ISSN 2250-3153

Distribution of localize algorithm for linear wireless sensor network

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Abstract- A distributed localization algorithm for determining the position ofnodes in a structured wireless sensor network is proposed. Detailsregarding the implementation of such algorithm are also discussed.Experiments were performed in a testbed area containing anchorand blind nodes deployed in it to characterize the pathlossexponent and to determine the localization error of the algorithm.The algorithm is shown to have localization error of 0.74m which isbetter than4.73m shown by centroid algorithm for three anchornodes.

Index Terms- Wireless, sensor, Node, Localization Network, and algorithm

I. Introduction

Oil, gas, and water pipelines are considered as the most important infrastructures in many countries and protecting the pipeline infrastructure is one of the important priorities of these countries, it has been required either by government regulations or internal polices to ensure the safety of these assets, as well as the population and environment wherethese pipelines run. In addition, the vandalization of oil pipelines in Nigeria by somerestive youths appears to be threatening the long term development prospects of the country. This calls for a drastic control measure in terms of technology that can be used to checkmate theseoccurrences.These technologies include; from physically walking the lines to satellite surveillance designed to provide a remote facility to monitor and to reportneeded pipeline system status.

In recent years, wireless sensor networks (WSNs) are emerging as a suitable new tool for a spectrum of new applications. These tiny sensor nodes are low cost, low power, easily deployable, and self-organizing. These are usually capable of local processing. Each sensor node is capable of only a limited amount of processing, but when coordinated with the information from a large number of other nodes, these have the ability to measure a given physical environment in great detail. This paper work proposes a simple distributed localization algorithm for wireless sensor networks used for long distance infrastructure monitoring. This algorithm will utilize received signal strength (RSS) range based method to locate the position of nodes.

II. Problem Statement

Research in the field of WSNs is relatively active and involves issues such as efficient routing algorithms, energy conservation technique, and localization algorithm and security mechanisms. However, these algorithms cannot be effectively applied to the class of linear wireless sensor Network needed for linear long distance infrastructure monitoring. Fortunately, the WSN needed for monitoring linear infrastructure such as oil pipeline is a structured network in which the nodes will be deployed along the pipeline and not in an adhoc manner. This work aims at developing algorithm for structured WSNs.

III. Materials

Wireless Sensor Network (WSNs) has been widely considered as one of the most important technologies for the twenty – first century (Business week, 1999).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 (Chony, C.Y. and Kumar, S.P, 2003). Distinguished from traditional wireless communication network, for example, cellular system and mobileadhoc networks (MANET), WSNs have unique characteristics forexample denser level of node deployment, higher unreliability ofsensor nodes, and severe energy, computing and storage constraints (Akyildiz, et al 2002)., which presents many new challenges in the development and application of WSNs.

A WSN typically consists of a large number of low-cost, low-power, and multifunctional sensor nodes that are deployed in a region of interest (Jun zheng et al, 2009). These sensor nodes are small in size but are equipped with sensors, embedded microprocessors, and radio transceivers, and therefore have not only sensory capability, but also data processing and communicating capabilities. These communicate over a short distance via a wireless medium and collaborate to accomplish a common task.

Sensors can be used to detect or monitor a variety of physical parameters or conditions (Akyildis, et al2002)., for example:Illuminousity(light),Sound, Humidity, pressure,temperature, soil composition, air or water quality and attributes of an object such as size, weight, position, speed anddirection. Wireless sensors have significant advantages over conventional wired sensors (Zhao, F. andGuibas, L, 2004). These cannot only reduce the cost and delay in deployment, but also be applied to any environment, especially those in which conventional wired sensor networks are impossible to be deployed, for example, inhospitable terrains, battlefields, outer space or deep oceans. WSNs were originally motivated by

military applications, which range from large scale acoustic surveillance system for ocean surveillance to small networks of unattended ground sensors for ground target detection(Business week, 1999). The characteristics of sensor networks and requirement of different applications have a decisive impact on the network design objectives in terms of network capabilities and network performance. 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.
Localization is the process by which an object determines its spatial co-ordinates in a given field or it can be defined as the mechanism for discovering spatial relationship between objects.

Existing Localization Algorithm

This paper work surveyed different techniques available for localization and proposes a better algorithm for localization of sensor nodes. Chris Savarese andRabacy, Jan.(2002) used a minimum of fouranchor 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.

IV. Methodology

WSN System Model for localization Algorithm

This section presents localization system model that was used to establish the 2D Cartesian coordinates of the blind nodes. Real time experiments were also carried out on an experimental TinyOS-based WSN test bed environment to measure Received Signal Strength Indicator (RSSI) at the receiving nodes in other to estimate distance between communicating nodes. In this research work, the focus is on a pipeline segment which runs on a few kilometres (1-2 km); the sensor nodes on a pipeline segment are assumed to transmit their sensed data (temperature, light andhumidity) to one base station (sink) located in a distance far awayfrom the remote site; and the sensed data is collected through amultihop forwarding scheme. Consider a case where sensor nodes are deployed along a pipeline consisting ofsensor nodes {N1, ------, Nn}. This is used to monitor an oil pipeline segment of length (**L=** 1km). Here, the pipeline segment is assumed to be a straight line. The closest to the sink is Nn and node

N1 is the farthest one as shown in Fig1. It was further assumed that sensor nodes transmit the sensed data in a multihopfashion towards the base station. Let S1x and S1y refer to the X and Y coordinates of the location of sensor N1 in 2-dimensional (2D) plane.

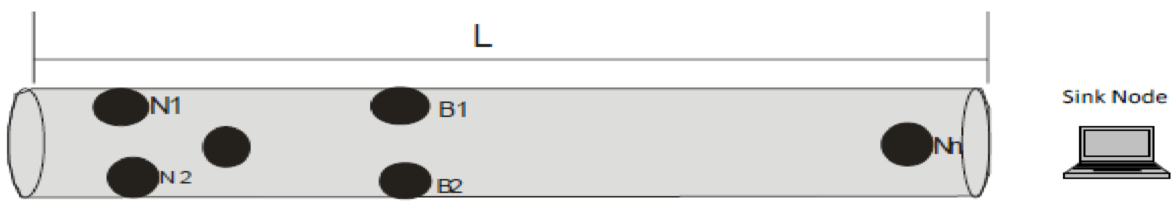

Figure 1: A pipeline segment with nodes

To determine location of sensor nodes along the pipeline constitutes the localization problem. However, some sensor nodes are aware of their own positioning through manual configuration or by placing it in an already known position; these nodes are known as anchor or beacon nodes. All other nodes that are not aware of their position are called blind nodes; these nodes localize themselves with the help of location references received from the anchors. It was assumed that there are a set of B beacon nodes among the Sensors, and there positions (xb, yb) for all b Є B. The positions (xn,yn) for all blind nodes n Є N would be found.

The localization system model is comprised of both the signal propagation model and the trilateration model. Trilateration is a localization technique used when there is an accurate estimate of distance between a node and at least three anchor nodes in a 2Dplane. This method finds the intersection of three circles centredat anchor as the position of the node. The scenario is shown in Figure 2

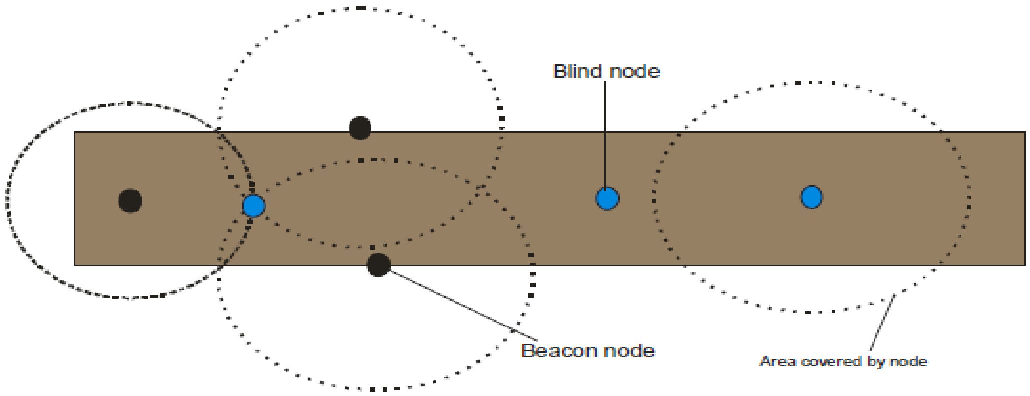

Figure 2: Trilateration of nodes

Deployment Strategy

The problem of how to manually deploy the blind nodes along the pipeline to ensure connectivity gave rise to this section. Topology control for a sensor network is how to set the radio range for each node so as to minimize energy usage, while still ensuring that the communication graph of the nodes remains connected and satisfies other desirable communication properties. The critical transmitting range (CTR) is a term used in describing the minimum common transmitting range, *r*, such that the network is connected. The solution to the CTR problem depends on information about the physical placement of the nodes. If the node positions are not known then the problem now becomes to estimate the range *r* that guarantees network connectivity among the nodes after placement. For example, Panchapakesan P. andmanjunath, D. (2001) show that if n nodes are uniformly distributed in a unit square, then the critical transmission range is, with high probability:

Received Signal Strength Indicator (RSSI) Measurement

Figure 3: Experimental test bed Environment

The test bed environment is depicted in figure 3. The Environment consists of the outdoor environment of the faculty of Engineering wing B, NnamdiAzikiwe University Awka, AnambraState. The Area covers (100 X 50) m^2 around the packing site for staff. The test bed has four (4) telosbmotes(TPR 2420CA) equipped with a chipcon CC2420 radio chip operating in the 2.4 GHzfrequency band and running on tiny operating system(tiny OS). Thenodes 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.

Measurement Environment

The measurement environment is located at Awka, Anambrastate of south-east of Nigeria. Most of the measurements were carried out during the later end of the rainy season (August) and earlyOctober. The area is not a level ground but somewhat sloppy, and the temperature ranges between 28-33 degree centigrade. The area also has high rise buildings scattered around.

RSSI/Distance Measurement

To determine the path loss exponent *n* of the test bed area, RSSImeasurements 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). The nodes ID's is what identify each node when transmitting to the sink. Hence, for this paper work the following node ID's were adopted;100, 200, 300 and 700. The node ID 700 is sorely reserved for the sinknode. Since the path loss exponent *n* is to be determined every direction as considered by placing node 100 at $180^0$of the sink node, node200 at $90^0$of the sink node and node 300 at 270^0 of the sink. 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) etc. carried out can be seen. 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 collected data are presented below

Result and Discussion

Some of the data will be used to determine the pathlossexponent *n* of the test bed area while others will be used to find theRSSI and the estimated distance between a blind node and an anchor node based on the known path loss exponent *n* without assuming it to be 2 as in free space. All these will assist in achieving the proposed localization algorithm.

Table 2 shows the RSSI values in dBm for the three nodes at 5seconds interval. The measurements represent the average measurements carried out during the months of August - September (first month), some were done in the morning hours, others in the afternoon hours while others in the evening hours. The result shows that the further the distance of the nodes from the sink node, the lower the received signal strength indicator values.

Table 1: Total Average Receive signal Strength measurement 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

Table 1 the data collected was used to developa mat lab script for computing the pathlossexponent *n* of the test bed area. From the computation, *n* was computed to be 2.2. Hence, $n = 2.2$ will be used as thepath loss exponent in this paper work.

The results of the measurements for first and second months are depicted. Figure 4 shows the total average of the RSSI values for all the nodes with respect to distance for the first and second month

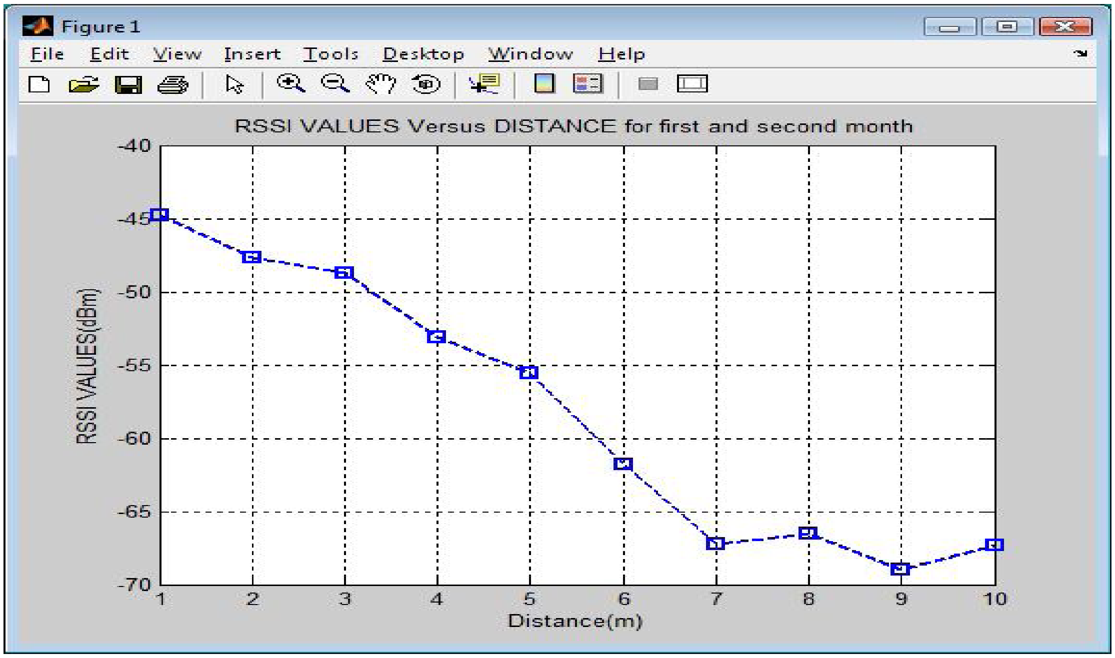

Figure 4: Total Average Values of RSSI versus Distance

Figures 4 shows that as distance increases, the values for the RSSI decreases. Based on the result obtained, one can express distance as x (m) and the measured RSSI as y (dBm) for the test bed area. One can now model the relationship between distance and Received signal strength

Proposed Algorithm

The goal of this algorithm is to determine specific blind node's location within the distributed nodes along a long distant infrastructure. If the positions of the blind nodes are not known ina network, the event these monitor and report cannot 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 upof two phases: initialization phase and the final phase.

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 a linear structure such as pipeline, 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 anchornodes. 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.

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.

Algorithm Implementation

To study the robustness of the proposed localization algorithm, aMATLAB program was developed; this program implemented the algorithm using the *input statement* and other matlabstatements which is more interactive and better for analysis. This is normally called structured programming.

Input Parameters

The table 2 shows all necessary inputs to the algorithm; some of the values have been described already in this work.

Table 2: 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 shows the parameters needed as input to the algorithm in order for it to produce the required output. Path loss exponent n =2.2 was experimentally determined, A= -44.8 was also experimentally determined (see table 1). 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.

Experiment 1

In order to evaluate the algorithm, it was assumed that one has a few nodes been deployed along a pipeline segment of width 36inchs(approximately 100cm) and length of 100m and are within the communication range of one another. The nodes consist of anchor nodes (nodes that are aware of their positions) and blind nodes(nodes that are not aware of their positions).The question becomes; given some blind nodes located somewhere along the pipeline and at least 3 anchor nodes, find the position of a particular blind node and report to sink?

Assumptions

If

1. Xa = 35, Ya = 10 are the 2D coordinate for anchor node A.
2. Xb = 50, Yb = 5 are the 2D coordinate for anchor node B.
3. Xc = 60, Yc = 15 are the 2D coordinate for anchor node C.

The proposed algorithm can locate the positions of the blind node ifthe blind node in question can receive packets (positioning and sensed parameter) from the three anchor nodes.

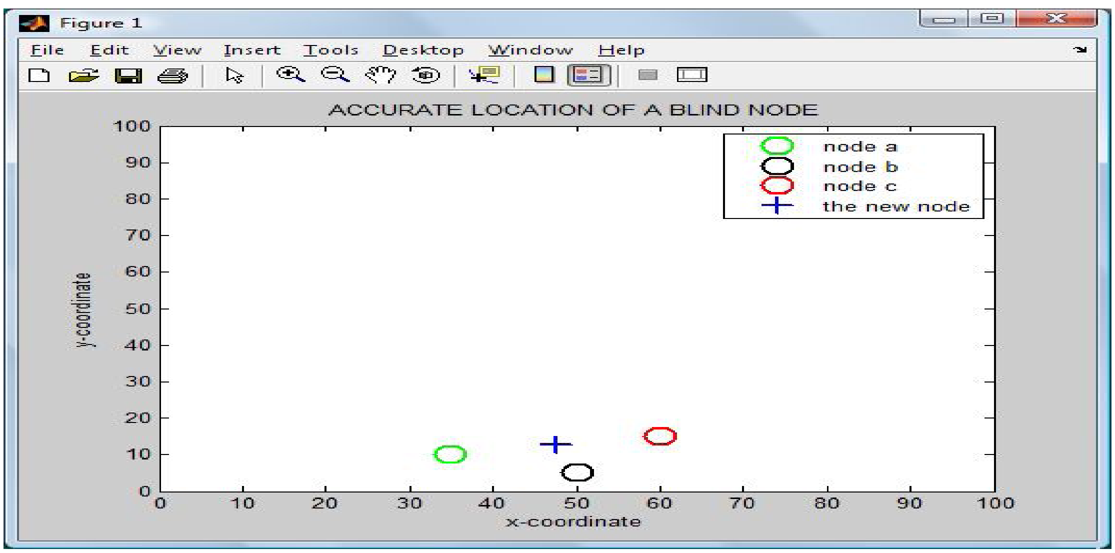

Figure 5: Accurate locationing of a blind node

Figure 5 shows a representation of the assumed pipeline segment with width 100cm and length 100m. Node a, Node b and node care all anchor nodes while the new node is the blind node; the points where these appear in the pipeline segment represent their locations. The position of the blind node was found to be X =47.5cmand Y = 12.6m after the algorithm was implemented for this case.

Hence the 2Dcoordinates of the blind node represent the point of intersection ofthe three anchor nodes. If there is locationing error so that the blind nodes true position is different from the localized position then it means that the position of the blind node does not represent the point of intersection of the three anchor nodes.

Metric for Evaluating Algorithm

- Localization Error
- Distance Error
- Anchor node density

Localization Error

Localization Error is defined as the difference between the estimated and the actual distances between the coordinates of the node

Distance Error

Distance Error is defined as the difference between the estimated distance and the actual distance.

Anchor Density

Anchor density is the number of anchor nodes in a network with respect to other blind nodes. Theoretically more anchors bring higher location accuracy. However, too many anchors cause high-energy consumption and calculation complexity.

Performance Evaluation

In other to evaluate the performance of the proposed algorithm based on the above stated metrics, let's consider a case where 3anchor 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 testbedarea is taken to be (36inch) approximately100cm width and 100mlength, (assumed pipeline dimension).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 shows the summary of data collected while figure 6 shows the accurate position of the blind node at (32.27, 43.87), and figure 7 shows the estimated position (inaccurate) at (31.79, 44.43). The localization error of this algorithm for this case is 0.74m.

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: 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)

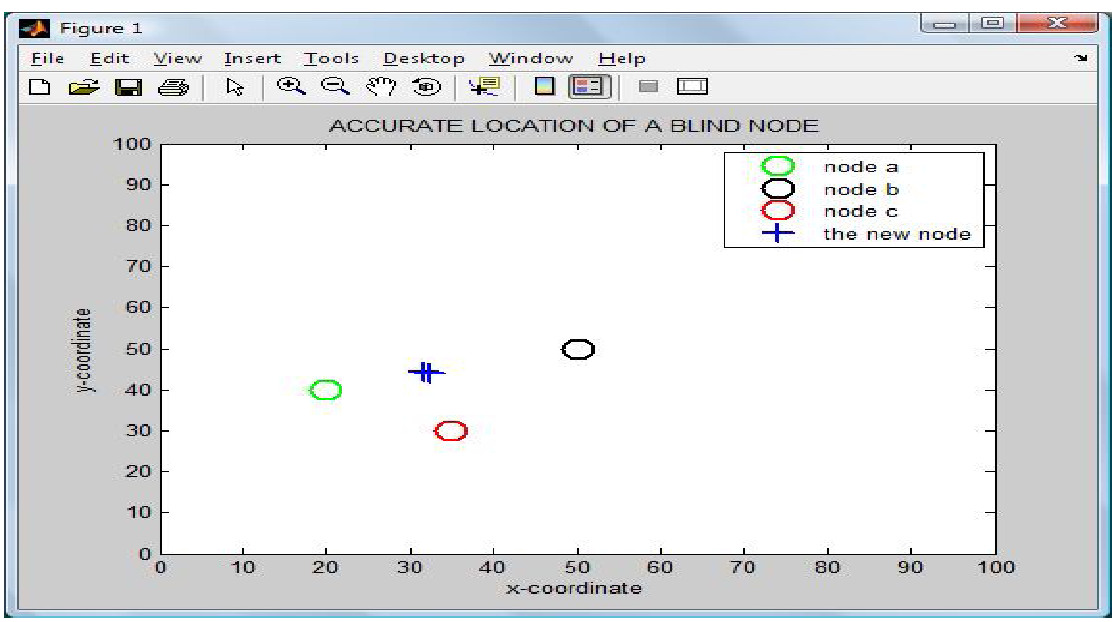

Figure 6: Actual position of blind node (new node)

ISSN 2250-3153

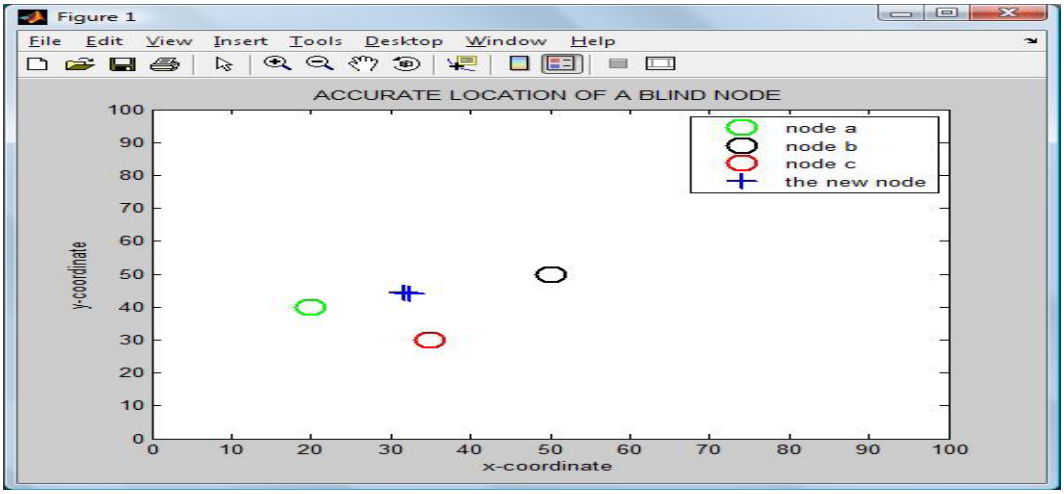

Figure 7: Estimated position of blind node

The distance error between the blind node and anchor node A, anchor Node B and anchor node C are computed to be 0.2m, 0.6mand 1m respectively(14 -13.8, 20 -19.4 and 16 -15) Due to the limited number of nodes available for experiments; assumptions were made to see how anchor density affects the localization error. In the experiment carried out, the Localization errors for three and four anchor nodes for this algorithm were0.74m and 0.56m respectively. Hence, it means that with the addition of one anchor node to the three anchor nodes present in the network, the localization error reduces by 0.18. Based on this fact, one assumes to have anchors (Na= 3, 4, 5, 6, 7) and the localization errors will now be (Le= 0.74, 0.56, 0.38, 0.20, 0.02). The position errors are shown in figure 8.

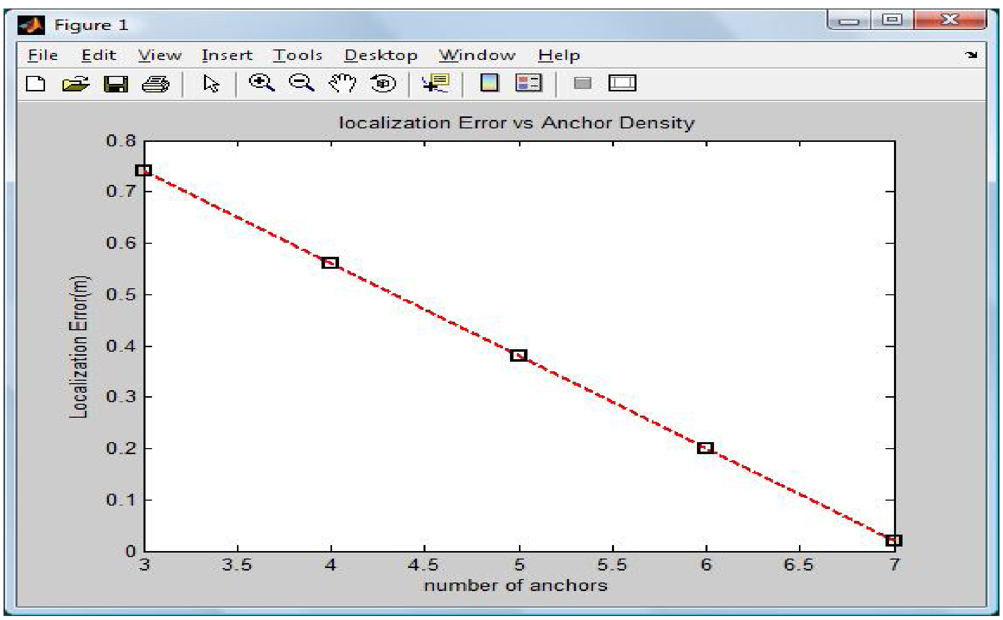

Figure 8: localization Errors vs. Anchor density

From the figure.8 one will notice that as the number of anchor nodes increases the localization error decreases.

Comparative Evaluation

For the proposed algorithm to be evaluated and score high, it has tobe compared with an existing algorithm. The proposed algorithm will be compared with the centroid localization algorithm, which is one of the best existing algorithms. Some of the data needed for comparison will be collected experimentally.

Centroid Localization Algorithm

Bulusu, N.Heidemain, J. AndEstrin, D. (2000).proposed a range proximity-based,coarse grained localization information that uses anchor beacons, containing location information (x_1,y_1), to execute blind no deposition; where i = 1 …N. After receiving these beacons, a blind node estimates its location using the following centroid formula.

$$(x_{est}, y_{est}) = \left(\frac{x_1 + \dots + x_N}{N}, \frac{y_1 + \dots + y_N}{N}\right)$$

(1)

Some of the reasons of comparing the proposed algorithm with thecentroid algorithm are because it is easy to implement and has low computation cost.

Let's still use the experimental data recorded in table 3 as one of the basis for comparison.

In table.3, there are three anchor nodes (anchor A, Anchor B and
Anchor C) with their positions (20, 40), (50, 50) and (35, 30).
To find the position of the blind node, centroid algorithm proposes

That

$$(x_{est}, y_{est}) = (\frac{x_1 + \cdots + x_N}{N}, \frac{y_1 + \cdots + y_N}{N}) = (\frac{20+50+35}{3}, \frac{40+50+30}{3}) = (35, 40)$$

But the accurate position of the blind node in the experiment is (32.27, 43.87), the proposed algorithm estimated the blind nodes position to be (31.79, 44.43). Finding the localization error (LE) for the centroid algorithm. It was computed to be 4.73m. While the localization error for the proposed algorithm is0.74m. This means that the proposed algorithm is quite better than the centroid algorithm when using 3 anchors. Theoretically, the more the anchor nodes in a network the lesser the distant and localization errors accumulated but the trade-off is that it affects the life span of the nodes and is costly.

V. Conclusion

A simple localization algorithm for a special class of wireless sensor networks (WSNs) used for long distance infrastructure monitoring was developed. This was achieved through experiment and by characterizing the test bedenvironment where these sensor nodes will be deployed. A path lossexponent=2.2 was obtained for the test bed environment, this pathlossexponent is used as an input parameter to the proposed algorithm which helps in reducing the localization error exhibited by it. The proposed algorithm is shown to have a localization error of 0.74mwhich is better than 4.73m shown by centroid algorithm for three anchor nodes. From the experiments carried out it was concluded 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. Future works should be done in a real pipeline facility. Quite a few numbers of nodes were used during the real time experiment; for future works more nodes should be used for the experiments.

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