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Trilateration Based localization Algorithm for Wireless Sensor Network

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Abstract— ***A Trilateration based localization algorithm for determining the position of nodes in a wireless sensor network is proposed. Details regarding the implementation of such algorithm are also discussed. Experiments were performed in a testbed area containing anchor and blind nodes deployed in it to characterize the pathloss exponent and to determine the localization error of the algorithm. The pathloss exponent of the testbed area was computed to be n=2.2 where as the algorithm is shown to have localization error of 0.74m which is acceptable because is not much.***

***Index Terms*— Algorithm, beacon, pathloss, Trilateration**

I. INTRODUCTION

Wireless Sensor Network (WSNs) has been widely considered as one of the most important technologies for the twenty – first century [1]. Enabled by recent advances in micro electromechanical system (MEMS) and wireless communication technologies, tiny, cheap, and smart sensors deployed in a physical area and networked through wireless links and the internet provide unprecedented opportunities for a variety of civilian and military applications; for examples, environmental monitoring, pipeline monitoring, battle field surveillance, and industry process control [2]. The core function of WSN is to detect and report events which can be meaningfully assimilated and responded to only if the accurate location of the event is known. Also, in any WSN, the location information of nodes plays a vital role in understanding the application context. Automatic localization of the sensor nodes in this wireless network is a key enabling technology. The overwhelming reason is that a sensor's location must be known for its data to be meaningful. There are three visible advantages of knowing the location information of sensor nodes [3]. Firstly, location information is needed to identify the location of an event of interest. For instance, the location of enemy tanks in a battle field is of critical importance for deploying rescue and relief troops. Second, location awareness facilitates numerous application services, such as location directory services that provide doctors with the information of nearby medical equipment and personnel in a smart hospital, target-tracking applications for locating survivors in debris, or enemy tanks in a battlefield. Third, location information can assist in various system functionalities, such as geographical routing [4] and network coverage checking [5]. Hence, with these advantages and much more, it is but natural for location-aware sensor devices to become the defacto standard in WSNs in all application domains that provide location – based service. A straightforward solution is to equip each sensor with a Global Positioning System (GPS) receiver that can accurately provide the sensors with their exact location. This however, is not a feasible solution from an economic perspective since sensors are often deployed in very large numbers and manual configuration is too cumbersome and hence not feasible.

Hence for location discovery in a sensor network, there must be a set of specialty nodes known as beacon (Anchor) nodes. These nodes know their location, either through a GPS receiver, or through manual configuration, which these provide to other sensor nodes. Using this location of beacon nodes, sensor nodes compute their location using various techniques. In this paper, range-based localization process would be used to determine the position of a node in a network. In range-based localization, the localization of a node is usually computed relative to other nodes. In its vicinity, range-based localization depends on the assumption that the absolute distance between a sender and a receiver can be estimated by one or more features of the communication signal from the sender node to the receiver node. The features of the communication signal that are frequently used in literature for range-based localization are as follows:

- Angle of Arrival (AOA): Range information is obtained by estimating and mapping relative angles between neighbors. [6] Makes use of AOA for localization.
- Received Signal Strength Indicator (RSSI): use a theoretical or empirical model to translate signal strength into distance. RADAR [7] is one of the first to make use of RSSI. RSSI has also been employed for range estimation in [8].
- Time of Arrival (TOA): To obtained range information using TOA, the signal propagation time from source to destination is measured. A GPS is the most basic example that uses TOA. To use TOA for range estimation, a system needs to be synchronous, which necessitates use of the expensive hardware for precise clock synchronization with the satellite.
- Time Difference of Arrival (TDOA): To obtain the range information using TDOA, an ultrasound is used to estimate the distance between the node and the source. Like TOA, TDOA necessitates the use of special hardware; rendering it two expensive for

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WSNs [9] is a localization technique that makes use of TDOA.

In this paper our aim is to determine a simple localization algorithm that uses distances estimation (Range based) to compute 2D position of wireless sensor node in a network.

II. RELATED WORKS

There is a lot of related works already being done in the field of localization. There are multiple techniques via which the coordinate resolution will be achieved for a blind node (a node that is unaware of its position). But these techniques have their own advantages and disadvantages. This research work surveyed different techniques available for localization and proposes a better algorithm for localization of sensor nodes.

Chris Savares and Jan Rabaey in [10] used a minimum of four anchor nodes in trying to get a robust positioning algorithm for wireless sensor networks; in their assumptions, it was considered that all nodes are equal in terms of their processing ability with the exceptions of few ; the use of centralized algorithms were also criticized which is okay. Distributed algorithms were preferred to centralized algorithms because all computations were done on the sensor nodes themselves and communicate with each other to get their positions in a network; the developed positioning algorithm relies on range measurements to estimate the distance between neighboring nodes. However, this developed algorithm is indifferent to which range method (Distance or Hop count) used to actually locate the position of node; the authors claim that the algorithm can still serve the purpose in spite of any range method used; but am of the view that any developed algorithm should be more effective when programmed to solve a particular problem and not many at a time.

L. Eirod and D. Estrin in [11] claimed that much better results were obtained based on node localization, when time of flight measurements were used as the range method, particularly when acoustic and Rf signals were combined, though they have a good point, but their report can only be justified when the nodes to be localized are unobstructed in terms of the lines of sight, whereas, if there is no line of sight between nodes then this algorithm will be ineffective, in addition, acoustic signals are temperature dependant, hence, the accuracy of this algorithm will be dependant also on temperate conditions.

Doherty et al in [12] proposed a drastic approach that avoids the range error problems which is the use of connectivity between nodes to formulate a set of geometric constraint and solve it using convex optimization. However, the drawback in this algorithm is that convex optimization is performed by a single centralized node which brings about high communication cost of moving data back to the base station.

“DV-hop” approach by Niculescu and Nath [13] in contrast, is completely adhoc and achieve an accuracy of about one-third of the radio range for dense networks. In the first phase, anchors flood their location to all nodes in the network. Each unknown node records the position and (minimum) number of hops to at least three anchors. Whenever an anchor a, infers the position of another anchor a_2, it computes the distance between them, divides that by the number of hops, and floods this average hop distance to convert hop counts to distances, and they perform a triangulation to three or more distant anchors to estimate its own position. “DV-hop” works well in dense and regular topologies, however, but for sparse or irregular networks the accuracy degrades to the radio range.

Recently, a number of approaches have been proposed that required few anchors [14, 15]. These are quite similar and operate as follows; a node measures the distances to its neighbors and then broadcasts this information. This results in each node knowing the distance of its neighbor and some distances between those neighbors. This allows for the construction of (partial) local maps with relative positions. Adjacent local maps are combined by aligning (mirroring, rotating) the co-ordinate systems. The known positions of the anchor nodes are used to obtain maps with absolute positions. When three or more anchors are present in the network, a single absolute map results. However this style of locationing is not very efficient because range errors usually accumulate when combining the maps.

Kamin Whitehouse et al in [15] make use of RF profiling technique for node localizing. RF profiling requires a pre deployment stage in which the RSS of each anchor node is recorded at each position in two dimensional regions to be localized. The reading taken at a particular position can be called the RF profile of that position. At a later time, a node matches the RF profile of its current position to the profiles of the positions already recorded.RF profiling is not considered a ranging- based technique because the RSS readings are never used to estimate distance; they are used to directly estimate the nodes location. It is also not multihop because the mobile nodes must always have direct radio communication with the anchor nodes hence its main limitation is that it requires pre-collected data and dense infrastructure of anchor nodes.

Trilateration based localization algorithm is a distributed beacon-based localization algorithm; which is range based, i.e. it uses distance estimation to compute the 2D position of nodes in a network with the help of a feature of the communicating signal from the sender node to the receiving node called Received Signal Strength Indicator(RSSI). It differs from Time of Flight (TOF), Angle of Arrival (AOA) and Time Difference of Arrival (TDOA) range based distance estimation scheme in [11] in that TOF needs line of sight to effectively locate nodes, AOA needs extra hardware to be added to nodes before effective localization can take place, TDOA measurements accuracy is usually affected by multipath. Where as RSSI measurements don’t need any extra hardware or line of sight to localize nodes, though multipath and shadowing are two major phenomena that affect the reliability of RSSI measurements because different magnitude signals arriving out of phase at the receiver causes both constructive and destructive interferences. However, spread spectrum radios have effectively mitigated those problems by averaging the received power over multiple frequencies. Hence this paper proposes a RSSI based trilateration localization algorithm that uses range based distance estimation scheme to accurately localize these nodes.

III. TRILATERATION TECHNIQUE

The localization algorithm proposed in this research work is the RSSI-based trilateration localization technique. This is based on the laterations process. Considering the basic formula for the general equation of a sphere as shown in equation (1.0);

$$d^2 = x^2 + y^2 + z^2 \quad (1.0)$$

For a sphere centered at a point (x_a, y_a, z_a) the equation is simplified as shown as in equation (2.0);

$$d^2 = (x - x_a)^2 + (y - y_a)^2 + (z - z_a)^2 \quad (2.0)$$

Since one assumes all the nodes spans out on the same plane, consider the three anchor nodes (a, b and c) that has distance (d_a, d_b, d_c) to the blind node as illustrated in Fig. 1.0;

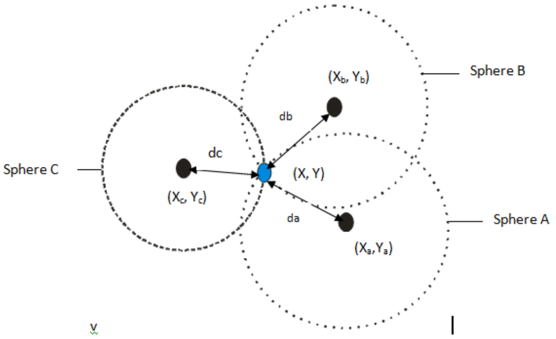


Figure 1.0: Intersection of three spheres in 2D

The formula for all spheres on one plane is shown below in the following equations:

Sphere A; $d_a{}^2 = (x - x_a)^2 + (y - y_a)^2$ (3.0)
Sphere B; $d_b{}^2 = (x - x_b)^2 + (y - y_b)^2$ (4.0)
Sphere C; $d_c{}^2 = (x - x_c)^2 + (y - y_c)^2$ (5.0)

Equations (3.0), (4.0) and (5.0) can further be expanded to bring about the following equations:

$$d_a{}^2 = x^2 - 2x.x_a + x_a^2 + y^2 - 2y.y_a + y_a^2 \quad (6.0)$$

$$d_b{}^2 = x^2 - 2x.x_b + x_b^2 + y^2 - 2y.y_b + y_b^2 \quad (7.0)$$

$$d_c{}^2 = x^2 - 2x.x_c + x_c^2 + y^2 - 2y.y_c + y_c^2 \quad (8.0)$$

The three equations (6.0), (7.0) and (8.0) are independent non-linear simultaneous equations which cannot be solved mathematically; however, using method proposed by Dixon [16] to obtain radical plane for sphere intersection, equation (8.0) was subtracted from equation (7.0) to get the following linear equation:

$$d_b{}^2 - d_c{}^2 = 2x\ (x_c - x_b) + x_b^2 - x_c^2 + 2y\ (y_c - y_b) + y_b^2 - y_c^2 \quad (9.0)$$

And subtracting equation (6.0) from equation (7.0), the following linear equation is obtained:

$$d_b{}^2 - d_a{}^2 = 2x\ (x_a - x_b) + x_b^2 - x_a^2 + 2y\ (y_a - y_b) + y_b^2 - y_a^2 \quad (10.0)$$

Rearranging the equation (9.0) to produce a new equation and a new variable as follows,

$$x\ (x_c - x_b) + y\ (y_c - y_b) = \frac{(d_b{}^2 - d_c{}^2) - (x_b{}^2 - x_c{}^2) - (y_b{}^2 - y_c{}^2)}{2} = v_a \quad (11.0)$$

Rearranging the equation (10.0) to produce a new equation and a new variable as follows,

$$x\ (x_a - x_b) + y\ (y_a - y_b) = \frac{(d_b{}^2 - d_a{}^2) - (x_b{}^2 - x_a{}^2) - (y_b{}^2 - y_a{}^2)}{2} = v_b \quad (12.0)$$

Resolve the equation (11.0) and equation (12.0) to gain the intersection point ‘x’ and ‘y’ of these two equations as the following equation for ‘y’ value and equation for ‘x’ value respectively:

$$y = \frac{v_b(xc - xb) - v_a(xa - xb)}{(ya - yb)(xc - xb) - (yc - yb)(xa - xb)} \quad (13.0)$$

$$x = \frac{v_a - y(yc - yb)}{(xc - xb)} \quad (14.0)$$

The values for x and y gives us the accurate position in two dimension (2D) for the blind node. But these values can’t be obtained without the signal propagation model.

A. Signal Propagation model

In this section the signal propagation model in wireless sensor network will be addressed. The most common signal propagation model in wireless sensor Network (WSN) is the free space model. The free space model assumes that the receiver within the communication radius can receive the data packet. One possibility to acquire a distance of the node from another node is by measuring the received signal strength of the incoming radio signal. The idea behind Received Signal Strength (RSS) is that the configured transmitted power (P_t) at the transmitter device directly affects the received power (P_r) at the receiving device. According to frii’s free space transmission equation [17], the detected signal strength decreases quadratically with the distance to the sender.

$$P_{r\,(d)} = \frac{p_t G_t G_r \lambda^2}{(4\pi d)^2} \quad (15.0)$$

Where $P_{r\,(d)}$ = Received power at the receiver
P_t = Transmission Power of sender
G_t = Gain of Transmitter
G_r = Gain of Receiver
λ = Wavelength
d = Distance between the sender and the receiver normally
$G_t = G_r = 1$, in embedded devices.

B. Power Law Model

The majority of embedded system operates in a non-line-of sight (NLOS) environment. Based on empirical data, a fairly general model has been developed for NLOS propagation. This model predicts that the mean path loss $P_L(d_i)$ [dB] at a transmitter receiver separation d_i is:

$$P_L(d_i)\ [\text{dB}] = P_L(d_0)\ [\text{dB}] + 10n \log_{10}(\frac{d_i}{d_0}) \quad (16.0)$$

Where n = pathloss exponent
$P_L(d_0)$ = pathloss at known reference distance d_0

For free space model n is regarded as 2 because multipath and shadowing were not considered. The free-space model however is an over idealization, and the propagation of a signal is affected by reflection, diffraction and scattering. Of course, these effects are environment (indoors, outdoors, rain, buildings, etc.) dependent. However, it is accepted on the basis of empirical evidence that it is reasonable to model the pathloss $P_L(d_i)$ at any value of d at a particular location as a random and log-normally distributed random variable with a distance-dependent mean value [18]. That is:

$$P_L(d_i)\ [\text{dB}] = P_L(d_0)\ [\text{dB}] + 10n \log_{10}(\frac{d_i}{d_0}) + S \quad (17.0)$$

Where S, the shadowing factor is a Gaussian random variable (with values in dB) and with standard deviation σ [dB]. The path loss exponent, *n*, is an empirical constant which depends on propagation environment.

To determine the pathloss coefficient *n* of the test bed area/ environment. Equation (16.0) can be used to manually compute it as:

$$n = \frac{\{P_L(d_i) - P_L(d_0)\}}{10\log_{10}\left(\frac{d_i}{d_0}\right)} \qquad (18.0)$$

Using linear regression, the value of *n* can be determined from the measured data by minimizing total error, R^2, as follows:

$$R^2 = \sum_{i=1}^{M}\left[P_L(d_i) - P_L(d_0) - 10n\log_{10}\left(\frac{d_i}{d_0}\right)\right]^2 \qquad (19.0a)$$

Differentiating equation (19.0a) w.r.t. *n*,

$$\frac{\partial R^2(n)}{\partial n} = -20\log_{10}(d)\sum_{i=1}^{M}\left[P_L(d_i) - P_L(d_0) - 10n\log_{10}\left(\frac{d_i}{d_0}\right)\right] \qquad (19.0b)$$

Equating $\frac{\partial R^2(n)}{\partial n}$ to zero,

$$0 = -20\log_{10}(d)\sum_{i=1}^{M}\left[P_L(d_i) - P_L(d_0) - 10n\log_{10}\left(\frac{d_i}{d_0}\right)\right]$$

$$\sum_{i=1}^{M}[P_L(d_i) - P_L(d_0)] - 10n\log_{10}\left(\frac{d_i}{d_0}\right) = 0$$

$$\sum_{i=1}^{M}[P_L(d_i) - P_L(d_0)] - \sum_{i=1}^{M}\left[10n\log_{10}\left(\frac{d_i}{d_0}\right)\right] = 0$$

$$\sum_{i=1}^{M}[P_L(d_i) - P_L(d_0)] = \sum_{i=1}^{M}\left[10n\log_{10}\left(\frac{d_i}{d_0}\right)\right]$$

$$n = \frac{\sum_{i=1}^{M}[P_L(d_i) - P_L(d_0)]}{\sum_{i=1}^{M}\left[10\log_{10}\left(\frac{d_i}{d_0}\right)\right]} \qquad (20.0)$$

C2420 is the radio used by the TPR 2420CA Telosb nodes, used in this research work, it has a built in received signal strength Indicator (RSSI) which provides a digital value that can be read from the eight bit, signed 2's complement RSSI.RSSI_VAL register(RSS raw values). The RSSI register value RSSI.RSSI_VAL can be referred to the power *P* at the RF pins by using the following equation.

P [dBm] = RSSI_VAL + RSSI_OFFSET (21.0)

Where RSSI_OFFSET = -45 is constant for all telosb nodes.The above equation makes it possible to get the real value of the received signal strength during empirical measurement. Hence received signal strength is related to distance using the equation below.

RSSI [dBm] = -10*n* $\log_{10}$ (d) + A [dBm] (22.0)

where *n* is the propagation pathloss exponent, d is the distance from the sender and A is the received signal strength at one meter of distance. In order to determine the pathloss exponent to be used in this research work, the RSSI values within 10m of the sink will be measured with a step size of 1m and the root mean square (RMS) of the measured RSSI values will be calculated and then the best value for the pathloss exponent *n* for the test bed area will now be determined. The models described provide the simplest way of calculating the estimated distances from a receiving node to a transmitting node based on received signal strength indicator. The proposed algorithm will be using at least three beacon nodes, the outline of this localization system is found in figure 2.0. The blind nodes can estimate its distance from the beacon node using Received signal strength, but the actual position (x, y) in 2D of the node can be computed from the position information obtained from the three beacon nodes using trilateration technique.

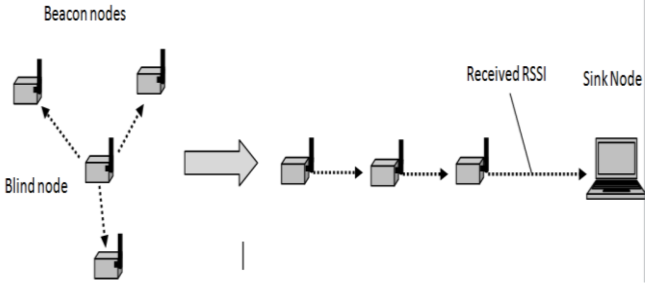


Figure 2.0: Localization system using RSSI measurement

IV. MEASUREMENT ENVIRONMENT

Figure 3.0: Experimental Testbed Environment

The test bed environment is depicted in figure 3.0. The Environment consists of the outdoor environment of the faculty of engineering wing B, Nnamdi Azikiwe University Awka, Anambra State. The Area covers (100 X 50) around the packing site for staff. The test bed has four(4) telosb motes(TPR 2420CA) equipped with a chipcon CC2420 radio chip operating in the 2.4 GHz frequency band and running on tiny operating system(tiny OS). The nodes both anchor and blind are deployed within this test bed environment. The sink node is located at the department of Electronic and Computer Engineering which is situated at the First floor of the faculty of engineering building. The sink node is usually attached to an Hp personal computer where the monitoring is carried out.

A. Measurement Instrument(Equipment)

The instrument used for measurement includes:

- Four crossbow's TelosB node TPR2420 which offers features including; IEEE 802.15.4 compliant RF transceiver, 8MHz T1 MSP430 microcontroller, 1MB External flash for data logging, sensor suite including integrated light, temperature and humidity, Runs TinyOS 1.1.11 or higher, programming and data collection via USB and powered by two AA batteries. Figure 3.6 shows a crossbow TelosB mote.
- An Hp laptop where the sink node is slotted for data collection and programming of nodes.
- Measuring Tape

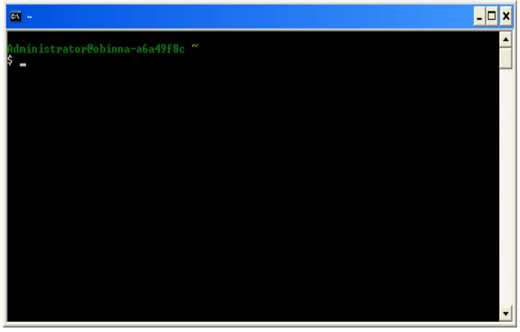
- CC2420 Module

The proposed RSSI-based algorithm will be implemented using Zigbee CC2420 modules in wireless sensor network.

Figure 4.0: A crossbow TelosB Node

A. RSSI/Distance Measurement

To determine the pathloss exponent n of the testbed area, RSSI measurements with respective distances were carried out. In this case four telosb nodes were used for the measurement. The nodes were programmed to have different identification numbers (ID'S). This is done using a cygwin bash which provides an interface where commands can be typed in. Figure 5.0 shows the interface for programming the nodes. The nodes ID's is what identify each node when transmitting to the sink.



```
Administrator@obinna-a6a49f8c ~
$ _
```

Figure 5.0: Cygwin bash for programming of Nodes

Hence, for this research work the following node ID's were adopted; 100, 200, 300 and 700. The node ID 700 is sorely reserved for the sink node.

Since the pathloss exponent n is to be determined, every direction was considered by placing node 100 at 180^0 of the sink node, node 200 at 90^0 of the sink node and node 300 at 270^0 of the sink.

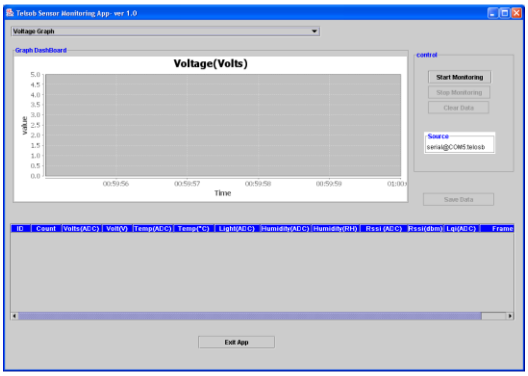


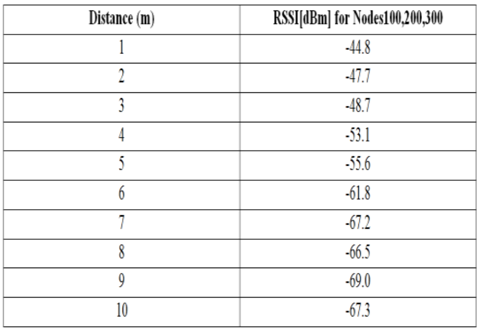
Figure 6.0: Interface used for Monitoring

The respective nodes senses environmental parameters such as temperature, humidity and light intensity and send to the sink node. The hp laptop housing the sink has a program in it that can be called up by double clicking the run sensor app at the desktop to produce an interface where various measurement such as RSSI [dBm], Link Quality Indicator(LQI) e.t.c. carried out can be seen. Figure 6.0 shows the interface used for monitoring live measured data from different nodes.

Through the above interface the various nodes and what they sensed can be monitored, by seeing how their respective values vary. It also has the option of saving the data collected and also clearing the data not saved.

The RSSI values within 10 meters of the sink from the respective nodes were measured with a step size of 1 meter and collected for two months. The average collected data are presented in Table 1.0.

Table 1.0: Total Average Receive Signal Strength for First and Second Month



Distance (m)	RSSI[dBm] for Nodes100,200,300
1	-44.8
2	-47.7
3	-48.7
4	-53.1
5	-55.6
6	-61.8
7	-67.2
8	-66.5
9	-69.0
10	-67.3

From Table 1.0 the data collected was used to develop a matlab script for computing the pathloss exponent n of the testbed area. From the computation, as shown in figure 7.0 n was computed to be 2.2. Hence, n = 2.2 will be used as the pathloss exponent in this research work.

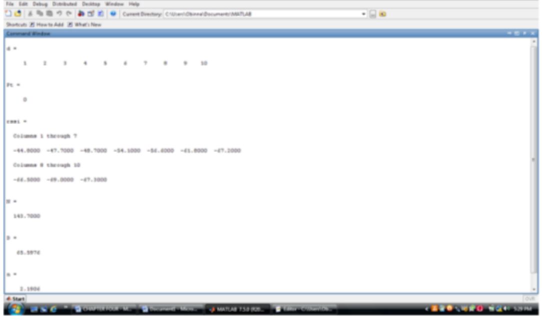


Figure 7.0:Computation of pathloss exponent *n*

Figure 8.0 shows the result of the total average measurements for first and second month combined.

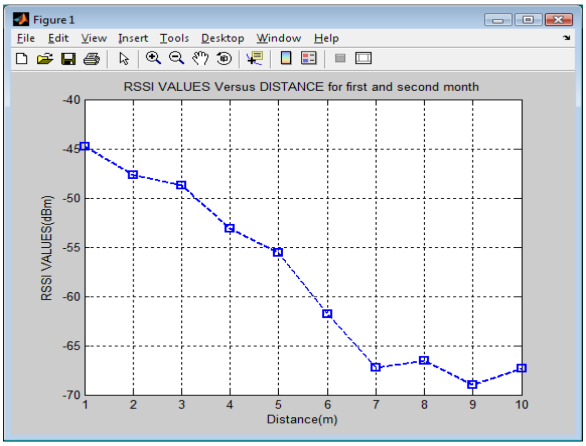


Figure 8.0: The average values of RSSI versus distance

V. PROPOSED ALGORITHM

The goal of this algorithm is to determine specific blind node's location within the distributed nodes along the testbed area. If the positions of the blind nodes are not known in a network, the event these monitor and report can not be located if need be. The primary obstacles to localization in wireless sensor network is the sparse anchor node problem, hence, this algorithm is structured to solve the problem. The proposed algorithm is made up of two phases: initialization phase and the final phase.

A. Initialization Phase

Prior to the implementation of the positioning algorithm, most of the nodes in a network have no positioning data, with the exception of the anchors but all the nodes have identification number (IDs).The network being considered for this algorithm will be scalable to very large number of nodes, which will be spread over the testbed area, relative to short radio ranges that each of the nodes is expected to possess. Furthermore, it is expected that the percentage of nodes that are anchor nodes will be small. This results in a situation in which only a very small percentage of nodes in the network are able to establish direct contact with any of the anchor nodes. In other to overcome this initial information deficiency, this initialization phase is usually initiated at all anchor nodes by making them broadcast their data which includes their location position and other parameters sensed. The blind node within the range of the broadcast should be able to store the anchor locations once for a particular node and estimate the range to anchors based on the Received Signal Strength; after which these also broadcast the anchor locations to other blind nodes. Through this process all blind nodes will know the location of the anchors.

B. Final Phase

If a blind node is able to estimate its distance to at least three anchor nodes; then the blind node can perform trilateration to get its accurate location in 2D, this blind node becomes a "converted" anchor node, its positioning will now be sent to the sink. This process (initialization and final phases) will continue until all blind nodes become converted.

This procedure is summarized in the following piece of pseudocode:

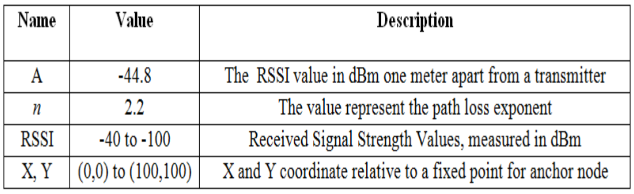
```
1.  When a positioning packet has been broadcast by anchors
2.  IF a blind node is within the range of broadcast
3.  Then store the positioning packet and compute the estimated range to the anchor using $d = 10^{\frac{A-RSSI}{10n}}$, broadcast the anchor node position to other blind nodes.
4.  Else do nothing
5.  IF a blind node receives packets from at least three different anchors
6.  Then perform trilateration
7.  Else do nothing
8.  If the trilateration is successful, blind node becomes converted anchor node
9.  Then Go to 1
10. Else repeat 6
11. End
```

The pseudocode shows the step by step method the proposed algorithm can be implemented.

C. Algorithm Implementation

To study the robustness of the proposed localization algorithm, a MATLAB program was developed; this program implemented the algorithm using the *input statement* and other matlab statements which is more interactive and better for analysis. This is normally called structured programming. The proposed algorithm was developed with MATLAB using structured programming which involves more of *input statement.* For the algorithm to actually compute the location of the blind node it needs some input parameters. The table 2.0 shows all necessary inputs to the algorithm; some of the values have been described already in this work.

Table 2.0: Input parameters for algorithm



Name	Value	Description
A	-44.8	The RSSI value in dBm one meter apart from a transmitter
n	2.2	The value represent the path loss exponent
RSSI	-40 to -100	Received Signal Strength Values, measured in dBm
X, Y	(0,0) to (100,100)	X and Y coordinate relative to a fixed point for anchor node

Table 2.0 shows the parameters needed as input to the algorithm in order for it to produce the required output. Pathloss exponent $n = 2.2$ was experimentally determined, A= -44.8 was also experimentally determined (see table 1.0). The RSSI values will not be static but varies, and will be dependent on real time values. (x ,y) values are fixed positions for anchor nodes.

D.Metric for Evaluating Algorithm

- Localization Error

Localization Error is defined as the difference between the estimated and the actual distances between the coordinates of the node. It is computed using the equation below, where (x^i_{est}, y^i_{est}) and (x^i_a, y^i_a) are node *i's* estimated and actual coordinates respectively.

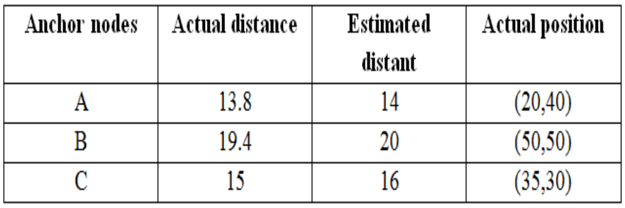
Localization Error (LE) = $\sqrt{(x^i_{est} - x^i_a)^2 + (y^i_{est} - y^i_a)^2}$

(23.0)

D. Performance Evaluation

In other to evaluate the performance of the proposed algorithm based on the above stated metric, let's consider a case where 3 anchor nodes are deployed together with blind nodes; the goal is to determine how accurate this localization algorithm is. Experiments were carried out in the test bed area. The dimension of the area in the testbed is taken to be 100cm width and 100m length. The actual distance between the blind nodes and the anchors are measured and recorded, the estimated distances between the blind nodes and anchor nodes were also calculated through the algorithm and recorded. The table 3.0 shows the summary of data collected while figure 9.0 shows the accurate position of the blind node at (32.27, 43.87), and figure 10.0 shows the estimated position (inaccurate) at (31.79, 44.43). The localization error of this algorithm for this case is 0.74m (Using equation 23.0). The error is not that much, and is usually caused by distance error which normally depends on the RSSI values between the communicating nodes.

Table 3.0: Node distance Measurement



Anchor nodes	Actual distance	Estimated distant	Actual position
A	13.8	14	(20,40)
B	19.4	20	(50,50)
C	15	16	(35,30)

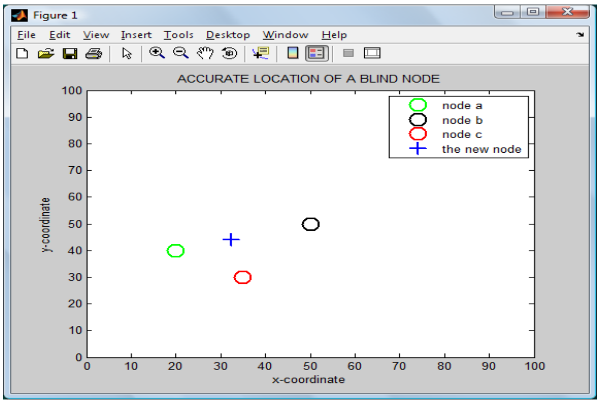


Figure 9.0: Actual position of blind node (new node)

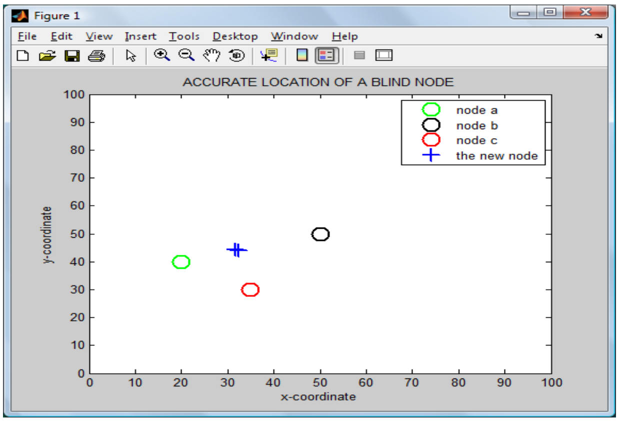


Figure 10.0: Estimated position of blind node

VI. CONCLUSION

In this research work, a Trilateration based localization algorithm for wireless sensor networks (WSNs) was developed. This was achieved through experimental analysis. From this analysis, we conclude that whenever anchor nodes broadcast packets containing their locations and other sensed parameters, the blind node within the broadcast range can always estimate its distance to the anchor nodes, and if peradventure the blind nodes receive packets from at least three anchors, the blind node can localize its position and send to sink.

REFERENCES

[1] "21 ideas for the 21st century", Business week, Aug. 30 1999, PP. 78-167.

[2] C.Y. Chony and S.P Kumar, (2003), "sensor networks. Evolution opportunities, and challenges", proceedings of the IEEE, Vol. 91. No 8, pp. 1247- 1256

[3] Avinash srinivasan and Jie wu, (2002), "A survey on secure localization in wireless sensor networks." Florida Atlantic University, Boca Raton, F2 USA.

[4] J.C Naves and T. Imielinski., (1997), "Geographic Addressing and routing" in proceedings of MOBICOM '97, Budapest, Hungary.

[5] T. Yan, T. He and J.a stankovic, (2003), "Differentiated surveillance service for sensor networks." In proceeding of first ACM conference on embedded networked sensor system (sensys'03).

[6] A. Nasipum and K.Li, (2002), "A directionality based location discovery scheme for wireless sensor networks." In proceeding of the ACM WSNA '02.

[7] P. Bahl and V.N padmanabham, (2000), "RADAR: An in-Building Rf-based user location and Tracking system." In proceeding of the IFEE INFOCOM' 00.

[8] J. Hightower, E. Boriello, and R. Want. , (2011), "Spot on: an Indoor 3D location sensing technology based on RF signal strength." Technical report, university of Washington.

[9] A. Harter, A. Hopper; P, steggles, a. ward, and P. Webster. (1999), "The anatomy of a context aware application" in proceeding of the MOBICOM'199.

[10] Chris savarese and Jan Rabacy, (2002), "Robots positioning Algorithm for Distributed adhoc wireless sensor networks" Berkeley wireless research centre.

[11] L. Girod and D. Estrin, (2001), "Robust range estimation using acoustic multimodal sensing" in IEEE/RSJ international conference on intelligent Robots and system (IROS), Maul, Hawaii.

[12] L. Doherty, K. pister and L.E Ghaoui, (2001), "convex position estimation in wireless sensor networks". In IEEE Infocom, anchorage,

[13] D. Niculescu and B, Nath, (2001), "Adhoc positioning system". In IEEE Globecom

[14] S. Capkum, M. Hamdi and J.P Hubaux, (2004), "GPS- free positioning in mobile ad-hoc networks". In Hawaii international conference in system sciences (Hicss -34), pages 3481-3490, maul, Hawaii

[15] Kamin Whitehouse, Chris Karloff and David culler, (2007), "A practical Evaluation of Radio Signal Strength for Ranging-based Localization" in ACM international workshop on wireless sensor networks.

[16] Dixon, John C., (2009), "Suspension Analysis and computational Geometry: John Wiley and sons limited

[17] Rappaport, Theodore S., (1996), "Wireless Communications: Principle and practice", New Jersey: prentice-Hall Inc.

[18] Vijay k Garg, (2007), "Wireless Communication Networking", San Francisco: Morgan Kaufman publishers.

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