# Performance Analysis of RSSI based Localization in WSNs

**Conference Paper** · July 2020



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# Performance Analysis of RSSI based Localization in WSNs

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***Abstract*—Location information is critical in Wireless Sensor Networks(WSNs) used for the purpose of monitoring. Catastrophe can occur due to system failure and lack of location information of failure point. Many localization approaches are proposed by authors which use different methods of finding the distance between nodes and by manipulating the distances,the nodes' location is estimated.In this paper we have presented analysis of a unique approach based on combination of existing work which uses Received Signal Strength Indicator (RSSI) values for distance estimation with trilateration and centroid positioning systems.The algorithm is coded in C++ programming language and tested using the hardware measurements on IRIS motes.The path loss exponent was calculated to be 2.4. The evaluation of the given localization algorithm is done on the basis of performance with regard to localization error and number of anchor nodes. The simulation results prove that trilateration is a better positioning system than centroid.**

***Index Terms*—RSSI, Trilateration,Centroid, IRIS, TOA ,AOA**

## I. Introduction

The Wireless Sensor Networks have now become very famous because of their various applications in different environments. WSNs are deployed in agriculture, miltary, environmental monitoring, ecology, robotics, factories, weather forecasting, target tracking, and so on [1]. Such a wide range of applications bring many challenges as well. The major challenges that WSNs face are energy consumption, scalablity, security, dynamic topoplogy, data routing and localization [2], [3]. The modern WSNs are bidirectional, also enabling the control of sensor activity [4]. Localization has become a critical challenge in WSN [5]. Node position is important to find the exact place of the events ,sensor queries, routing and network coverage issues. Localization is one of the key player in WSNs [6]. When we are unsure about the position of any object,then the location finding techniques are used which make deployed system more intelligent.A number of submission are put forward to calculate the positions for unsequentially placed sensing elements such as; range-based techniques, with higher accuracy but higher cost as compared to the range-free techniques with lower prcision at low expense [7]. In [8], centralized method is discussed, where single cental processor handles all the calculations and thus uses a lot of power and requires more storage. The decentralized or distributed localization methods are different from centralized where each node independently tries to estimate its position with the help of neighboring nodes [9]. The localization is main feature in sensor networks which in recent times is encouraging the researcher's attention [10]. The numerous features of sensor node localization are predicted to appear in coming time with the additional development in wireless communication. [11]. An improved fingerprinting based localization algorithm is presented in [12], which uses fuzzy path loss models for the calculation of RSSI values.The proposed algorithm is specifically designed for bluetooth application for low power consumption and low processing.In this paper,the given approach takes the effect of the closest anchor nodes for the calculation of blind nodes' location parameters. The distances are measured using RSSI values and positional coordinates are found using trilateration and centroid. The localization error of given work is low and acceptable.A cooperative trilateration based localization is proposed in [13], which is application specific. The trialteration based results are compared with cooperative techniques.The distance is calculated using RSSI values of the nodes, but the results are not that better becuase trilateration is not good for outdooir positioning.In this paper we present a simpler approach than the existing works and applies step wise approach for the calculation of node position. Furthermore, the blind nodes selects three nearest nodes which significantly increases the accuracy of the algorithm and reduces the error. The practical realization of our algorithm algorthim is done using IRIS motes in [14], where of the path loss exponent(PLE) was found 2.4.

The paper is further divided as follows. Section II consist of the related work, section III-IV discuss the brief introduction of localization and distance estimation method. Section V explains position estimation technique. Section VI consist of the proposed system architecture and section VI-VII discuss the implementation and final sections VIII-IX are results and conclusion respectively.

## II. Related Work

Bulk of research is available on localization in WSNs. We present some of the related work done using RSSI ranging methods. An RSSI based trilateration technique is introuduced with minimum generalization error which improves the accuracy and makes the alogrithm efficient but adds the overhead [15].In [16], an RSSI based trilateration is demonstrated using

ISBN-978-969-23372-0-5

Variable Log Normal Shadowing Model (VLNSM) with adaptability in different environments and provides more accurate results. In [17],the distance was measured using RSSI values with TelsoB motes with CC2420 radio within the range of 1m to 8m. The mean error was found to be 2.24m, which was due to absence of calibration. RSSI is popular as compared to other ranging methods for calculating the distance. In [18], it is concluded that the discussed algorithm can estimate the distance with error of 10%, if devices are placed within the range of 1.5 m. In [19], authors identified the major factors that have impact on the performance of the localization system in terms of accuracy. It was concluded that transmission power, frequency of operation, orientation of the node, characteristics of the antenna, the localization algorithm itself and the correctness of the reference measurement are factors that have effects on the distance measurements.

In [20], a trilateration based algorithm was proposed which determines the position of the blind nodes by getting information from at least three beacon nodes, and if the node estimates its position, then it becomes anchor node. In [21], an RSSI based centroid mechanism with some improvement is proposed with self calibration capabilities. In [22], a centroid algorithm is evaluated for composite indoor environments which focuses on the solution for unknown node area. A Kalman filtering algorithm is utilized for the blind node area calculation. The positioning method was proved to the low cost, ease of deployment and is suitable for the catastrophe rescue in the real time scenarios [23].

This proposed work shows the performance analysis based on combination of existing work which uses RSSI values for distance estimation with trilateration and centroid positioning systems. Results are also compared with the current work and proves the given combination as more accurate.

## III. Localization in WSN

Recent advancement in radio and embedded systems have rapidly increased the growth of sensor networks. WSNs are widely being used in various places to carry different survileince jobs such as monitor, rescue, disaster relief and tracking. Node location is necessary to report the happening of the events, help the sensor queries, routing and solving issues related to the network coverage [24]. The localization of node is systematic procedure which includes: finding the distance of the unknown nodes and then utilizing the given distances to estimate the node location, hence the first step is to find the distance. General classification of localization in WSN is given in Fig. 1. It is classified into centralized and decentralized algorithms. Decentralized alogirthms then fall into range-based and range-free distance estimation technique. Various range-based distance estimation methods used are further discussed in below sections.

## IV. Received Signal Strength Indicator (RSSI) based Distance Estimation

The location of the node is predicted by manipulating the distance from the anchor node(a node with known position).

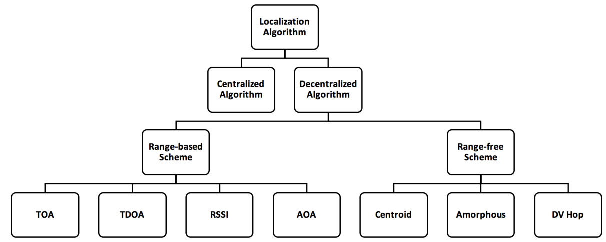


Fig. 1. Classification of Localization Methods

There are a number of techniques available in literature such as RSSI, Time-of-Arrival (TOA),Time-Difference-of-Arrival (TDOA) and Angle-of-Arrival (AOA) which are used to find the distance of an unknown node from the anchor nodes. The accuracy of the distance estimation highly depends on the type of the technique used. In this work, RSSI based distance estimation method is used.

In RSSI strategy a sensor node evaluates its position using received signal strengths. It does not require any extra hardware for the implementation, this makes it cost efficient as well [19].The RSSI has limited capability in open atmosphere with more obstacles in between transmitter and receiver. However, the received power in free space can be calculated using Friis transmission equation, which includes the transmitted power Pt, received power Pr, operating wavelength$\lambda$, gain of transmitting Gt, and distance between the transmitter and receiver d. The received signal strength decreases by the square of the distance indicated as in equation (1)

$$P_r = \frac{P_t G_t \lambda^2}{(4\pi)^2 d^2} \tag{1}$$

## V. Position Estimation

Different position estimation methods are used to calculate the coordinates of the blind nodes. In this paper, we are using trilateration and centroid techniques and comparing them in terms of localization error.

### A. Trilateration

The trilateration requires the distance between the receiving and transmitting devices to be measured. This can be found by utilizing RSSI, ToA, and so on. The position of obscure node is found by three pair wise distances from the obscure node to various reference point nodes.Many iterations can be done between unknown and known nodes to improve the exactness of the localization method [25]. The trilateration takes effect of the three circles and finds the intersecting point of all the circles as depicted in Fig.2. The coordinates of a node are calculated using equations distance equation whereas the unkwnown point is $(x, y)$ and known point is $(xi, yi)$ which are distances $ri$ from unknown points then we can get the given equations (2),(3) and (4).

$$(x - x_1)^2 + (y - y_2)^2 = r_1^2 \tag{2}$$

$$(x - x - 2)^2 + (y - y_2)^2 = r_2^2 \tag{3}$$

$$(x - x_3)^2 + (y - y_3)^2 = r_3^2 \tag{4}$$

expanding these equations (2),(3) and(4) we get;

$$x^2 - 2x_1x + x1^2 + y^2 - 2y_1y + y_1^2 = r_1^2 \tag{5}$$

$$x^2 - 2x_2x + x_2^2 + y^2 - 2y_2y + y_2^2 = r_2^2 \tag{6}$$

$$x^2 - 2x_3x + x3^2 + y^2 - 2y_3y + y_3^2 = r_3^2 \tag{7}$$

Further classifying the above the equations we reach the solution as shown by (8) and (9).

$$A_x + B_y = C \tag{8}$$

$$D_x + E_y = G \tag{9}$$

Finally the coordinates are extracted using (10) and (11).

$$x = (CE - FB)/(EA - BD) \tag{10}$$

$$y = (CD - AF)/(BD - AE) \tag{11}$$

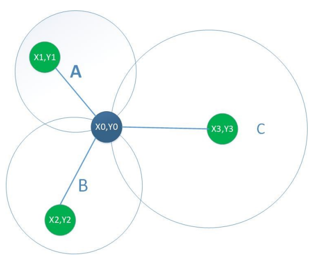


Fig. 2. Node position estimation based on trilateration

### B. Centroid

The centroid algorithm utilizes the coordinates of all the neighboring nodes for the calculation of centroid. This technique is less accurate compared to trilateration.This method becomes more accurate if the number of surrounding nodes is higher. The equation (12) is used to calculate the coordinates of the unknown nodes using centroid method.

$$X = (x1 + x2 + x3 + ...xn)/n, Y = (y1 + y2 + y3 + ...yn)/n \tag{12}$$

## VI. METHODOLOGY

The given algorithms works in 4 phases explained below.

- **Initialize Phase**: Initially any node with unkwnown position tries to catch signal strengths from the surrounding anchor nodes.The blind node must get signal strengths of at least 3 surrounding beacon nodes. The Signal strengths are extracted using the expression shown in(13).

$$RSSI = (-10 * n * log_{10}(d/d_o) + A) \tag{13}$$

  Where n is PLE, A is the reference RSSI at $d_o$ of 1m and d is the distance between transmitter and receiver.
- **Distance Estimation Phase**: after getting RSSI from all the nodes then the distance is evaluated using equation (14).

$$d = 10^{\frac{A-RSSI}{10n}} \tag{14}$$

- **Trilateration & Centroid Algorithm**: The node now performs trilateration and centroid techniques to retrieve the coordinates.
- **Position Estimation Phase**: Finally the mobile nodes' position is estimated showing its X coordinate and Y coordinate.

## VII. IMPLEMENTATION

In our scenario, we have created 50 mobile blind nodes using rand function of the C++, where each node is getting random place in an area of 800x800 $m^2$. And 30 anchor (Nodes with known positions) nodes are created which are increased timely by stepping of 3. Anchor nodes are also placed randomly keeping the practical scenario in mind, because anchor nodes aren't deployed in grid manner in real time. A blind node selects three nearest anchor nodes and tries to estimate the RSSI values and then estimates the distances from all the three nodes.The Fig.3 shows the scenario. Once the distance from all the three nodes are estimated,trilateration in one case and the centroid localization in the other case is applied for position estimation. After calculating the coordinates i.e x and y of the nodes,the localization error is found by taking the Root Mean Square (RMS) of the exact position and the estimated position using the formula in (15).Whereas, $Xest$ and $Yest$ represent the estimated coordinates while $Xc$ and $Yc$ represent the actual coordinates.

$$LocalizationError = L.E = \sqrt{(X_{est} - X_c)^2 - (Y_{est} - Y_c)^2} \tag{15}$$

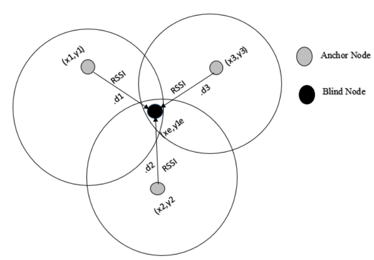


Fig. 3. A blind node surrounded by three anchor nodes

## VIII. RESULTS AND EVALUATION

The randomly generated nodes using programming acquire different locations. Total of 50 blind nodes and 30 anchor nodes are generated. The quantity of anchor nodes is increased by the stepping of 3. Here, we analyze the error by increasing the anchor nodes. The result is obviously reduced error because the population of the anchor nodes is increasing so the blind nodes are being covered easily. In Fig.4, the mean localization error is presented using the trilateration algorithm. The RSSI based localization accuracy depends upon the number of the obstacles in the environment. For an environment with many obstacles between nodes, it is less than 50% accurate. As the distance between the nodes increases the localization error also increases. But the scenario where accuracy is required, a

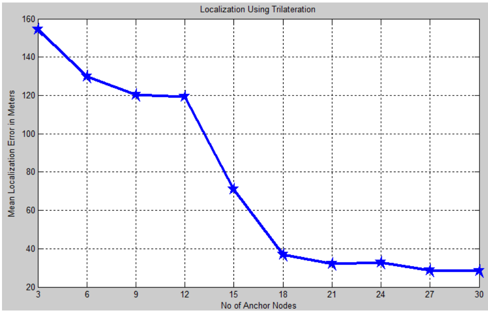


Fig. 4. Mean Localization Error(m) Using Trilateration Algorithm

large number of anchor nodes are deployed such as agricultural fields, forests, factories and army surveillance. From Fig.4, it is evident that increment in quantity on anchors reduces the mean location error. When there are only 3 anchor nodes the localization error is near to 160m. As anchor nodes are increased to 6 the localization error reduces to somewhere in between 140m to 150m. whereas, with 30 nodes, the localization error reaches to 20m. The trilateration is seen performing better than the centroid, because centroid is just an average of the distances calculated. While trilateration performs geometrical calculations to estimate the position. The

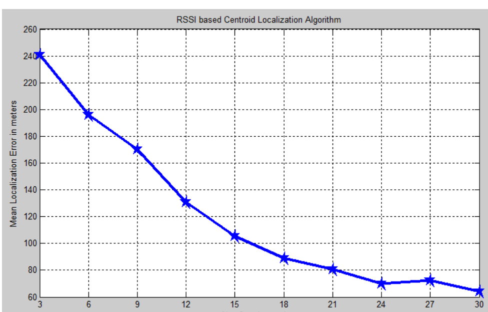


Fig. 5. Mean Localization Error(m) Using Centroid Algorithm

Fig. 5 shows the mean localization error using the centroid algorithm. The centroid is just mean of the distances from three anchor nodes. It can use more than three nodes but in our scenario the nearest three nodes are used. The centroid was seen less accurate as compared to trilateration. In centroid, when number of anchor nodes is 3 the localization error is around 240m, while at 20 anchor nodes the localization error is in 60m which is greater than the trilateration. The comparison of the both the techniques is shown in Fig. 6.

## IX. Conclusion

The RSSI based localization system using trilateration and centroid was implemented. The scenario of 30 anchor nodes and 50 blind nodes with an area of 800x800 $m^2$ was created. We presented the comparison of the increasing the number of anchor nodes and impact on the accuracy. The average localization error reduces when the number of anchor nodes is increased. The trilateration is seen much accurate than the centroid localization. The RSSI is less expensive as compared

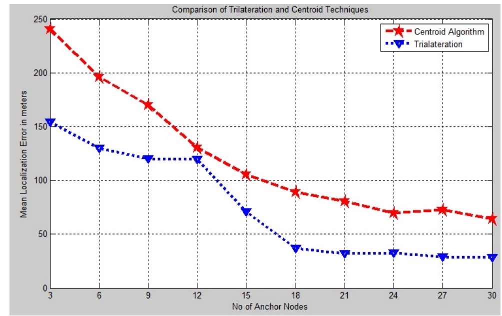


Fig. 6. Comparison Between Trilateration and Centroid methods

to TOA, TDOA and AOA and easily implemented. But it is less accurate and provides accuracy between 60%-70% if used in small coverage areas. When anchor nodes are 3 the localization error is 240 m in case of the centroid and 160m in case of the trilateration. When the anchor nodes are increased to 30, the localization error for centroid is 60m while the localization error in trilateration is in 20m.The methods can further be evaluated by using RSSI profiling methods and calibrating the values.

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