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BDALT: Bilateration and Double Anchor-based Localization Technique for Wireless Sensor Networks using Angle of Arrival (AoA) and Received Signal Strength (RSS) -A Hybrid Technique

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Abstract: ***Anchor based localization techniques are better and cost free alternate solutions against GPS based localization techniques in Wireless Sensor Networks (WSN) applications. Anchor based localization techniques using Zigbee technology in WSN have attracted highly in the recent years. As the technology is growing, customers can easily buy the Zigbee technology based beacon nodes at reasonable price. Anchor based wireless sensor networks are used in the localization process because of their advantages in location tracking applications. Many localization systems depend only on RSS and that is not highly reliable, and not accurate. However, the accuracy and the reliability of the network is rather important when it is used in wireless environments. In this paper, a hybrid technique is proposed, which uses not only the RSS as distance estimation parameter, but also the AoA as another angular estimation parameter to improve the localization accuracy. The proposed localization technique uses both the dynamic vectors based localization method, and the bilateration based localization methods to get the target node's coordinates with good accuracy. The main objective of this research work is to get the accurate location information of the target nodes by using double anchor nodes and simple mathematical computations. The proposed method is simulated in MATLAB and its performance is better than the existing localization techniques.***

Keywords: AoA, GPS, RSS, RSSI, WSN, Zigbee.

I. INTRODUCTION

Target tracking, search and rescue, cooperative monitoring of an area, defense, patient monitoring and many more are applications of the WSN [1]. All the applications use sensor nodes in the data collection, If the locations of the sensor nodes (where the data was collected) are available, the data collected by the sensor nodes are useful [2]. The information about the location of the sensor nodes not only useful for security and safety, but also to improve the work efficiency in applications of wireless sensor networks. In general, there are two types of sensor nodes available in the wireless sensor networks: anchor nodes, they know their location information a prior (manually configured or uses GPS's services on the devices), and target nodes, they do not know their location (to be estimated or determined) [3]. A big problem in navigation, object tracking, communication and IoT applications, is the estimation of the location of the target nodes [4]. Many localization models have been developed for the location estimation of the target nodes, but they provide relative information instead of the desired level of information.

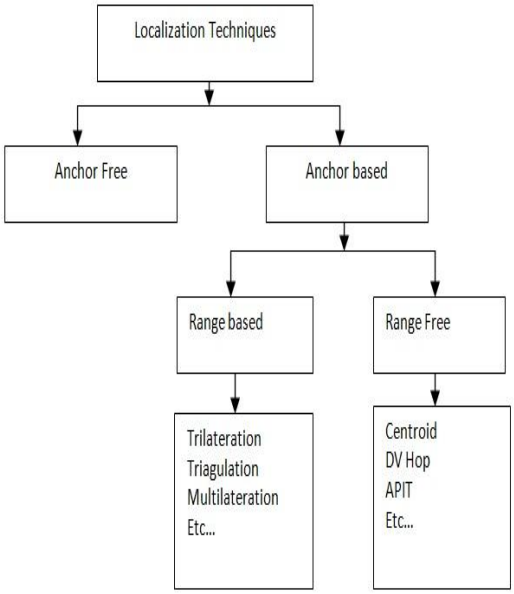

Fig.1.Classification of Localization Techniques

There are two classifications of localization algorithms available for the location estimation in WSN shown in the Fig.1, which are range-free and range-based localization algorithms [5].

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Received Singal Strength (RSS), Angle of Arrival (AoA), Time of Arrival (ToA), and Time Difference of Arrival (TDoA) are the range based distance measures, and which are used in the range based localization algorithms [6]. Hop count, Proximity, and Known locations are the range free distance measures, and are used in the range free localization techniques [7]. The proposed localization algorithm is a range based localization algorithm, which uses RSS and AoA information for localizing the target nodes. Angle of Arrival is not only used to measure the distance between the nodes, but also used to draw the adjacent vectors for the received signal strength. To get the AoA of received signal strength of the target node, an additional hardware is required on anchor nodes. The additional hardware can be an array of antennas or an electromagnetic compass. Received Signal Strength(RSS) is a simple and easy distance measure technique, that does not need additional hardware for collecting the RSS [8]. Trilateration, Multilateration, and Triangulation, Triangular Areas Segmentation based Localization (TASLT) techniques are some of the range based localization techniques, whereas Centroid, DV Hop, Approximation Point in Triangle (APIT), and Amorphus techniques are range free localization

$$P_d = P_0 - 10\times n\times \log_{10}(f) - 10\times n\times \log_{10}(d) + 27.56 \qquad (1)$$

techniques [9]. The Zigbee technology available for the wireless communication is selected based on various factors such as cheaper in cost, long range communication, public availability, popularity and use in the localization applications [10]. Zigbee is the most popular wireless technology and consumes low battery, have long range communication capacity, and often used in localization applications [11]. There are very less number of wireless devices in the real environment use Zigbee technology and that could not access the transmitting information and the medium in the sensor network application field, which could not produce more noise that would improve the performance of the localization system. The Zigbee communication protocol is used in the proposed work to connect the anchor nodes and the target nodes, even if they are within the range of 100 meters. This paper discusses the simulation of the proposed work, experimental results, the comparison of the accuracy, and the number of anchor nodes used in the models of Trilateration, Multilateration, Trinaglulation, Single Anchor based Localization Techniques (like TASLT). Double anchor based localization using AoA and RSS and Bilateration technique (RSS based) have been merged to improve the accuracy of the target nodes.

The remaining sections are organized as follows, the literature is described in Section-2, The proposed localization technique is explained in Section-3, The simulation work and results are presented in Section-4, and The conclusion and future work are discussed in Section-5.

II. LITERATURE

A lot of research work is being carried out by the researchers to improve the accuracy of the localization techniques. All the localization algorithms have advantages as well as disadvantage. Localization techniques use ranging information or range free information in many applications [12]. This research works uses only ranging information (RSSI and AoA ranging information). RSS and AoA can be called as range based distance measures [13]. The following sections discuss the RSS, the AoA techniques, and the existing localization techniques which are similar to the proposed model. From the literature, the existing localization techniques such as the trilateration, multilateration, triangulation and single anchor node based localization are taken into consideration so as to compare its performance.

A. Received Signal Strength (RSS)

RSS is one of the distance measures in the range based localization techniques. The primary ranging information is the received signal strength (RSS) and can be produced without installing an additional hardware on every anchor node [14]. RSS information can be used to estimate the distance between two nodes. The distance between two nodes is inversely proportional to the received signal strength [15]. The RSS consumes very low energy and is influenced by the environmental factors [16]. Many of the research works have been conducted based on the RSS information because of its advantages and simplicity. The RSS will be converted into distance by using the Received Signal Strength Indicator (RSSI) Pathloss model is given in "(1)"[17].

Where: 'P_d(in dBm)' is the signal power at the distance 'd', 'P_0(in dBm)'
is the signal power at zero distance between sender and receiver, and 'f' is the signal frequency (2-GHZ) and 'd' is the distance (meters) between the sender (transmitter) and the receiver, 'n' is the path-loss constant (free space n=2) and the fading effect in 'IEEE 802.15.4 network's value is 27.56.

B. Angle of Arrival (AoA)

AoA is a distance measure in the range based localization techniques, but in this work the AoA is used to identify the adjacent vectors for the direction of received signal of the target node [18]. The AoA is the incident angle of the received signal at the receiver, and is transmitted by the transmitter (target node) [19]. The AoA values are noted down at the anchor node by using an exclusive hardware device (Electro magnetic Compass or Array of Antennas). Technically, In AoA based localization systems, anchor nodes are equipped with special or exclusive hardware to capture the angle of arrival of the received signal [20]. The accuracy of the AoA measurement is higher than the RSS distance measure [21].

C. Communication Protocol

Zigbee is a communication protocol and is very simple in its nature, and consumes less battery power, and secure networking features [22]. Zigbee is the IEEE 802.15.4 based technology and is used in Wireless personal area networks for less battery consumption [23]. Zigbee has good ranging capacity than other techniques and can provide its services from 0 to 260 meters between the sender and the receiver [24]. Mostly, Zigbee is used in WSN due to its low power consumption feature [25].

D. Range based Localization Techniques

Relevant existing localization techniques are discussed to identify the best localization techniques. The relevance of the research work has been identified based on the area covered by the anchor nodes. There are no similar research works are existed, according to the concerned parameters, and the processing techniques. The following algorithms are considered to compare the performance of the proposed localization technique.

1) Trilateration

Trilateration is a geometric technique and that can determine the location of the target node with the help of the locations of the three anchors/beacon nodes, and the distances from the reference nodes to the target node [26]. To perform the trilateration, the location information of the three anchor nodes/beacon nodes, target nodes and their distances from the anchor nodes are required [27]. The positions of the anchor nodes should not be in a straight line and the target nodes lie in the triangular area and is formed by the anchor nodes. The target nodes receive the signals from the anchor nodes and which can be converted into distances by using the path-loss distance model [28].

2) Multilateration

Multilateration is an advanced technique than the trilateration and which uses more than three anchor nodes [29]. All the anchor nodes should not be placed in a straight line. The RSS based distances, and the locations of the anchor nodes are used to estimate the target nodes location information [30].

3) Tringulation

Triangulation is a location estimation technique using angular information and three anchor nodes [31]. Usually in WSN, this technique uses three non-collinear anchor nodes to send/receive signals to the node (target node) which resides inside the triangular area formed by the anchor nodes. The receiving signals at the anchor nodes incident with certain angles can be measured by an array of antennas or an electro-magnetic compass [32]. The collected angular information can be used to calculate the distances between the target node and the anchor nodes. Once, the distances are calculated then the location of the target nodes can be estimated by making use of the straight line equations of the distances and the location coordinates of the target nodes.

4) Triangular Area Segmentation based Localization Technique (TASLT)

It is a range based localization technique which uses single anchor for localizing the target nodes [33]. In this method, RSS and AoA ranging information could be used to perform the localization technique, and also uses static vector segment's information. The localization accuracy of the TASLT model is poor. The values of the estimated target node have more error, if the target nodes are too far from the anchor node. The procedure involved in the localization technique uses the lookup table information to get the static vector's segment information, RSS to calculate distances, and AoA for new angles estimation. The search time on the lookup table takes more time and requires huge memory space to store lookup table's data at the anchor node.

5) Double Anchor-based Localization Technique for Wireless Sensor Networks using RSS and AoA Measures (DALT)

Range based Double Anchor-based Localization Technique (DALT) is given in [34]. This DALT technique does not use a lookup table in the localization process. The location estimation could be performed using dynamic linear vector segments and RSS, AoA distance measures to improve the accuracy. Dynamic linear vectors can be formed by adding angular error to the AoA of the target nodes. The accuracy of the DALT technique is good, but the estimated coordinates are calculated based on the vector segments only.

The proposed work can be used to localize the target nodes, which will move into the triangular area covered by the anchor nodes. The triangulation, trilateration, multilateration and TASLT, DALT can be performed in the similar triangular area. Three anchor nodes can be used by the triangulation technique in the location estimation process which leads to more installation cost. Proper coordination is to be required between the anchor nodes to perform the triangulation. The AoA distance measure is used by the Triangulation technique to perform the localization. The angular error in the AoA cannot be addressed in the triangulation technique. Three anchor nodes are used by the trilateration technique to perform the location estimation. The use of three anchor nodes in the location estimation process increases the installation cost of the model. The RSS based distance measures can be used by the trilatearation and the distance measures can be influenced by the noise, and which leads to inaccuracy in distance estimation. The inaccurate distance measures can give inaccurate location information in the localization process. More than 3 anchor nodes can be used in the mutlilateration localization technique and which also increases the installation cost of the model. The multilateration uses RSS based distances like trilateration, to estimate the target node's location information. If the number of anchor nodes increases, the impact of the noise is added to the RSS. The added noise in RSS can give inaccurate distances. Only the RSS based distance measure alone cannot give good results in the location estimation process. Triangular area segmentation based localization technique (TASLT) for tracking the nodes in a triangular area, and it reduces installation cost. The accuracy of the TASLT method is not good. Static vector segment information (from a lookup table) can be used by the TASLT method to estimate the target node's location. The use of a lookup table on every sensor node needs more memory, and during the location estimation process the search operation in the lookup table consumes more time. Static vector segment information and RSS based distances can be used in the TASLT method which leads to inaccurate results in the estimated coordinates of the target nodes. Double Anchor-based Localization Technique (DALT) does not use a lookup table to create linear vectors, but it uses angular error information along with the AoA of target nodes. The accuracy of the DALT depends only on the dynamic linear vectors and RSS information, but based on the performance results. Still the accuracy of the estimated nodes is to be improved in BDALT.

Generally, the accuracy of a model can be improved by adding another model to it. To overcome the challenges existed in the existing localization techniques, Bilateration model is added with the Double Anchor- Dynamic Linear Vectors based Localization technique. The BDALT have been proposed in this paper, and which improves the accuracy of the estimated coordinates of the target nodes.

III. PROPOSED LOCALIZATION TECHNIQUE

In recent years, many localization techniques are designed and developed to provide good localization accuracy. A good localization technique always ideal in many environmental conditions and can estimate the target node's location information accurately. This proposed method is developed based on the ranging information such as received signal strength and angle of arrival and two assisting anchor nodes in a triangular area. RSS and AoA measures are used by this method to improve the location accuracy of the estimated nodes. The use of two anchor nodes and dynamic linear vectors to perform the localization for the triangular area (the same area can be used in the existing localization) can increase the accuracy and robustness of the model. The proposed research work has been carried out by placing two anchor nodes diagonally on the corners of a right triangle, and dynamic linear vector segments. There are three phases in the proposed localization technique, which are: (1) Data collection (2) Formation of Dynamic Vectors, and (3) Target Node Location Estimation.

A. Network Architecture

The deployment of two anchor nodes in a triangular area, and localization procedure are explained in this section. The parameters are used for the simulation are given in the Table-I. The parameters mentioned in the Table-I are more suitable for the implementation of the proposed localization technique. The parameter's suitability can be identified based on the hardware and communication protocol used in the proposed model.

The block diagram of the proposed model as shown in Fig.2.

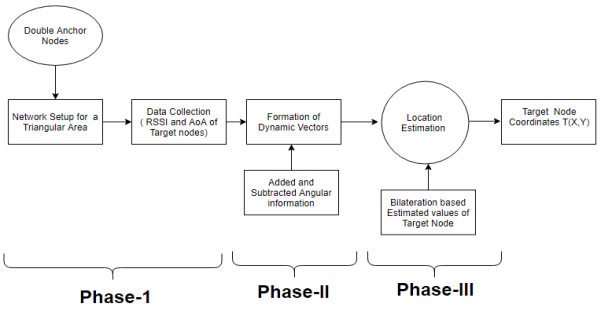


Fig.2. Block diagram for the proposed Localization Technique (A three phase approach)

Table-I. Parameters for the simulation of the proposed work network setup

SL NO	SIMULATION PARAMETERS	VALUE/ STATUS
1	Network Area	½*70*70m=2450 square meters
2	Anchor Nodes Deployment	Manual and strategic (Right angle Triangle)
3	Environment	Outdoor /Indoor
4	Distance measures	RSSI and AoA
5	No.of Anchor Nodes	2
6	Communication range between Anchors	Max 100 meters
7	The antenna used on Anchors	Directional
8	Antennas used on Targets	Omni Directional
9	Special H/W on Antenna (Anchors)	Electromagnetic Compass/ Array of Antennas
10	Channel (on Anchors)	Dual (Anchor to anchor and anchor to Target)
11	Channel (on Target)	Single (Target to Anchor)
12	No. of Targets	7 (Seven in the triangular area)
13	Communication Protocol	Zigbee (IEEE 802.15.4)

The anchor nodes 'A_1' and 'A_2' are placed at the corners of the right angle triangle as shown in the Figure 3. The anchor nodes are static nodes and have their location information a prior (Configured manually or with the help of GPS). The distance (hypotenuse of the triangle) between the anchor nodes 'A_1' and 'A_2' is to be 98.99 meters. Every anchor node is to be equipped with Zigbee protocol supported antennas which have communication range 100 meters. The anchor nodes installed with directional antennas (the coverage's angle is 45° degrees) are to be faced towards each other. The triangular area ½*70*70m (2450 square meters) is covered by the anchor nodes for the experimentation. Omni directional antennas are to be installed on the unknown nodes or the target nodes. Assume that the target nodes are being moved in the triangular area. In the given Fig.3, The horizontal line is 'A_1C' and also considered as a reference line to calculate AoA with respect to anchor node 'A_1'. 'A_2C' is a vertical reference line to calculate AoA calculation with respect to anchor node 'A_2'. The lengths of the horizontal, and vertical reference lines is '70m' meters. The target nodes don't have their location information and are mobile in nature. In the Fig.3, the target node '$U(X_e,Y_e)$' is represented in the triangle area, and few more target nodes are also given (These nodes are to be estimated in the localization process).

B. THREE PHASE APPROACH

There are three phases in the proposed approach; namely 1) Data Collection, 2) Formation of Dynamic Vectors, and 3) Target Node Location Estimation.

1) First Phase (Data Collection)

Once the network setup is completed, the data collection phase is to be executed. RSS and AoA ranging data are required to implement the proposed localization technique.

Here, RSS and AoA data collection process is explained initially. Every anchor collects the RSS of the target node to estimate the distance between the target node and the anchor node. The distance can be calculated using the RSSI path loss model is given in "(1)". The RSSI model takes RSS data as input and convert it into the distance in meters.

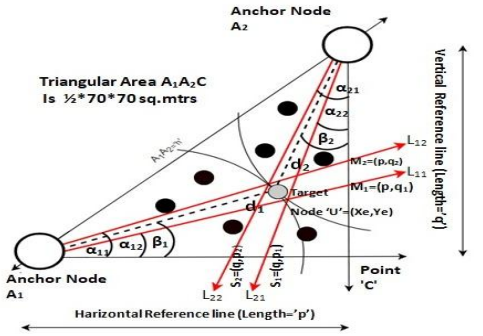


Fig.3. Proposed Localization technique-network diagram

In the Fig.3, 'A_1U' is the distance (d_1) between the anchor node 'A_1' and the target node 'U', and 'A_2U' is the distance (d_2) between anchor node 'A_2' and the target node 'U'. Every anchor node collects the AoA of the target node's signal. To collect the AoA, every anchor node must be equipped with special hardware such as electromagnetic compass or an array of antennas.

In the simulation, the angle between the two vector formula is used for collecting the angular information. From the target node 'U', two vector lines are to be drawn from anchor nodes 'A_1' and 'A_2' to form $A_1U$and A_2U. The vector 'A_1U' makes an angle 'β_1' with the horizontal reference line 'A_1C' (Vector 'A_1C'). Similarly, the vector A_2U makes an angle 'β_2'with the vertical reference line BC. The collected distances d_1 and d_2, as well as the angle 'β_1'and 'β_2 are used in the localization process. The collected angular data can be used to form dynamic vectors such as L_{11}, L_{12}, L_{21}, and L_{22}. The formation of dynamic vectors is explained in the second phase.

2) Second Phase (Formation of Dynamic Vectors)

Usually, the minimum of AoA error (Δ) is '1' degree in many localization techniques. Inclusion and exclusion of error in AoA (Δ) from the incident angle at anchor nodes can be used to form two more new angles. The new angles can be used to draw dynamic vectors. The data points on the vector segments are calculated with the help of the reference lines, and the angular information as shown in "(2) to (4)". In the given Fig.3, the target node's incident angle at the anchor node 'A_1' is 'β_1'. If the angular error (i.e., Δ = 1 degree) is subtracted from the angle 'β_1' to form the angle 'α_{11}' and also added to form one more angle 'α_{12}'. Similarly, the angles 'α_{21}', and 'α_{22}' are formed by subtracting and adding the angular error from 'β_2'.

The angles α_{11} and α_{12} can be derived by using the incident angle 'β_1' and the error in angle of arrival '$\Delta=1^o$'. The derivation of the angles at anchor node can be expressed in "(2)".

$$\tan(\alpha_{1j})_{foranchor'A_1'} = \left[\frac{q_j}{p}\right], \qquad (2)$$

$$where \quad \alpha_{1j} \in \begin{cases} \alpha_{1j} = (\beta_1 - \Delta) \\ \alpha_{1j} = (\beta_1 + \Delta) \end{cases}, j=1,2, \Delta=1^0, Q_1 \in [0,45^0]$$

At the anchor node 'A_1', the anchor node's coordinates (X_1, Y_1), and $[p, q_j=p*tan(\alpha_{1j})]$ are used to get the vector segment points on the vertical reference 'q' in Fig.3. The derived vector segment points are $M_1= (p,q_1)$ for vector L_{11} and $M_2= (p, q_2)$ *for vector* L_{12} shown in "(3)".

$$Vectorpo\,int's_{for\_anchor'A_1'} \begin{cases} q_1 = p*\tan(\alpha_{11}) & q_1 \in L_{1,1} \\ q_2 = p*\tan(\alpha_{12}) & q_2 \in L_{1,2} \end{cases} \qquad (3)$$

The angles α_{21} *and* α_{22} can be derived by using the incident angle 'β_2', and the error in angle of arrival '$\Delta=1^o$'. The derivation of the angles at anchor node can be expressed in "(4)".

$$\tan(\alpha_{2j})_{for\_anchor'A_2'} = \left[\frac{p_j}{q}\right] \qquad (4)$$

$$where \quad \alpha_{2j} \in \begin{cases} \alpha_{2j} = (\beta_2 - \Delta) \\ \alpha_{2j} = (\beta_2 + \Delta) \end{cases}, j=1,2, \Delta=1^0, Q_1 \in [0,45^0]$$

At the anchor node 'A_2', the anchor node's coordinates (X_2, Y_2), and $[q, p_j=q*tan(\alpha_{2j})]$ are used to get the points of vector segments on the horizontal reference 'p' in Fig.3. The calculated vector segment points are; $S_1= (q, p_1)$ *for vector* L_{21} and $S_2= (q, p_2)$ *for vector* L_{22} shown in "(5)".

$$Vectorpo\,int's_{for\_anchor'A_2'} \begin{cases} p_1 = q*\tan(\alpha_{21}) & p_1 \in L_{2,1} \\ p_2 = q*\tan(\alpha_{22}) & p_2 \in L_{2,1} \end{cases} \qquad (5)$$

3) Third Phase (Target Node's Location Estimation)

In this phase, there are three sub stages which are used to estimate the location of the target node. The first stage is to estimate the target node's location using dynamic linear vector segments, the second stage is to estimate the target node's location using bilateration, and the third stage is to refine the location of the target node by averaging the outputs of the first and second stages.

Stage-1: Dynamic Linear Vectors based Location Estimation (DLVLE)

Once the data collection and formation of the dynamic vectors is completed, the stage-1 is to be performed. At this stage, the target node's location is estimated by using the dynamic linear vector segments, and the distance between the anchor and target nodes. The given algorithm's the steps from 1 to 4 explains the location estimation process using dynamic vectors. The distance between anchor nodes and target node, and the dynamic vectors are used together, to estimate the target node location information. The distances are d_1, d_2, and the dynamic vectors are L_{11}, L_{12}, L_{21}, and L_{22}. The following equations "(6)" to "(17)" are used together in the location estimation process to estimate the target node 'U' values. The given equations are derived based on the available information. In this stage, the proposed method uses distance measures and dynamic vector's information, and also perform some calculations in the location estimation process. The step-2 of the given algorithm uses "(6)" to "(12)" with respect to vector L_{11}. In this section, the equations with respect to vector L_{11} only be explained, and the same procedure will be used for the remaining vectors to get the target node location values.

1. Let the coordinates of the Anchor node 'A_1' are (X_1, Y_1), and the coordinates of the Target node 'U' are (X_t, Y_t), and 'd_1' is the distance between the anchor node 'A_1' and the target node 'U'. The Euclidian distance of the 'd_1' is calculated by using the following "(6)".

$$d_a^2 = (x_i - x_t)^2 + (y_i - y_t)^2 \tag{6}$$

2. Every target node can communicate with the anchor nodes if they lie in the triangular region. The target node 'U' can communicate with anchor node 'A_1'. In this case, the received signal strength of the target node can be used to estimate the distance 'd_1' by using the RSSI path loss model. The following "(7)" can be derived based on the RSSI path-loss model and the distance 'd_a'.

$$d_1 = 10^{\left(\frac{P_0 - P_d - 10*n*\log_{10}(f) + 27.56}{10\times\eta}\right)} \tag{7}$$

Where, At the distance 'd_a'(the distance between the sender and the receiver) the signal power 'P_d' and, 'P_0' is the signal power at '1' meter distance between the sender and the receiver's antennas. The signal frequency 'f' is in MHZ (2400MHZ), The path-loss constant (n=2 in free space), and Fading effect in the IEEE 802.15.4 networks is 27.56.

3. The vector segment endpoints A_1 (X_1, Y_1) and M_1 (p, q_1) = [p, q_1= (p*tan (α_{12})] are used to calculate the slope of the vector L_{11} with the help of the following "(8)".

$$m_1 = \left[\frac{p*\tan(\alpha_{12}) - y_1}{p - x_1}\right] \tag{8}$$

Here, α_{12} is the angle between the vector L_{11} and the reference vector 'A_1C', 'P' is the length of the reference 'A_1C'.

4. The liner vector L_{11} (i.e, A_1M_1) equation can be represented as shown in the following "(9)".

$$(y - y_1) = m_1(x - x_1) \tag{9}$$

5. Assume the partial target node coordinates as '$U_{L_{11}}$ = (X_{e1}, Y_{e1})' with respect to the anchor node 'A_1' and the Vector 'L_{11}'. Consider "(6)" to "(9)" and perform substitutions to get the target node '$U_{L_{11}}$' values. [34] The following equations are used to represent the coordinates of the target node '$U_{L_{11}}$.'

$$U_{L_{11}}(x, y) = (x_{e1}, y_{e1}) \tag{10}$$

$$x_{e1} = x1 \pm \sqrt{\left[\frac{d_1^{\,2}}{1 + m_1^2}\right]} \tag{11}$$

$$y_{e1} = \left[\frac{p*\tan(\alpha_{12}) - y_1}{p - x_1}\right]\left[\left(x_1 \pm \sqrt{\left[\frac{d_1^{\,2}}{1 + m_1^2}\right]}\right) - x_1\right] + y_1 \tag{12}$$

At the anchor node 'A_1', the vectors L_{11} and L_{12} give the partial coordinates (X_{e1}, Y_{e1}) of the target node and are expressed in "(10)". The average of the partial coordinates gives the target node 'U_1' values and is given in "(14)". Similarly, at the anchor node 'A_2', the target node coordinates are also estimated. The average of the partial coordinates of the target nodes at the anchor node 'A_2' gives the target node 'U_2' values and is given in "(16)".

$$Target\ \ U_1(x, y)_{\ at\ \ Anchor'A_1'} = avg\begin{cases} U_{L_{11}} = (x_{e1}, y_{e1}) \in L_{11} \\ U_{L_{12}} = (x_{e2}, y_{e2}) \in L_{12} \end{cases} \tag{13}$$

$$U_1(x, y) = \left[\sum_{i=1, j=1}^{j=2}\left(\frac{U_{L_{ij}}(x)}{2}\right), \sum_{i=1, j=1}^{j=2}\left(\frac{U_{L_{ij}}(y)}{2}\right)\right] \tag{14}$$

$$Target\ \ U_2(x, y)_{\ at\ \ Anchor'A_2'} = avg\begin{cases} U_{L_{21}} = (x_{e3}, y_{e3}) \in L_{21} \\ U_{L_{22}} = (x_{e4}, y_{e4}) \in L_{22} \end{cases} \tag{15}$$

$$U_2(x, y) = \left[\sum_{i=2, j=1}^{j=2}\left(\frac{U_{L_{ij}}(x)}{2}\right), \sum_{i=1, j=1}^{j=2}\left(\frac{U_{L_{ij}}(y)}{2}\right)\right] \tag{16}$$

At the anchor node 'A_1' and 'A_2', the target node values have been calculated as U_1, and U_2 respectively. The calculated target node coordinates (U_1, U_2) are used to estimate the final coordinates of the target node Uv (Assume that the target node final coordinates 'Uv'). The target node 'Uv' values can be computed by averaging the U_1, U_2 values, and is expressed in "(17)".

$$U_v(x, y) = \left[\left(\frac{U_1(x) + U_2(x)}{2}\right), \left(\frac{U_1(y) + U_2(y)}{2}\right)\right] \tag{17}$$

Stage-2: Bi-Lateration based location estimation (BLE)

Once, the locations of the two anchor nodes, the distance between the anchor nodes, and the distances of target node from the anchor A_1 and the anchor A_2 are available, the bilateration (Given in the Fig.4) technique can easily be performed in order to get the coordinates of the target node (Assume that the target node coordinates 'U_b= (X_{eb}, Y_{eb})' estimated using bilateration). The following "(18)" and "(19)" are used to perform the bilateration technique for the estimation of the target node 'U_b (X_{eb}, Y_{eb}) values by using the distances, 'h', 'r_1' and 'r_2'[35].

$$x_{eb} = \left(\frac{x_2 + x_1}{2}\right) + \frac{(x_2 - x_1)(d_1^2 - d_2^2)}{2h^2} \pm \frac{(y_2 - y_1)}{2h^2}\sqrt{\left((d_2 + d_1)^2 - h^2\right)\left(h^2 - (d_2 - d_1)^2\right)} \tag{18}$$

$$y_{eb} = \left(\frac{y_2 + y_1}{2}\right) + \frac{(y_2 - y_1)(d_1^2 - d_2^2)}{2h^2} \mp \frac{(x_2 - x_1)}{2h^2}\sqrt{\left((d_2 + d_1)^2 - h^2\right)\left(h^2 - (d_2 - d_1)^2\right)} \tag{19}$$

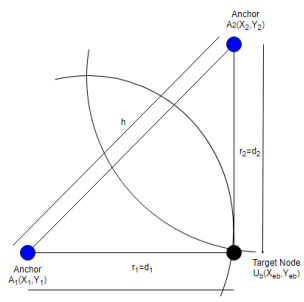


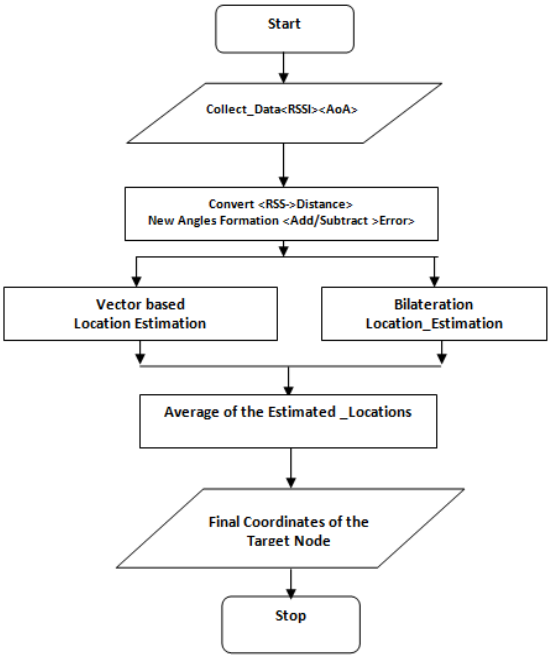
Fig.4. BilaterationTechnique

Stage-3: Final location of the Target node (Average method)

At this stage, the final values of the target node 'U' can be derived by averaging the outputs of the stage-1 and stage-2 [The output of the stage-1is $U_v(X, Y)$, and The output of the stage-2 is $U_b(X, Y)$].

$$U(x_e, y_e) = \left[\left(\frac{U_v(x)+U_b(x)}{2}\right), \left(\frac{U_v(y)+U_b(y)}{2}\right)\right] \quad (20)$$

The steps involved in the proposed localization technique are illustrated in the below flow chart-1.



Flow chart.1: The proposed Localization Technique

The steps involved in the proposed model are explained below and the associated algorithm is given algorithm-1.

Algorithm-1: Explains the steps involved in the Proposed Technique

Algorithm $(d_1, d_2, \alpha, R, \beta_1, \beta_2, \alpha_{11}, a_{12}, a_{21}, a_{22}, X_{e1}, Y_{e1}, X_{e2}, Y_{e2}, X_{e3}, Y_{e3}, X_{e4}, Y_{e4}, h, r_1, r_2, X_{eb}, Y_{eb})$

{

Input: *'N' is the number of sensor nodes, R=100 meters (the transmission range of every node)*
Output: (X_e, Y_e): *Target node estimated position.*

1. ***Initialize*** *'k=2', 'k' is numbers of anchor nodes in the sensor field and 'N' is the number of target nodes*

   //Network setup
   Place Anchor_Nodes A_i, and A_j, in a right angle triangle format, & the extremes of the hypotenuse should be in the communication range of anchor nodes.

2. ***for*** *each Anchor_Node' k' i.e., {A_i, and A_j}* ***do***

   //Angle and Distance Measurements

   If *(The target nodes are within the transmission range of A_i)* ***then for*** *Anchor_A_i* ***do***

   Retrieve distance (d_i) between Anchor_A_i, & the target node 'U' using RSSI.

   Retrieve the incident angle (α_i) of the target node at Anchor_A_i

   // Formation of Dynamic Vector Segments

   Consider incident angle 'α_i' at the anchor 'A_i'

   $$\alpha_{i,j} = (\beta_i + \Delta) \quad and \quad \alpha_{i,j+1} = (\beta_i - \Delta)$$

   $$where \quad \Delta = 1^0 (error\_in\_AoA), i = 1, j = 1, 2.$$

   Use $a_{i,j}$, $a_{i,j+1}$ angles and trigonometry principles to draw vector segments, and also identify linear vector segment points on the horizontal and vertical reference lines.

   //Position Estimation using Dynamic Vector Segments

   Estimate the target node 'U' partial position using vectors L_{ij} and L_{ij+1} with respect every anchor node using "(10)".

   Find (X_{e1}, Y_{e1}) by averaging the partial position of target node 'U_{L11}' values.
   end
   end

3. ***Repeat*** *the steps* ***2 and 3*** *w.r. t Anchor A_j then, get* (X_{e2}, Y_{e2}) *values by using d_j and 'β_j'.*
4. *Find the target node coordinate values (w.r.t every anchor node {A_i, and A_j}) .*
   i.e., (X_{e12}, Y_{e12}) by averaging the (X_{e1}, Y_{e1}) and (X_{e2}, Y_{e2}).

   //Position Estimation using Bilateration method

5. *Consider the distance between the anchor nodes* ***'h'****, and distance between anchors and target nodes, i.e.,* ***'r_1', and 'r_2'.***

6. *Estimate the target node partial values using "(18)","(19)", and get U_b= (X_{eb}, Y_{eb})*

   // Final values of the target node

7. *Find the target node* ***'U'*** *coordinate values (Final values) using"(20)" ,*
   i.e., U=(X_e, Y_e) by averaging the U_v= (X_{estv}, Y_{estv}) and U_b= (X_{eb}, Y_{eb}).

}

IV. EXPERIMENTAL RESULTS

The proposed model is implemented to check its performance by using Matlab 15a. There are no existing best fit models to compare with this proposed model. Hence, the locations of the estimated values of the target nodes are compared with existing localization techniques, which are suitable based on the triangular area used for the localization. The proposed localization technique is implemented in a triangular area with two anchor nodes, and many target nodes, but '7' target node's information is shown in the results. The main goal of the proposed localization technique is to improve the accuracy. The experimentation of the proposed technique is done based on the area ½*70*70m (2450 square meters). The actual positions of the target nodes and the anchor nodes are collected and represented in the Table-II. Similarly, The estimated positions of the target nodes are calculated by using the proposed localization technique. The following Table-II shows the experimental data for the estimated and actual positions of the target nodes. The Fig.5 shows the actual and estimated node's positions. The experimental results proved that the proposed localization technique performs better than existing models. The difference between the actual location of the target nodes and the estimated nodes can be used to calculate the error. The maximum and the minimum errors are Min=0.00123 meters and Max=0.00348 meters.

Table. II. Proposed method's Estimated Nodes

Sl No	Target Coordinates (U)	Anchor Coordinates A (0,0), B (70, 70)	Distance Between Anchor&Target *(RSS based)* d_1 & d_2	Incident Angle of Target node (β)	Angle of First Vector ($\alpha_{11}=\beta_1-\Delta$) ($\alpha_{21}=\beta_2-\Delta$) $\Delta=1$	Angle of Second vector ($\alpha_{12}=\beta_1+\Delta$) ($\alpha_{22}=\beta_2+\Delta$) $\Delta=1$	Estimated Location U'(X_e, Y_e)	Error (U-U')
1	T1 (45,25)	A_1	48.96	29.05	28.05	30.05	(44.998, 25.001)	0.00143
		A_2	51.47	29.05	28.05	30.05		
2	T2 (55,35)	A_1	62.01	32.47	31.47	33.47	(54.997, 35)	0.00203
		A_2	38.07	23.19	22.19	24.19		
3	T3 (60,50)	A_1	74.29	39.80	38.80	40.80	(59.997,49.998)	0.00296
		A_2	22.36	26.56	25.56	27.56		
4	T4 (69,30)	A_1	71.57	23.49	22.49	24.49	(68.996, 30)	0.00348
		A_2	40.01	1.43	0.43	2.43		
5	T5 (15,15)	A_1	20.17	45	44	46	(15.002, 15.002)	0.00287
		A_2	77.78	45	44	46		
6	T6 (35,12)	A_1	35.19	18.92	17.92	19.92	(35, 12.002)	0.00233
		A_2	67.74	31.10	30.10	32.10		
7	T7 (42,25)	A_1	46.49	30.76	29.76	31.76	(41.999,25.001)	0.00123
		A_2	53	31.89	30.89	32.89		
							Max=0.00348 Min =0.00123	

Table-III. Comparison of the accuracy of the proposed method and other existing methods.

Target (Actual Node Coordinates)		Trilateration (Estimated Node)		Multilateration (Estimated Node)		Triangulation (Estimated Node)		Single Anchor based Localization Technique (TASLT) (Estimated Node)		Double Anchor Baed Localization Technique (DALT) (Estimated Node)		Proposed Method (BDALT) (Estimated Node)	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
45	25	43.5	26.49	43.99	26	45.32	24.55	43.47	26.52	44.51	25.48	44.998	25.001
55	35	53.46	35	53.46	35	55	34.07	55.45	34.43	54.02	35	54.997	35
60	50	60.76	48.64	60.04	49.361	59.1	47.19	60.34	49.98	58.77	49.26	59.997	49.998
69	30	63.61	29.63	64.76	28.48	68.1	27.98	68.51	28.14	67.34	30.24	68.996	30
15	15	16.24	13.64	15.37	14.51	15.75	12.44	16.86	12.38	15.97	15.97	15.002	15.002
35	12	35	16.53	35	16.53	35	10.64	34.4	13.26	35	13.12	35	12.002
42	24	39.99	26.49	41.65	24.84	42.2	23.32	42.7	23.07	41.65	25.48	41.999	25.001
		Total Error = 20.18 Average Error = 2.88 Accuracy (%) = 97.1		Total Error = 14.15 Average Error = 2.02 Accuracy (%) = 97.9		Total Error = 11.33 Average Error = 1.61 Accuracy (%) = 98.3		Total Error = 10.91 Average Error = 1.5 Accuracy (%) = 98.5		Total Error =7.84 Average Error =1.12 Accuracy (%) =98.88%		Total Error =1.018 Average Error =0.145 Accuracy (%) = 99.86	
		No. of Anchors = 3		**No. of Anchors = 4**		**No. of Anchors = 3**		**No. of Anchors = 1**		**No. of Anchors = 2**		**No. of Anchors = 2**	

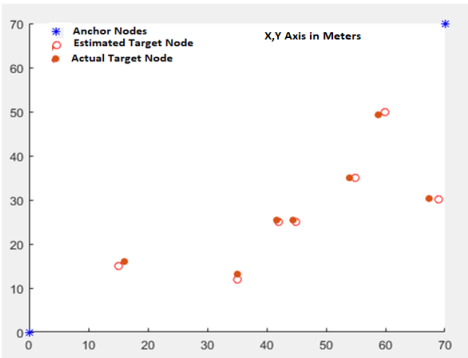


Fig.5. Scattered Plot diagram for the given nodes in the Table-II.

The Table-II values have been used so as to draw the scatter plot diagram (Fig.5). The estimated target node's position, the actual node's positions, and anchor node's positions are shown in the following scatter plot. Comparison of the accuracy of the proposed method with existing localization techniques is performed and the data given in the Table-III, and the values that represent the proposed method outperforms the existing localization techniques

A. Performance Measures used for the proposed model

By using the following performance measures given in "(20), (21) and (22)" (Includes total error, average error, the accuracy), the performance of the proposed and existing localization techniques are calculated.

$$Accuracy = \left(\frac{AverageError}{Range \ of \ AnchorNodes} \right) \quad (20)$$

$$TotalError = \sum_{i=1}^{n} \sqrt{(x_e - x_i)^2 + (y_e - y_i)^2} \quad (21)$$

$$AverageError = \left(\frac{TotalError}{No.of \ Target \ Nodes} \right) \quad (22)$$

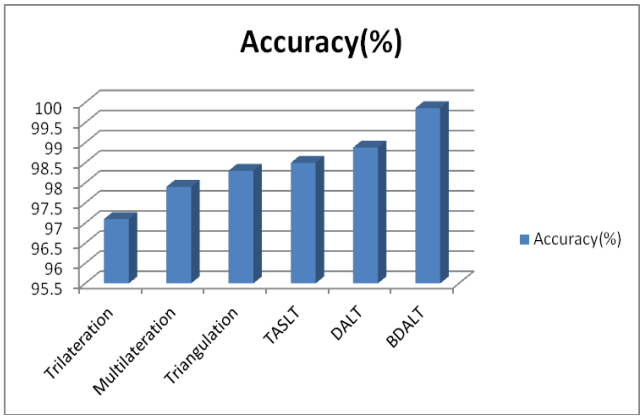


Fig.6.Comparison of Accuracy of the proposed and existing techniques in percentages

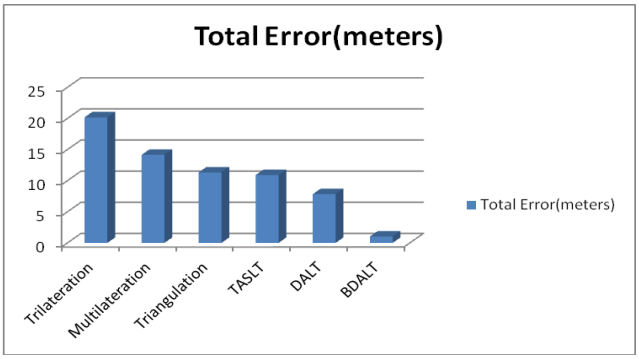


Fig.7: Comparison of the Total Error of the proposed model with the existing localization techniques in meters

Table.IV. Comparison of the Proposed method and existing techniques in terms of hardware and accuracy

Sl No	Method (Technique)	No.of Anchor Nodes (A)	Special Hardware (B)	Cost C= (A+B)	Accuracy
1	Trilateration	3	No	Medium	Poor
2	Multilateration	4	No	Medium	Average
3	Triangulation	3	Yes	High	Average
4	TASLT	1	Yes	Low	Good
5	DALT	2	Yes	Medium	Very Good
5	Proposed Model (BDALT)	2	Yes	Medium	Excellent

No. of Anchor Nodes: There are two anchor nodes used in the proposed localization technique for the coverage area 2,450 square meters (½*70*70 meters). The same area can be used to perform the existing localization techniques includes trilateration, multilateration, triangulation, and TASLT techniques. The target nodes in the triangular area can be localized by the proposed localization technique. The main use of two anchor nodes of the proposed localization technique to improve the accuracy and to make the system robust.

Accuracy: The proposed localization technique uses RSSI, AoA measures, dynamic linear vectors with respect to two anchor nodes to improve the accuracy of the estimated node location values. The accuracy of the proposed localization algorithm has been increased more than the existing localization techniques.

Cost: When compared the proposed localization techniques with trilateration, and multilateration techniques, the proposed localization technique uses the least number of anchor nodes, but it also uses special hardware for the angle estimation. As compared to triangulation technique the proposed method uses less anchor nodes and less special hardware for angle estimation. If the proposed model was compared with the TSALT, the cost of the model could be high due to use of two anchor nodes in the localization, but this cost is acceptable to achieve localization accuracy.

V. CONCLUSION

The high accuracy of the localization techniques is important in many practical applications of Wireless Sensor Networks. In this paper, a hybrid range based localization technique is implemented to improve the localization accuracy. The proposed localization technique uses RSS and AoA measures, dynamic linear vectors, and bilateration technique to get the target nodes location information with improved accuracy. The simulation results established that only two anchor nodes are sufficient to get the best localization accuracy. The proposed localization algorithm can be performed with the coordination of anchor nodes and the target nodes. The accuracy of the proposed BDALT is higher than the DALT existing technique. The introduced technique has been compared with DALT and other existing techniques which are similar in the working of the sensor field (area). The proposed research work has been simulated and the results make it clear that the proposed localization algorithm gives more accurate location information than other localization techniques, and the achieved localization accuracy is 99.86% percentage.

REFERENCES

1. Juan Luo, Zhenyan Zhang, Chang Liu, and Haibo Luo, “Reliable and Cooperative Target Tracking based on WSN and WiFi in Indoor Wireless Networks ”, *IEEE Access*, vol. 6, no. 2018, pp. 24846-24856, 2018.
2. Slavisa Tomic, Marko Beko, Rui Dinis, "3D Target Localization in Wireless Sensor Networks Using RSS and AoA Measurements," *IEEE Transactions on Vehicular Technology*, vol. 66, no. 4, pp. 3197-3201, 2017.
3. Sebastian Sadowski, Petros Spachos, "RSSI based Indoor Localization with the Internet of Things," *IEEE Access*, pp. 30149-30161, 2018.
4. Benjamin Molina, Eneko Olivares, Carlos Enrique Palau, Manuel Esteve, "A Multimodal FingerPrint Based Indoor Positioning System for Airports," *IEEE Access*, pp. 10092-10106, 2017.
5. Klemen Bregar, Mihael Mohorcic, "Improving Indoor Localization Using Convolutional Neural Networks on Computationally Restricted Devices," *IEEE Access*, vol. 6, no. 2018, pp. 17429-17441, 2018.
6. Xuejian Zhao, Xinhui Zhang, Zhixin Sun, And Pan Wang, "New Wireless Sensor Network Localization Algorithm for Outdoor Adventure", *Special Section On Human-Centered Smart Systems And Technologies*, pp. 13191-13199, 2018.
7. Ashraf Tahat, Feorges Kaddoum, Siamak Yousefi, Shahrokh Valaee, Francois Gangnon, "A Look at the Recent Wireless Positioning Techniques with a Focus on Algorithms for Moving Receivers," *IEEE Access*, pp. 6652-6680, 2016.
8. R Vsalli, S Sundhar, V Vignesh, Sukanth Kotari, "Simulation and Analysis of RSSI based Trilateration algorithm for localization in CONTIKI-OS," *ICTACT Journal on Communication Technology*, vol. 7, no. 3, pp. 1351-1355, 2016.

9. Arora, S. S. S., "Node Localization in Wireless Sensor Networks Using Butterfly Optimization Algorithm," *Arab Journal of Science and Engineering*, vol. 42, pp. 3325-3335, 2017.
10. Huping Xu, Feng Li, Yancheng Ma, "A Zigbee based miner localization system," in *IEEE 16th International Conference on Computer Supported Cooperative Work in Design*, 2012.
11. Sebastian Sadowski, Petros Spachos, "RSSI-Based Indoor Localization With the Internet of Things," *IEEE Access*, vol. 6, no. 2018, pp. 30149-30161, 2018.
12. Sadik Kamel Gharghan, Rosdiadee Nordin, Aqeel Mahmood Jawad, Haider Mahmood Jawad, Mahamod Ismail, "Adaptive Neural Fuzzy Inference System for Accurate Localization of Wireless Sensor Networks in Outdoor and Indoor Cycling Applications," *IEEE Access*, vol. 6, no. 2018, pp. 38475-38489, 2018.
13. S.B Kotwal, S Verma, Suryansh, Arnva Sharma, "Region based Collaborative Angle of Arrival Localization for Wireless Sensor Networks with Maximum Range Information," *International Conference on Computational Intelligence and Communication Networks*, 2010.
14. Joshi, V. G. S., "Localization in Wireless Sensor Networks : A Survey," in *CSIR Sponsored X Control Instrumentation System Conference*, 2013.
15. Zengfeng Wang, Hao Zhang, Tingting Lu, T Aaron Gulliver, "A Grid based Localization Algorithm for Wireless Sensor Networks Using Connectivity and RSS Rank," *IEEE Access*, vol. 6, no. 2018, pp. 8426-8439, 2018.
16. Kapil Uraiya, Dilip Kumar Gandhi, "Genetic Algorithm for Wireless Sensor Network with Localization based Techniques," *International Journal of Scientific and Research Publications*, vol. 4, no. 9, pp. 1-6, 2014.
17. Farhan.S, "RF Propagation Antennas and Regulatory Reqirements," *Zigbee Wireless Networks and Transeivers*, Newnes, 2009, pp. 171-172.
18. Shun Kawakami, Tomoaki Ohtsuki, "Localization using iterative angle of arrive method sharing snapshots of coherent subarrays," *EURASIP Journal on Advance in Signal Processing*, vol. 2011, no. 46, pp. 1-7, 2011.
19. Qguejiofor O.S, Aniedu A.N, Ejiofor H.C, Okolibe A.U, "Trilateration based Localization Algoirithm for Wireless Sensor Network," *International Journal of Science and Modern Engineering*, vol. 1, no. 10, pp. 21-27, 2013.
20. M. S. U. T. R. A. P. Kumarol, "Localization System for Wireless Sensor Network," *International Journal of Computer Science and Electronics Engineering (IJCSEE)*, vol. 2, no. 1, pp. 6-10, 2014.
21. Henk Wymeersch, Jaime Lien, and Moe Z. Win, "Cooperative Localization in Wireless Networks," in *Proceeding of the IEEE*, 2009.
22. Zan Li, Torsten Braun, Xiaohui Zhao, Zhongliang Zhao, Fengye Hu, Hui Liang, "A Narrow-Band Indoor Positioning System by Fusing Time and Received Signal Strength via Ensemble Learning," *IEEE Access*, pp. 9936-9950, 2017.
23. SHEN Xuesong, CHEN Wu, LU Ming, "Wireless Sensor Networks for Resource Traking at Building Constructions," *Tsinghua Science And Technology*, vol. 13, no. 67, pp. 78-83, 2008.
24. Juan Ignacio Huircána, Carlos Mu˜noza, Héctor Younga, Ludwig Von Dossowa, "ZigBee-based wireless sensor network localization for cattle monitoring in grazing fields," *Computers and Electronics in Agriculture* , vol. 74, no. 2010, p. 258–264, 2010.
25. M. Tarkowski, K. Bizewski, M. Rzymowski, K. Nyka, L. Kulas, "Wireless Multimodal Localization Sensor For Industrial Applications," in *21st International Conference on Microwave, Radar and Wireless Communications, MIKON 2016*, 2016.
26. Ashraf Tahat, Georges Kaddoum, Siamak Yousefi, Shahrokh Valaee, Francois Gagnon, "A Look at the Recent Wireless Positioning Techniques with a Focus on Algorithms for Moving Receivers," *IEEE Access*, vol. 4, no. 2016, pp. 6652-6680, 2016.
27. Kumar, Sudhir Tiwari, Shriman Narayan Hegde, Rajesh M, "An adaptive anchor navigation algorithm for localization in MANET," in *International Conference on Signal Processing and Communications, SPCOM 2014*, 2014.
28. Ahmadi, Hanen Bouallegue, Ridha, "Exploiting machine learning strategies and RSSI for localization in wireless sensor networks: A survey," in *13th International Wireless Communications and Mobile Computing Conference, IWCMC 2017*, 2017.
29. Nabil Ali Alrajeh, Maryam Bashir, Bilal Shams, "Localization Techniques in WirelessSensor Networks," *Interantional Journal of Distributed Sensor Networks*, vol. 2013, pp. 1-9, 2013.
30. Cook. B, Buckberry.G, Scowcroft. I, Mitchell.J, and Allen. T, "Indoor Location Using Trilateration Characteristics," in *Proceedings London Communications Symposium*, London, 2015.
31. Huan-Chin Pu, Chuan-Hsian Pu and Hoon-Jae Lee, "Indoor Location Tracking Using Received Signal Strength Indicator," in *Emerging Communications for Wireless Sensor Networks*, InTech, 2011, pp. 229-256.
32. M. I. AlHajri , A. Goian, M. Darweesh, R. AlMemari, R. M. Shubair, L. Weruaga, and A. R. Kulaib, "Hybrid RSS-DOA technique for enhanced WSN localization in a correlated environment," in *International Conference on Information and Communication Technology Research*, 2015.
33. Mamidi Kiran Kumar, V Kamakshi Prasad, "TASLT: Triangular Area Segmentation based Localization Technique for Wireless Sensor Networks using RSSI and AoA Measures - A New Approach," in *International Conference on Engineering and Technology*, Coimbathor, 2018. *To be published*.
34. Mamidi Kiran Kumar, V Kamakshi Prasad, "DALT: Double Anchor-based Localization Technique for Wireless Sensor Networks using RSS and AoA Measures", *International Journal of Innovative Technology and Exploring Engineering (IJITEE)* ISSN: 2278-3075, Volume-8, Issue-10, August 2019.
35. Khalid K. Almuzaini, Aaron Gulliver, "Range-Based Localization in Wireless Networks Using Density-Based Outlier Detection", *Wireless Sensor Network*, 2010, 2, 807-814, doi:10.4236/wsn.2010.211097.

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