
Manufacturer	:	Broadcom Corporation (10)

RESULTS AND DISCUSSION

This section discusses each parameter relation with distance and finding out the best suited parameter for handover decision. All of results are based on Algorithms 2, 3 and 4.

Figure 2 shows the relation between distance and real experimental RSSI. According to the observations from different USB Bluetooth dongles, this parameter is very dynamic. For each device the observed values are different for same distance which shows that RSSI is somehow device specific. According to Bluetooth specification, RSSI values are used for power control. The normal range of RSSI is -127 to +127. Negative values of RSSI indicate RX power level is less than GRPR range, while positive values indicate that the RX power level is greater than the GRPR (Kotanen *et al*., 2003). The RSSI value zero indicates that the RX power level lies within the GRPR range.

In experiments performed the upper limit is zero, while the lower limit is equal to -30. The value zero indicates the slave device is adjacent to the master devices and the values drop to negative when the slave devices are going away from the master device. RSSI readings were taken from every 30 cm to a maximum of 7 m. After this range the connection with the master device was broken and the disconnection message was shown. The range of the Bluetooth device was maximum upto 10 m but due to noise and the environmental conditions, path loss problem happened.

Figure 3 shows RSSI values converted to RX power level with the help of radio propagation model. RSSI values can be converted to RX power level only if the upper and lower threshold values are given (Zhou and Pollard, 2006). As it is mentioned earlier that the upper limit in experiment is zero, while the lower limit is -30.

Figure 4 shows the effect of transmitted power over distance, which is considered as a poor candidate for distance estimation. Therefore, this parameter shows the same value for different distance samples. The power

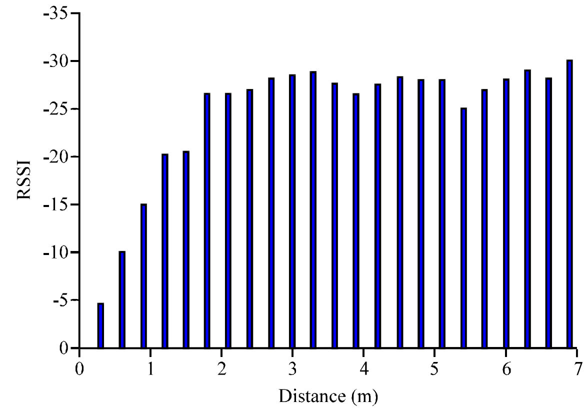

Fig. 2: Relationship between distance and RSSI

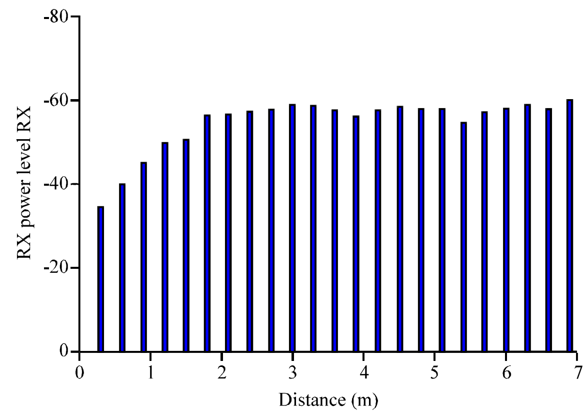

Fig. 3: Relationship between distance and Real RX

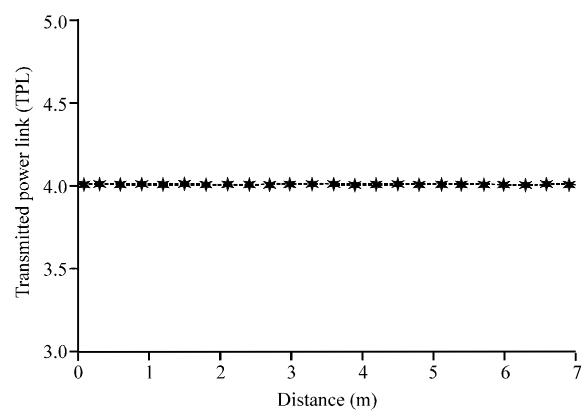

Fig. 4: Relation between distance and transmitted power

control feature in many Bluetooth devices has been disabled. In experimental observation from four different types of Bluetooth dongles, it is observed that for Class 1 devices, which have a range equal maximum up to 100 m, both the transmitted and power control parameter have been disabled. The result from experiments gave zero value for different distances.

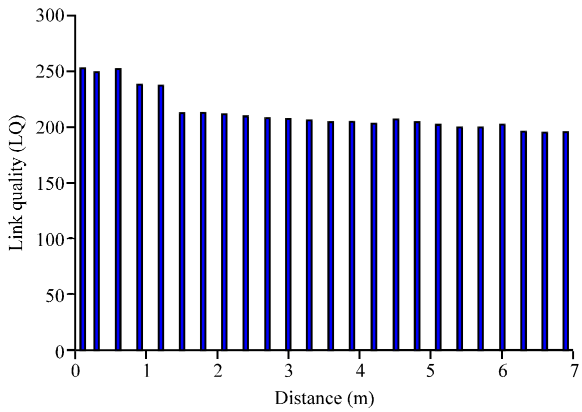

Fig. 5: Relation between distance and link quality

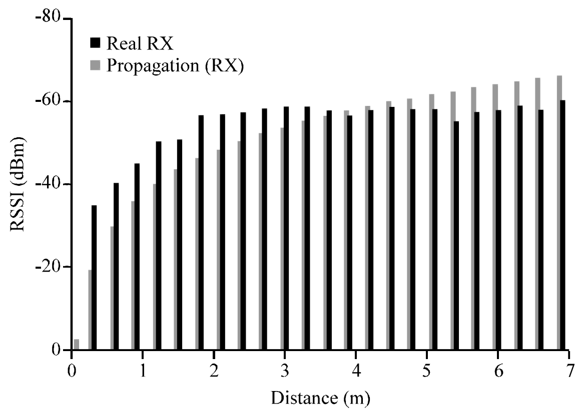

Fig. 6: Comparisons of experimental and model

Figure 5 shows distance and Link quality relationship. From this graph the variation is almost better than the TPL, but there are still very little variations even for large distance. Therefore this parameter is also considered as poor for distance estimation. From the experimental observation, this parameter is also disabled in most of the Bluetooth dongles; meaning Class 1 device gave zero link quality, while the other Bluetooth dongle gave 255, which is the maximum range. Therefore LQ can also be considered as a poor parameter for distance estimations, due to the small variations and device specific range.

Figure 6 is the comparison of Real RX power level with propagation model. This graph shows some variations between real values and model, which is due to the different environmental conditions which affects the signals. In order to obtain better results, the real values collected from the experimental observations were tested with different values of n. The value of n for indoor environment varies from 0 to 3. For obtaining precise measurements the value of n must be accurately selected. In this study four different values of n were taken in order

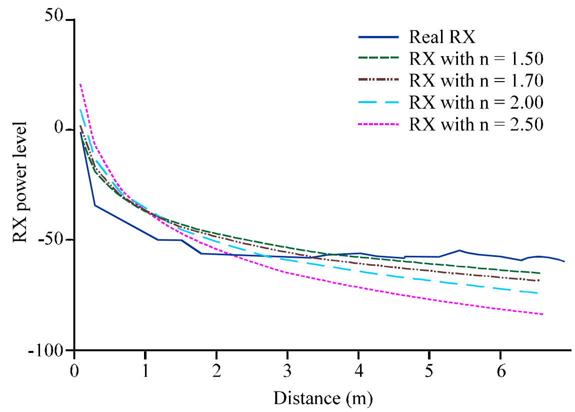

Fig. 7: Comparisons of distance and RX power level for different values of n

to test the best fitted value for propagation model. Figure 7 shows the comparisons of Real RX power with the different values of n. The value of n, which gives closer relation with the real distance, is selected. In Fig. 6, the comparisons show good results as compared to other values of n, therefore for n = 1.50, the propagation model for RX power gives good result.

According to the above discussion on different signal parameters and its relation with distance, RX power level is considered the better parameter for handover initiation compared to other signal parameters. In order to validate the proposed parameter for handover decision, more experiments were performed.

Validation test for proposed handover parameter: The experiment was performed for validation of the proposed handover parameter. Different sets of Bluetooth dongles were used and devices were organized in form of two piconets. Both the piconets were arranged in order to overlap the coverage area of one piconet to another piconet. Before performing the experiments, the distance between two master devices were calculated in order to fix the maximum distance. Both the piconets consisted of two fixed slaves and one mobile device for handover purpose. When the mobile device started moving from one coverage area to another, the RSSI values were tracked from the source piconet. When the mobile device reached the maximum range of the master device, the communication was broken down, meanwhile the mobile device entered the second piconet and master device requested for connection establishment. The program running on the second master device performed continuous inquiry and automatic connection was establishment. After the connection establishment, the master device tracked the RSSI values and stored the values in a table. The platform used for tracking the RSSI values was the same as previous. For measuring the RSSI values, both the master devices which were mini laptop and desktop were programmed for continuous measurement of RSSI readings. The RSSI data obtained from both the Master devices were then converted to RX power level using propagation model.

Analysis: According to the observations from all experiments conducted for measuring the RSSI values, the values obtained are very much random in nature; therefore 30 readings were collected at each step size of 1 to 7 m. According to the collected readings, RSSI gives different values at the same time and distance. On the other hand RX power level gives much more better and consistent values compared to RSSI. The values obtained greatly suffered from the environmental conditions, for example wall, temperature of the room or laboratory and air reflection. RSSI values are also hardware dependent. In the experiments, it is observed that different Bluetooth dongles give different results at the same step size. Its dependency on hardware and manufacturing faults greatly suffer the distance range due to the effect of environmental condition. Therefore RSSI readings are converted to RX power level using the standard radio propagation model. The conversion process from RSSI to RX power level also depends on the model parameters. Therefore parameters for propagation model, which are already used by Zhou and Pollard (2006) and Kotanen *et al.* (2003) were selected.

The relation between RSSI and distance in both piconets were compared with RX power level. Figure 6 and 7 shows the final comparisons of RX power level with the real distance. This shows that RX power level provides much better result as compared to RSSI. In Fig. 6, the difference between RX power level and theoretical values depicts the error, which occurs due to the reflection of wall, temperature, humidity etc.

Conclusion and future work: The following conclusions have been drawn which are based on the experimental results obtained.

- RSSI is not a suitable parameter for distance estimation as well as for handover decision due to its dynamic nature. Also it is noticed that different Bluetooth devices have different sort of observations from the same distance
- There is a problem of disconnection within the range of the Bluetooth proximity of class 2 Bluetooth devices, which shows the interference of obstacles and other various environmental conditions which greatly affect the range of distance
- Link quality and transmitted power is not supported in many devices, due to the firmware design, therefore these two parameters are not considered for localization and handover decision parameter
- RX power level is strongly correlated with distance, as compared to RSSI. The reason behind this parameter is its dependency on hardware, manufacturing defects and other environmental conditions. Therefore this parameter can be considered for distance estimation and handover decision parameter

This study discussed the problem of handover in Bluetooth networks in detail along with the listed contribution by researchers. The paper further discussed various positioning techniques for Bluetooth networks, in order to estimate the range of Bluetooth networks in terms of signal parameters. Different experiments were performed for identifying the parameter for distance based estimation as well as threshold value for initiating handover in Bluetooth networks. In addition four different types of signal parameters were analyzed i.e., RSSI, LQ, TPL and RX power level; out of these four parameters RX power level is suggested as threshold value for handover activation. Further experiments for validation of RX power level were conducted. Therefore it is proposed that RX power level is selected as parameter for any kind of distance based estimation. This parameter can also be considered for indoor positioning.

The main focus in future research will be to remove the noise that occurred in data collections which lead to in accuracy. Furthermore extended Kalman filter will be used for real time data gathering and prediction, together with Trilitration and other indoor positioning techniques to find out object position with reference to some coordinate.

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