Novel Smoothing Approach for Indoor Positioning Bluetooth Networks using RSSI

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Abstract— In recent years, localization and navigation have been important topics in research. The most popular navigation system is an outdoor navigation with GPS. However, there are many impossibilities when trying to perform positioning within indoor environments, with the use of GPS technology. In order to overcome this limitation, this paper has discussed Bluetooth Low Energy technology based localization model. The BLE provides several major forms of parameters linked to location estimation such as RSSI and LQI. In real time applications such as object tracking and distance estimations, continuous receptions of RSSI measurements are needed in order to estimate accurately the position of the object. In adjacent to those considerations, there are some additional constraints to be inspected such as signal attenuation, signal loss, multipath effects, temperature, reflection, a human body and other communication signals. Hence, this research work has examined the RSSI smoothing approaches in order to obtain preferable results. Although there are so many solutions, no RSSI smoothing method has been recognized as a standard method. This paper presents a Feedback filter together with shifting technique at distance domain to reduce fluctuations of the real-time signals. The experimental outcome of this novel approach has shown that the probability of location-based identification is errorless, and it is better than the other existing interference avoidance algorithms.

Keywords — ***BLE, Feedback Filter, LQI, RSSI, Shifting Technique***

I. INTRODUCTION

Context-driven information systems are mostly driven by the growth of wireless and mobile communication technologies [1]. Precisely, at present mobile phones are equipped with several radio-frequency technologies, like Global Positioning System (GPS), Wi-Fi and Bluetooth and so forth. Hence, most of the mobile devices have an ability to provide localized with the assistance of GPS in an outside environment, but, it is ineffective to provide indoor localization due to the poor signal quality of the GPS. In order to overcome this limitation, the researchers have been working with Bluetooth Low Energy (BLE) technology since last decades with the Received Signal Strength Indicators (RSSI). In this paper, present a study of the Bluetooth signal as a source of information for the locating systems to provide a solution to find the exact indoor location. The proposed test environment consists of three beacon nodes connected network where each of them is composed of user's mobile telephone sets. It should be worked by inquiring the Received Signal Strength Indicators (RSSI) values of all the visible Bluetooth devices and may need to employ a fingerprinting technique, so it determines the current location of a person. Established in the Experimental Results of testing on the RSSI values, shifting technique, a method has been proposed, which can find the static RSSI values for the locating system. The experimental results show that the proposed method can reduce the average error.

The rest of this paper is organized as follows. Section II discusses Literature Survey. In section III discusses Research Methodology. Section IV discusses results and evidence. Lastly, Section V discusses Conclusion and Future work.

II. LITERATURE SURVEY

The massive influx of Bluetooth Low Energy (BLE) technology reveals more opportunities for innovations. It is shared by most of the people to communicate conveniently since available on the modern mobile devices. Ling Pei et al. [2], [3] present their system that finds the location using fingerprinting. According to them, the position is computed with the RSSI probability distribution and gained accuracy of 10 meters standard deviation. Fazli Subhan et al. [4] Stated that the uses trilateration for computing the status and the distance is gauged based on the radio propagation model combined with the Gradient filter for cutting down the interference. This method gains 2.67-meter accuracy. There are several profit-making BLE-based products in the market which assist in finding the objects [5], [6]. None of them fully communicate the correct path but specified whether the object is nearby or not.

Localization error can be decreased by simultaneously observing RSSI, so the beacon nodes provide information about RSSI of a received Bluetooth signal. Thus, the shifting algorithm proposed and developed in this paper is to determine the relation between RSSI and range, which would be applied in real-time location. There has been lot of efforts taken not only for smoothen the RSSI [7], [8], [9] but also to understand interrelationship between RSSI and distance and implementing relational database by considering correlation [10]. . According to Letchner et al. [11] they introduce a sensor measurement model in the particle filter framework that combines a Wi-Fi signal propagation model [12] and fingerprinting technique for locating. In [13] the authors proposed Bluetooth based indoor positioning with trilateration technique and mentioned accuracy in an indoor environment is 4.56 meters. In [14], the drawn-out author idea Kotanen [15] with wireless Local Area Networks and Extended Kalman Filter. Average error by using extended Kalman filter is 2.11 meters which lower than an average error in KNN approach (3.37 meters) and 2.11 meters using extended Kalman filter.

According to the above literature reviews which related to RSSI smoothing in the area of localization still need special attention. This paper has been proposed and achieved filtered RSSI output using the shifting technique.

III. RESEARCH METHODOLOGY

This research focuses on positioning a mobile node within the beacon network using RSSI smoothing approach. In order to process precise data regarding accuracy, author's intention is to create an algorithm for indoor positioning to remove inconsistent data. The intent of this algorithm is to generate the right position by removing unwanted information. Fig. 1 depicts a block diagram which provides an overview of the proposed indoor positioning methodology.

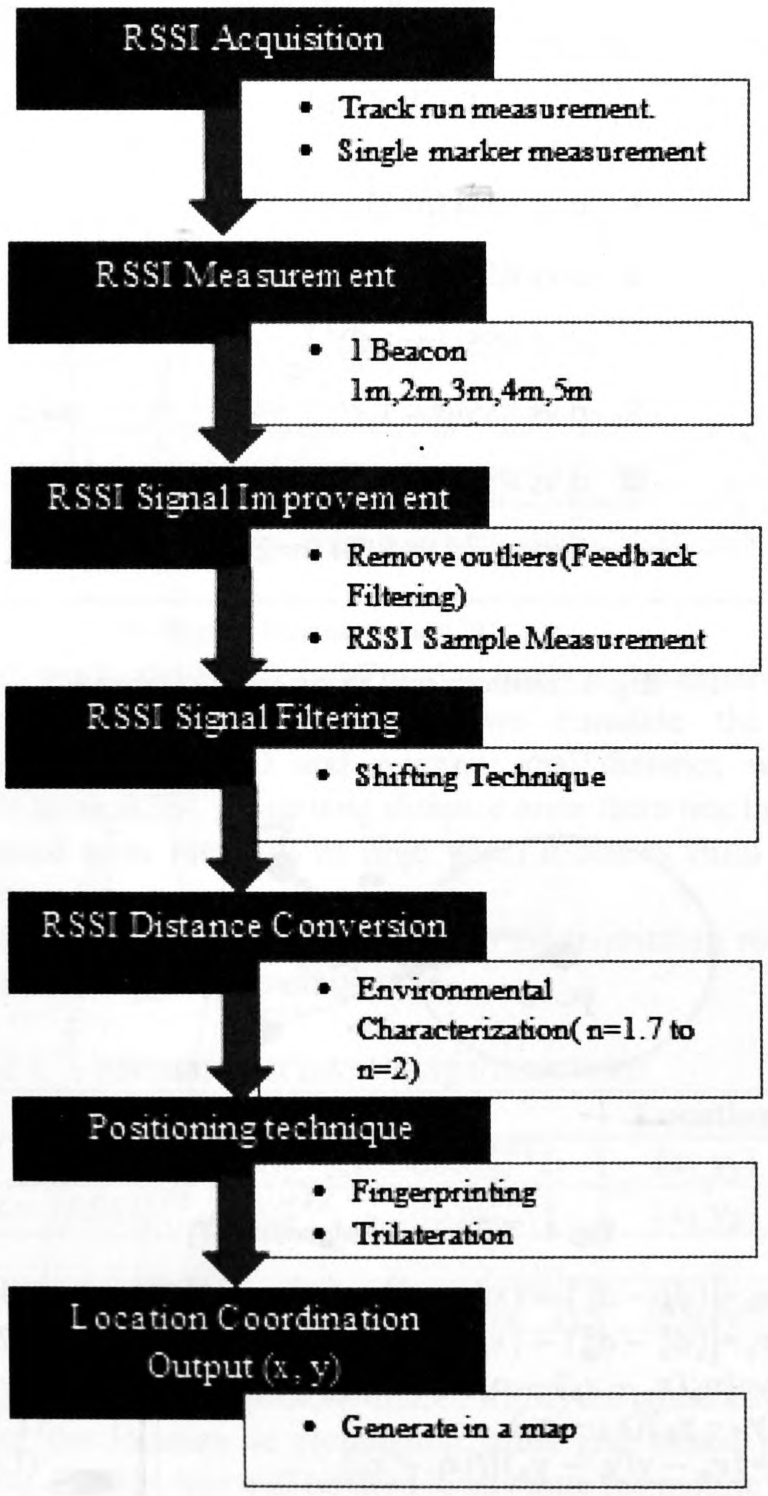

Fig. 1. Block diagram of the proposed indoor positioning

A. RSSI Acquisition

Bluetooth RSSI readings tend to change rather significantly. The deviation between the maximum value and the minimum value is high; then itis difficult to judge the distance using Bluetooth RSSI raw data. Hence, RSSI acquisition carried out in two stages. The track runs measurement and single marker measurement. The first entire area is split up into a rectangular grid of square blocks. In single marker measurement at each of these blocks, measure the RSSIs 20 times in order to predict measurements. Although single marker measurement is done with selected locations without following a line, these approaches remain at the ranging aspect. Nevertheless, track run measurement is collecting RSSIs while moving the object. Combinations of these two methods are utilized to collect RSSI values.

B. RSSI Measurement

The accuracy of the indoor positioning system is greatly dependent on the parameters selected for estimation and the measurements obtained from the environment. However, the measurements are corrupted by various environmental conditions such as temperature, reflection, presence of obstacles, the human body, and other communication signals. Thus, we need to get rid of the outliers and filter the measurements, for those proposed algorithms include "Feedback Filter."

C. RSSI Signal Improvement

The feedback filter used for eliminating noise in different environments is the filter used in this algorithm. If a filter approximation is employed, it can be expressed as where α represents the weighted value. In this equation, although the range of α value is 0-1, here the variable α is 0.75. RSSI n has represented the most recently measured value, and RSSI $n-1$ represents the previous averaged value. This approach ensures that a large difference in RSSI values will be smoothed.

$$RSSI_{smooth} = \alpha * RSSI_n + (1 - \alpha) \quad (1)$$

This means that the average RSSI value corresponding to the signal strength at a distance depends on both the previously averaged value and the most recently measured value.

D. RSSI Signal Filtering

Even though after getting rid of outliers, it is hard to track a specific RSSI range for a special position. To counteract this effect: the system is tested using median filtering and novel shifting algorithm. Test results were verified shifting algorithm smoothen the RSSI values better than average filtering. Finally, algorithm consists with novel filtering technique (Shifting algorithm) for placing a target node using RSSI.

In this research, collect the RSSI data using track run and single marker measurement. Hence, we defined a vector to store

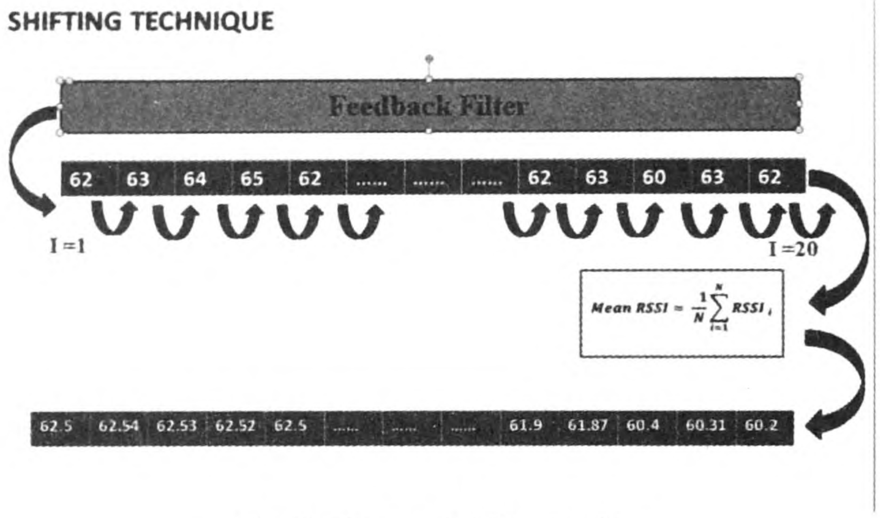

Fig. 2. The novel shifts algorithm

the training data which are coming after performing feedback filtering. Fig. 2 depicts shifting technique performing continuously while navigating and every time take an average of 20 values.

E. RSSI distance conversion

To obtain distances based on the measured RSSI the mathematical model in the equation as the following.

$$RSSI = -(10n\ log_{10}\, d + A) \tag{2}$$

$$d = 10^{\frac{A-RSSI}{10*n}} \tag{3}$$

In the equations, the RSSI is the RSSI value received (dBm), n: is the path-loss exponent of the distance, A: is the RSSI value at a "1" meter reference distance.

It is observable through values obtain from beacons, for the selected area RSSI values are variable according to the n value. This value is known as the path loss exponent and is extremely dependent on the surroundings. To examine the environmental characterization drew a graph (fig. 3) Using collected information from the experimental area and compared it to when n=1. 7 to n=2.

F. Positioning Technique

Trilateration algorithm will choose the estimated distance from at least three beacons as inputs. The method for localization requires the user's distance from three reference nodes with unknown coordinates because it uses the geometry of triangle [16]. Each beacon location represents a vertex a triangle while each estimated distance represents a side of the triangle. The process is called trilateration. Authors decided to take user input values from beacon to calculate the corresponding distance between the user.The beacons as arranged according to the Fig. 4.The equations: (1.1), (1.2), (1.3), and (1.4) employed to determine the X and Y coordinates of the current location of the user by using input values from A, B, C becomes as shown in Fig 4.

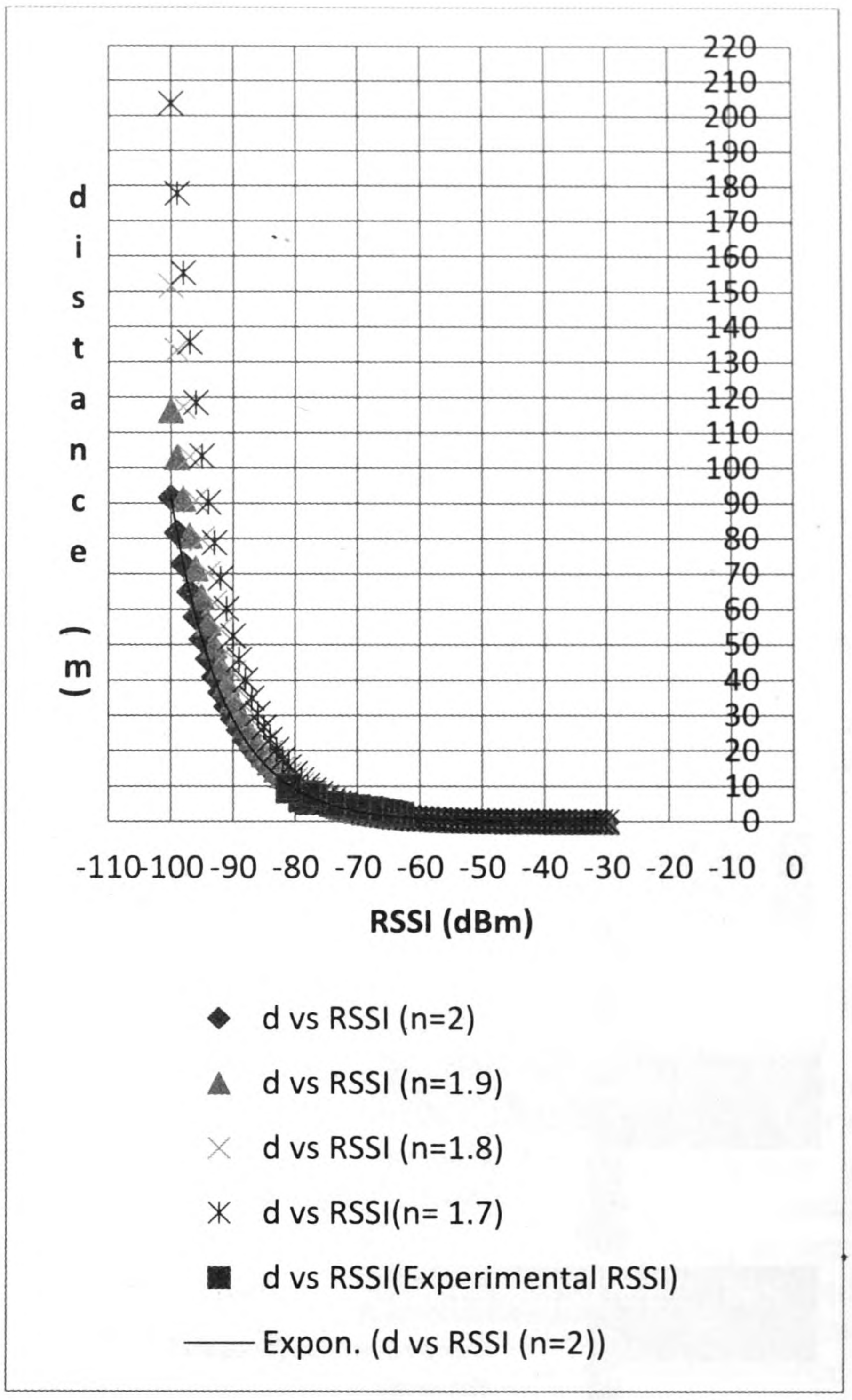

Fig. 3. Environmental characterization variation

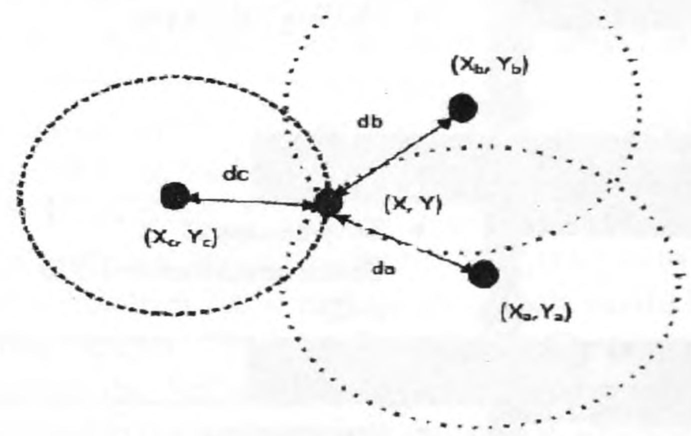

Fig. 4. Trilateration Algorithm[17]

$$v_a=[(d_b^2 - d_c^2) - (x_b^2 - x_c^2) - (y_b^2 - y_c^2)]/2 \tag{1.1}$$

$$v_b=[(d_b^2 - d_a^2) - (x_b^2 - x_a^2) - (y_b^2 - y_a^2)]/2 \tag{1.2}$$

$$y=[v_b(x_c - x_b) - v_a(x_a - x_b)]/\ [(y_a - y_b)(x_c - x_b) - (y_c - y_b)(x_a - x_b)] \tag{1.3}$$

$$x= [v_a - y(y_c - y_b)]/[x_c - x_b] \tag{1.4}$$

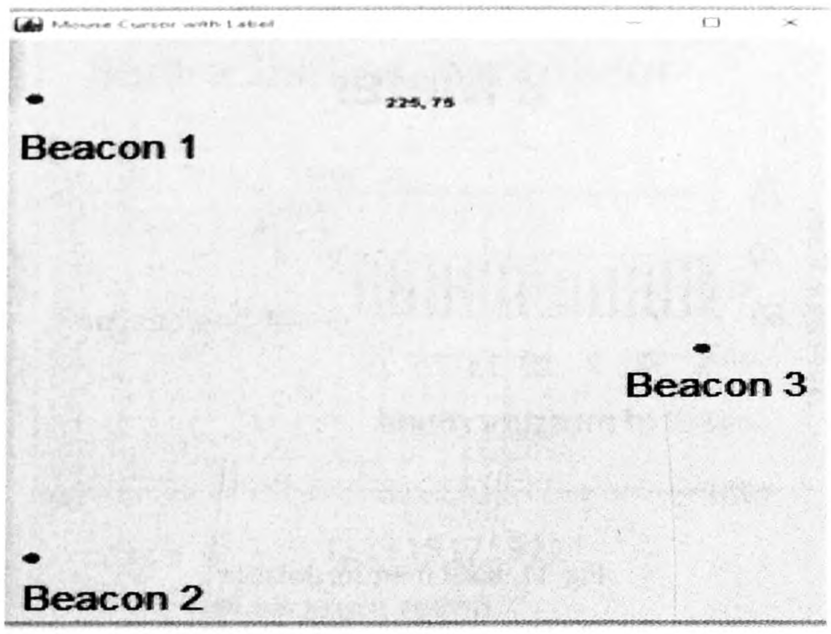

Fig. 5. Beacons and user location map in java 2D

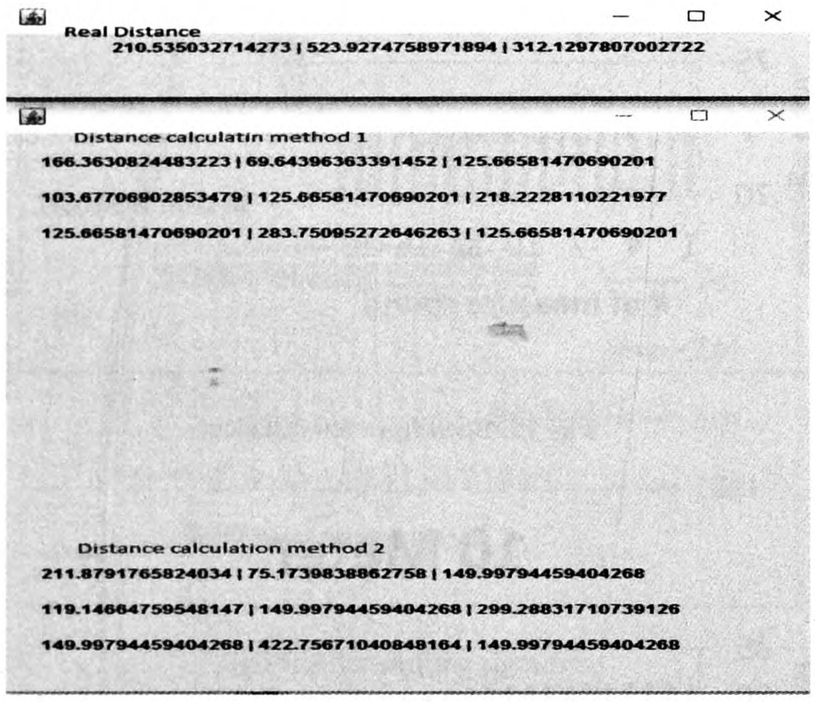

Fig. 6. Distance in java 2D

As shown in the Fig. 5 and Fig. 6 to analyze the capabilities of distance conversion functions we simulate the real environment in Java2D and compare real distance with a distance using RSSI. Observing distance error from one beacon determined error rate will be high when it comes from three beacons.

Thus, to get the (x, y) coordination fingerprinting method based on the suggested methodology.

TABLE I. FINGERPRINT DATABASE STRUCTURE

Fingerprint	Location
FP1 = $\{RSSI_1^{FP1}, RSSI_2^{FP1}, \ldots, RSSI_m^{FP1}\}$	(x_1, y_1)
FP2 = $\{RSSI_1^{FP2}, RSSI_2^{FP2}, \ldots, RSSI_m^{FP2}\}$	(x_2, y_2)
…………………………………………	…..
FPN = $\{RSSI_1^{FPN}, RSSI_2^{FPN}, \ldots, RSSI_m^{FPN}\}$	(x_N, y_N)

Then location fingerprints (Filtered RSSI) are gathered up by dividing the location in rectangular grids and stored in the database. Finally, this will be used to navigate the mobile node.

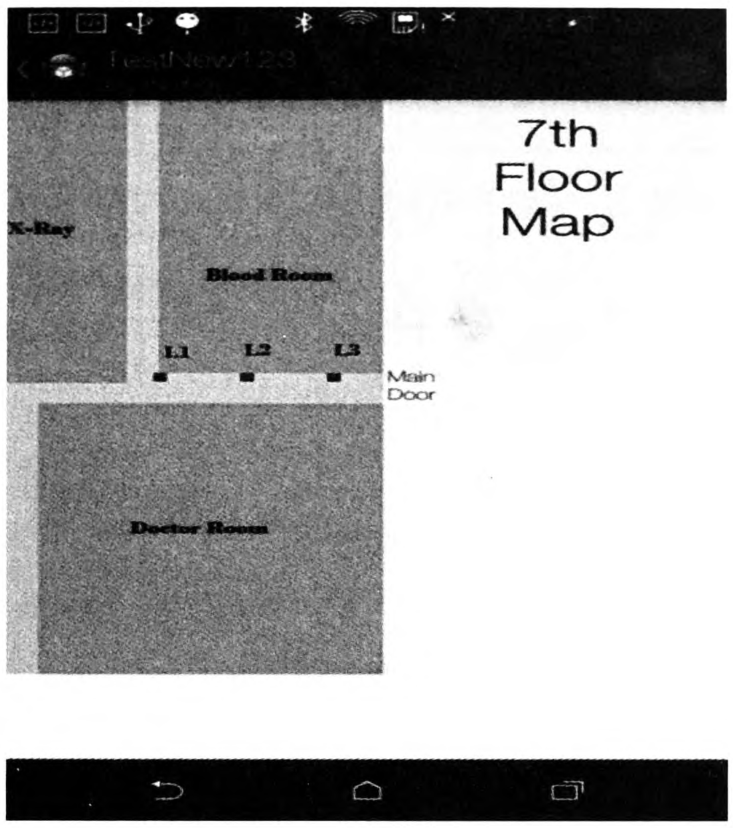

Fig. 7. Location coordination output

G. Location Coordination Output

The location coordination output (Fig.8) clearly indicates the course of the moving target. By using the fingerprint, the database structure is given in TABLE I, that the object locations are calculated.

IV. RESULTS AND DISCUSSION

This Section discusses the experimental setup that followed in establishing a relationship between RSSI values and distance. This purpose the Sri Lanka Institute Of Information Technology 7th floor was used as a sample test environment. The idea is to make a relationship that was to determine the error and to check which filter is most suitable for smoothing the RSSI values.

Fig. 8 shows the row RSSI and RSSI after performing feedback filtering which removes outliers. The red line shows very high RSSI and low RSSI are deducted.

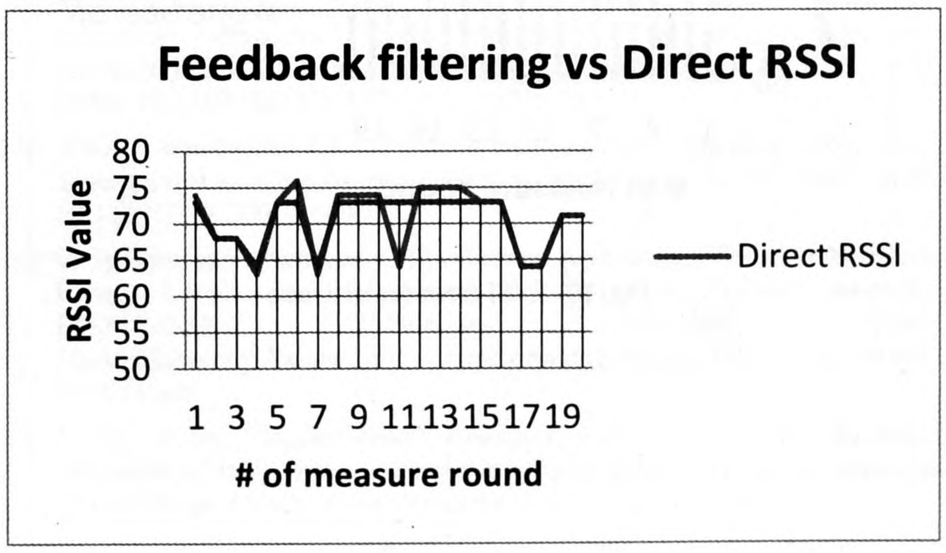

Fig. 8. Feedback filtering vs direct RSSI

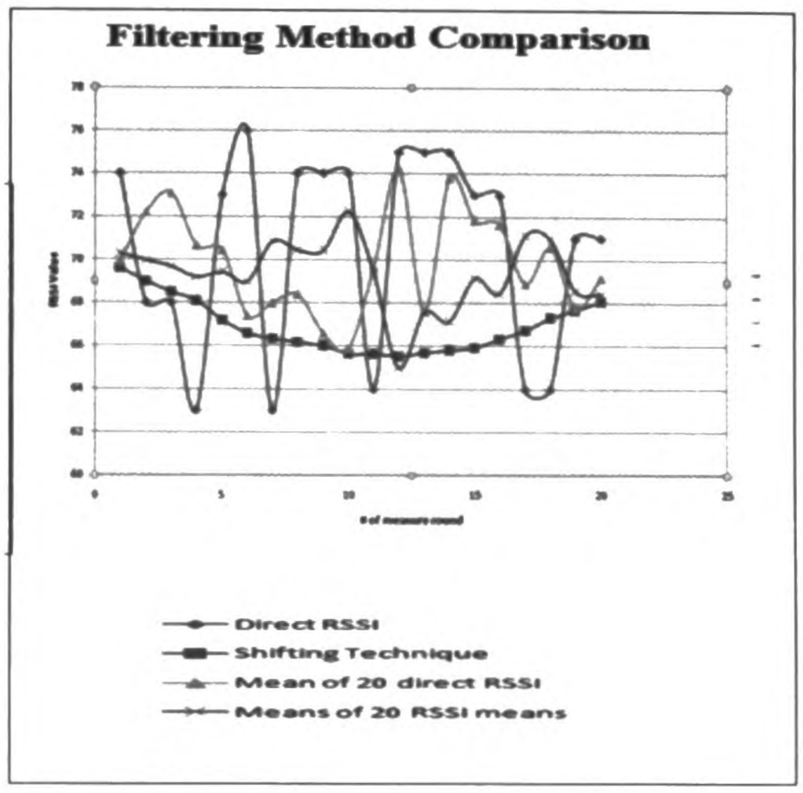

Fig. 9. Comparison of filtering methods

The authors followed three methods to find the static RSSI values.

- Get the RSSI mean value from 20 RSSI values.
- Get the RSSI mean value from 20 RSSI mean values.
- Get the RSSI mean value by shifting RSSI values.

In order to smooth the RSSI value three filtering techniques were tested above mentioned. Fig. 9 presents the experimental comparison of some filtering techniques. It's obvious to the common eye that new shifting technique, smooth and perform the best out of all.

Comparison with distance is tested after choosing the shifting technique.

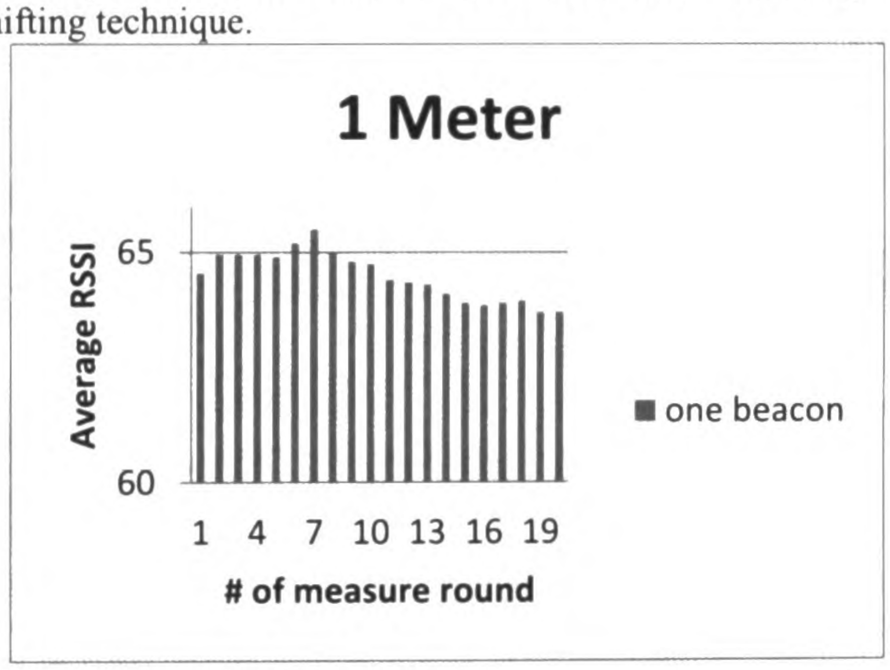

Fig. 10. RSSI from 1m distance

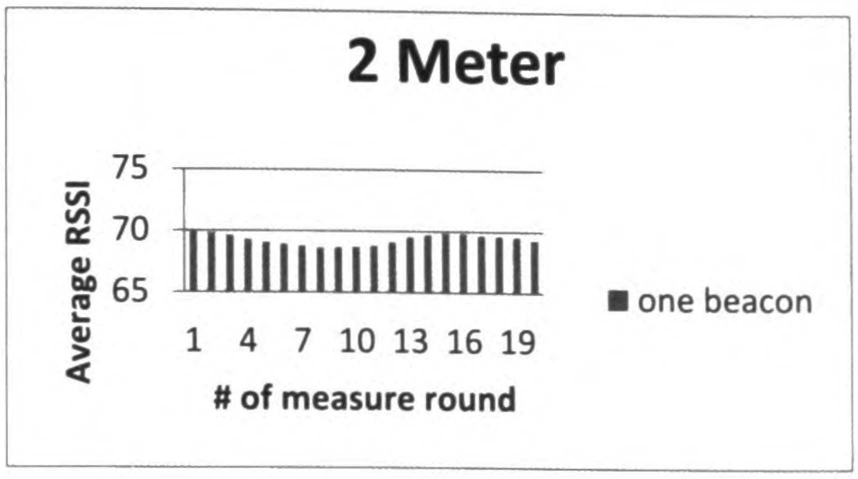

Fig. 11. RSSI from 2m distance

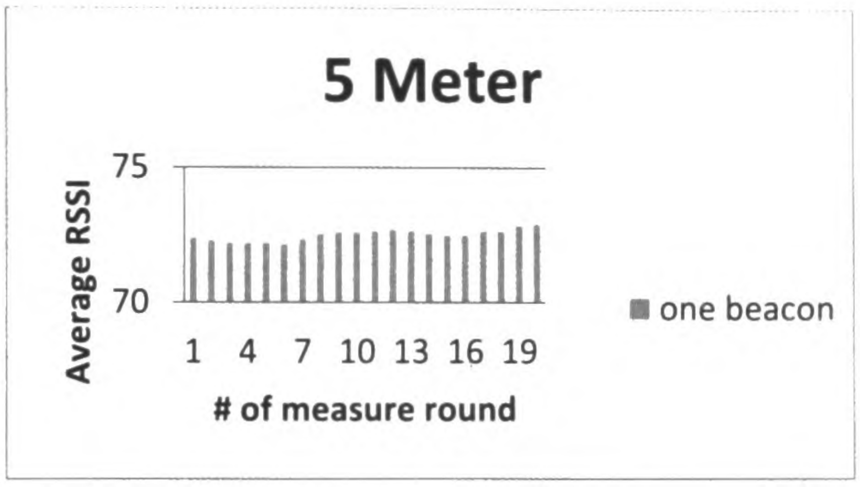

Fig. 12. RSSI from 5m distance

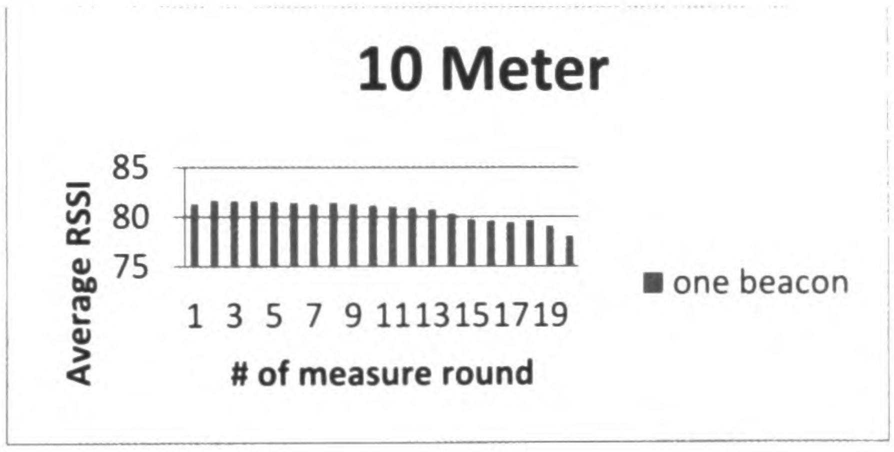

Fig.13. RSSI from 10m distance

Fig. 15 shows before executing shifting technique RSSI values are overlapping with different length. Therefore, it is very hard to define an exact RSSI range to the particular grid. To overcome this shifting algorithm is employed. Fig. 10- 14 shows RSSI value range is split up from one length to another.

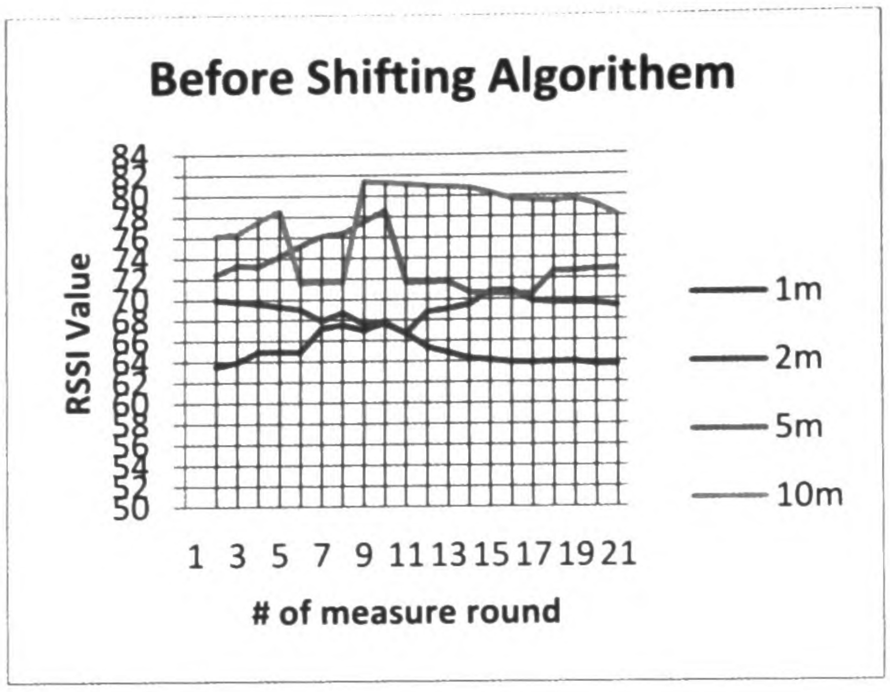

Fig.14. Before shifting algorithm

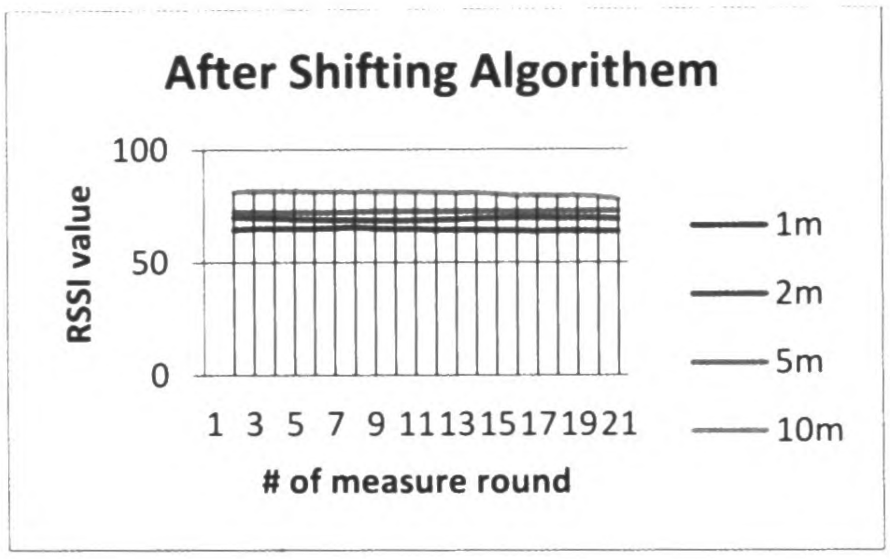

Fig.15: After shifting algorithm

V. CONCLUSION AND FUTURE WORKS

This research work demonstrated that the novel approach to finding indoor localization by omitting errors in existing algorithms.

In this research project, it is clear now that indoor positioning is a difficult task. Topology constraints in indoor environments are much more complex than those in outdoor environments. To conduct this research developed a smartphone application to make measurements of BLE signals as well as implementing ways to improve them. Took series of tests in a numeral of different distances to identify how the signals are impressed, so looked into the possible ways to improve the data as it is not suitable as raw information. In the end, the research work came up with novel technique (shifting) to obtain the static RSSI values to navigate the user accurately. The experimental results point out the proposed mathematical method can reduce the average error, and it is invariably safer than the other existing interference avoidance algorithms. This research can be used for a era of reference for future software developers in the field of indoor location systems and Bluetooth proximity zones that would make use of Smartphones.

In the future work planned to implement Trilateration together with fingerprinting online phase and learning benefits from the role of shifting filter in the measurement stage to minimize the errors.

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