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An Optimized Path Planning Model for Anchor-Free Localization in Wireless Sensor Networks

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ABSTRACT

In Wireless Sensor Network (WSN), localization process is considered as a major challenge which is intended to maximize with minimized traveling distance of the beacon node. Further, the important issue is to improve coverage area of the anchor-based node and accuracy in calculation of the location of nodes. This paper mainly focuses on an enhanced path planning model using beacon node based upon their location. The proposed model focuses to improve coverage of the network topology by moving in zig-zag path fashion so that it will enhance the reachability of message in almost every possible corner of the deployed area. The proposed model is simulated extensively in a self-simulator with different scenarios and compared with SCAN and anchor-based model. The tested performance of the model is presented along with its analytical model. The simulation result shows that the proposed model gives the better performance as compared to all others existing model in terms of percentage of nodes settled and energy consumption.

Keywords : Node Localization, WSN, Wireless Sensor Net- work, Energy Efficiency, Coverage Analysis

I. INTRODUCTION

Underwater Wireless Sensor Networks (UWSNs) are the network of self-governing devices with limited resources in which devices can communicate to each other with the help of water signals. The underwater sensor network is designed to operate inside of water. The communication for UWSN can happen through different media such as electromagnetic radio waves, optical waves, and acoustic waves. EM waves propagate at larger distance through the sea waves at minimum temperature and this needs large antenna with high power for transmission. Thus EM is not ideal for UWSN. As Optical fiber scatters a lot while travelling across the media so it is suitable for short range communication. UWSNs are used in different areas as follows.

(1) For continues Observation of Environment- It can be utilized for measuring the level of pollution, the deep-sea effect of currents and winds, as well as improvise forecasting weather.
(2) From Disaster Prevention – It observes activities from rough positions which provides tsunami, cyclone like notices to coastal areas and keep an eye under surveillance submarine volcanoes.

(3) Help in Assisted Navigation- UWSN can be utilized to locate hazardous rocks inside of waters.

Further, the information collected from sensors should contain the location, time and the measurement of information for the position calculation of beacon node. However, Localization is a way to find out the exact location of an unknown sensor node. We are intersected to find out the exact location of the deployed sensor nodes.

Different types of localization:
(1) GPS-Based Localization- GPS is mainly used to find the different sensing system with some pros and cons. It helps in the way in order to find out geographical positions and establishing as Navigation Satellite Timing and ranging (NAVSTAR) with fully operational global navigation satellite system (GNSS)
(2) Anchor free localization- In this process of localization techniques, only one GPS enabled node is required and with the help of that node all of the remaining unsettled node will find out its position.
(3)Anchor based localization- It is the method in wireless sensor network in which a sensor figures out its location by estimating the locations of either anchors nodes or already located senor nodes with utilization of their distance.

Some challenges related to UWSNs:
(1) Normally in the underwater WSNs it is generally preferred acoustic communication, because of the radio and optical signals having high attenuation and scattering possession at a very high rate as well as these cannot be preferred for long range communication
(2) In UWSNs, sensor nodes depend on batteries, so why all those methods related with data acquisition, process and transmission must require being well-organized and energy efficient.

Three major processes related to node localization methods are message broadcasting, distance calculation and position calculations. In the message broadcasting process the anchor node (vessel node) sends a message and that message is received by the beacon nodes (unsettled nodes) only if they are within the predefined range of the anchor node. The beacon node after collecting that message, which includes the position coordinates of the anchor node and using attenuation property of the energy, it can calculate its approximate distance from the anchor node. Now when the beacon node gets three messages and evaluates three distances, it can calculate its own position using trilateration method. Paper is mainly focused on different node localization algorithms available for localization and propose a better algorithm for localization of unsettled sensor nodes. The working model focuses to improve the coverage of the network of anchor nodes so that by equivalent movement of beacon node it will be able to settle a greater number of nodes.

The remained part of the paper is organized as follows. In section II, some existing literatures are discussed in details. In section III, different existing models are presented. In section IV we have presented the proposed model followed by its analysis with the simulated results in section V. Finally, the paper is ended with a conclusion with some future approaches in section VI.

II. LITERATURE REVIEW

In the recent times, the research in the field of underwater WSNs has contributed so much progress where the process localization is interesting emerging area [1]. In order to observe the underwater atmosphere, UWSN consist of several low cost, self-organized and sensor nodes which always monitor the underwater activities [2]. Recently, different offshores wireless sensor network localization methods have been proposed by many researchers [3]. Due to the different challenging conditions of underwater environments, none of offshores wireless sensor network localization methods can directly apply in UWSN [4]. Lot of researches have been contributed in the field of node localization techniques in the UWSNs. There are multiple algorithms by which the coordinate calculation will be achieved for beacon node. All of the algorithms have their own advantages and disadvantages. Vieira et. al. [5]. The paper gives various design procedure to comprehend energy efficient localization services in underwater. In the range-free based localization algorithms, different types of node localization techniques are there Like different algorithms such as Centroid algorithm, DV-Hop (Distance Vector-Hop) algorithm, APIT algorithm and amorphous algorithm [6], [7], etc. In the centroid Algorithm, every dumb node gets and listens to different signals of beacon nodes. These nodes estimate their own position by a centroid determination from all coordinates of the anchor node which are in the range. The algorithm is straightforward but having high distance inaccuracy.

The authors in [8] have used DV-hop localization algorithm where the beacon node usually counts the minimum number of the hop from the anchor node and then calculates its distance from the anchor node by using the multiplication of the hop number and average distance from each hop. After that the beacon node finds out their position using triangulation algorithms. These algorithms of underwater wireless sensor networks can be divided into two types such as: range- based schemes and range-free schemes [9]. In the range-based category communication, range of the sensor nodes are limited to large scale, only those nodes belong to a communication range of the node can calculate distance computation between that of anchor and dumb nodes and each other by corresponding communication directly. So why the coverage range of localization process depends on its density of the network. Range-based algorithms follows three different processes such as estimating distance, finding out position and refinement. The recursive localization method puts on high localization coverage [10]. This method can be implemented in a large and dense network. In the recursive localization algorithm, we require at least four nodes with known locations and it should be within the communication range of the beacon sensor node that needs to be located. With the predictable mobility patterns of underwater senor nodes, paper [11] talks about a new localization scheme for large-scale underwater sensor network with scalable properties, i.e., it can be used for the small as well as a large number of sensor nodes with mobility prediction where the anchor node moves in a spiral shaped path. And every alternate position it sends the message. An optimality path planning method for the mobile anchor node in UWSNs used in the localization scheme presented by Chia- Ho Ou, et al. [12].

III. DIFFERENT LOCALIZATION MODELS

Distance calculation between dumb node and anchor node- Anchor node or vessel node sends the message in a predefined format. That message format contains the location (x, y, z coordinate), time of message creation, and message itself. If any beacon node is within the range of that anchor node, then that node receives that message and store in the memory area. Now using the below mentioned distance formula, dumb node can calculate their distance from that of anchor node.

$$D= \sqrt{(dx - x)^2 - (dy - y^2} \qquad (1)$$

where, D = distance calculated between anchor node and dumb node, x = X-coordinate of anchor node, dx = X-coordinate of dumb node, y = Y-coordinate of anchor node, dy = Y- coordinate of dumb node.

Equation of the circle i centered at x and y

$$(x - xi)2 + (y - yi)2 = R2 \qquad (2)$$

where, xi and yi is the location of the nod, and Ri is the distance from anchor location to node location.

A. Trilateration method to calculate the position

Step 1- The distance between anchor node and that of dumb node will calculated using equation 1.

Step 2- Now the circles which obtained and the radius of the circle is same as that of distance calculated between that of dumb node and anchor node.

Step 3- now using above equations of circles (2) one inter- section point will be obtained and that intersection point will be the coordinate position of the dumb node. The intersection point can be found out using the equation 3 and equation 4 given below.

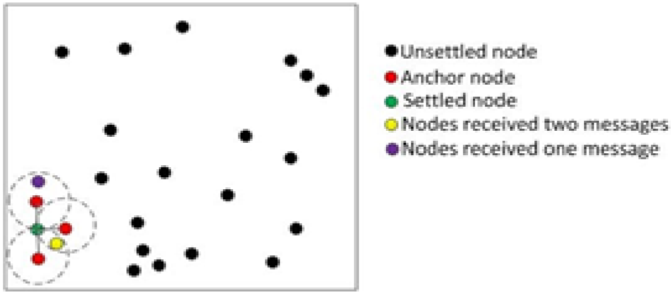

Fig. 1. Process of Localization in Anchor Based Approach

B. Anchor free localization

SCAN-Let the boundary is of the rectangular shape. The anchor node will start from a coordinate at left bottom corner and then after it will move in the horizontal direction and the shift will be according to the range. In every shifted position, it will send the message about its location information. When it active nearer to the boundary, the direction of movement will shift on the axis perpendicular to previous axis. The bacon node which is in the range of the anchor node will accept the message and using time of arrival it will calculate the distance of its own location from the anchor node. The operation of the algorithm is listed below:

Step 1: The anchor node determines its position with the help of the GPS system.

Step 2: Then, it will broadcast a message which will be receive by all beacon nodes which are in the range of the vesselnode.

Step 3: Then the value of the x-coordinate of the vessel node increases by addition of range in x-coordinates value.

Step 4: Further, the vessel node moves in horizontal direction until it will increase the value of the boundary.

Step 5: Then afterwards it changes the direction in upwards.

Step 6: It will change its direction in reverse and it travels in the same way up to its previous coordinates according to the path pattern shown in Figure 2.

Step 7: during the travel of vessel node all of the dumb nodes store maximum three messages. And with the help of that coordinates of vessel nodes that of dumb node calculates its position.

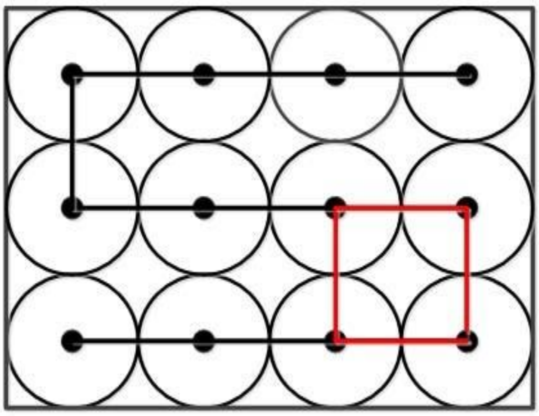

Fig. 2. Vessel node movement in anchor free during localization.

In the figure-2 we can see that during the movement if we take four successive position of the vessel node then the area between the four touching circle can be given by following relation-

Area of circle is πr^2 where, r=radius of the circle. Area of square is A^2 where A= side of the square Now in this figure area can be calculated as follows:

vacant area(Q) = area of square – area of circle
= $4r^2 - \pi r^2$(four quadrant form a circle)
= $0.86r^2$

C. Issues related to the Localization Process

Three circles linearity problem: It can be possible that in some cases the three circles will not intersect each other. Then in that case the dumb node cannot be able to calculate its position. This situation is represented in the figure-3. So, there are different types of algorithm which can be used to tackle this problem.

During localization process, when this problem will be raised then beacon node will delete one of the message received previously from anchor node and again it will start the process of receiving messages. So again, when it reaches to three, is starts the position calculation again.

When Obstacles Encountered During Prescribed Path:

This is the most commonly happening scenario while dealing with algorithms related to underwater sensor networks. During the path traversed by the vessel node, it may be possible that some obstacle hinders the path of anchor node, e.g., in the underwater environment, some big rocks, shark like fishes and may more obstacles can be detected. So how to deal with such types of problems is big the challenges for all of us.

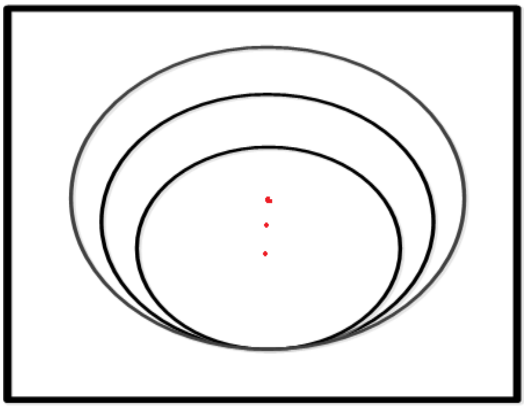

Fig. 3. 3-D Circles in the Collinear Form.

The localization algorithm should be able to deal with such type of scenario on self. We have also considered such type of scenario in our node localization algorithm. Here, the anchor node is supposed to move just around the obstacle till it encounters the next projected point as shown in figure-4.

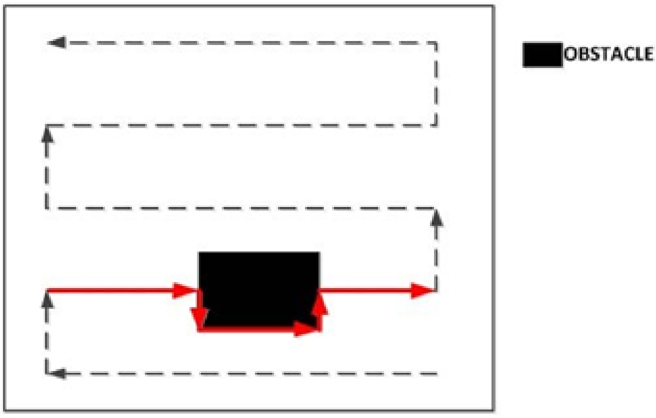

Fig. 4. Path overcome by beacon node.

What is the solution for obstacle problem in localization? Anchor node can locate out the position of the obstacles with the help of attenuated signal. It sends the signal in advance if this signal reflect back to it, then it may be possible that some types of rocks may be there. After finding the position of the obstacle, the anchor node can easily deal with it. When vessel node reaches the boundary wall of the obstacle it changes its direction toward the different other corner of the obstacle. It will cover the path according to the shape of the obstacle. The possible path traversed by the vessel node have already shown in the figure. And the coordinates of the anchor nodes keep updated in the same manner as it was previous.

IV. PROPOSED MODEL

Considering the main objective of data collection process from the nodes of sensor network, here we have proposed an more efficient localization model. In this model, we have tried to improve the percentage of nodes to be localized along with the energy consumption to carry out through the localization.

Further, we have tried to solve the linearity problem by receiving another message either from beacon node or any neighboring node upon further request. The proposed model focuses to improve the percentage of k-coverage by placing the dumb nodes in a rectangular spiral path instead of rectangular or squared manner. The different equations show the difference of coverage due to different positions maintained by dumb nodes. In this model, the anchor node follows some parallelogram trajectory instead of moving its direction on perpendicular axis when it reaches nearer to the boundary wall. The projected path by the proposed algorithm is shown in figure-5.

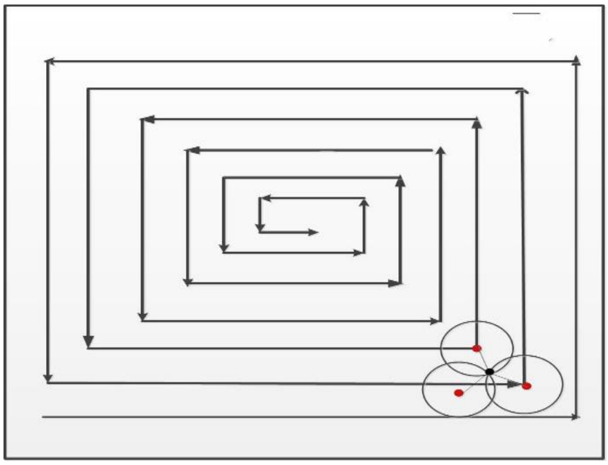

Fig. 5. Vessel node movement in proposed anchor free during localization.

Coverage Analysis

Let us consider two cases where the positions of dumb nodes create a square and equilateral triangle. The area due to three beacon node's location would be given by following equations

Vacant Area= area of triangle – area of one section *3

$= (0.4333*4*r^2)- (\pi r^2/6) *3= 0.004\, r^2$

The nodes maintain a counter to memorize the number of messages received from anchor node. Initially it is assigned to -1. The counter incremented by one when it receives a message. The nodes calculate their location by using three reference points collected from three messages using triangulation method. Nodes cannot calculate their location when three reference points are found to be collinear. In this scenario, the node rejects the third message and decrements the counter by one and allows the node to receive another message from the beacon node or any neighboring node.

V. RESULT AND ANALYSIS

The proposed model is simulated for different possible parameters as mentioned in the table I to VI. Further we compared it with different anchor based and anchor free model that uses SCAN path planning algorithm. It is also observed that anchor-based approach shows better output as compared to others ancho-based algorithms. In semi- dense network topology, anchor free localization performs better than anchor-based localization algorithms.

However, the different path planning algorithms also provides different outputs and performance but, in our simulation, we have analyzed the different topologies such as number of nodes are taken as 50, 100, 150 ,200 and 250. Similarity, the transmission range of anchor nodes varies from 100, 150, 200 and 250 meters.

TABLE I
Number of Nodes Settled (for range 100)

No of Nodes	Anchor based	Proposed Model
50	46	47
100	92	92
150	140	141
200	186	188

TABLE II
Number of Nodes Settled (for range 200)

No of Nodes	Anchor based	Proposed Model
50	42	46
100	87	89
150	131	135
200	176	179

TABLE III
Number of Nodes Settled (for range 300)

No of Nodes	Anchor based	Proposed Model
50	39	44
100	82	85
150	124	129
200	168	170

While sending the messages anchor nodes also loss it's energy so we have done the energy calculation also based upon that we can show how optimal our algorithm is based upon energy efficient.

TABLE IV
Energy Remaining After Nodes Settled (For range 100)

No of Nodes	Anchor based	Proposed Model
50	0.612	0.637
100	0.635	0.643
150	0.631	0.639
200	0.631	0.629

TABLE V
Energy Remaining After Nodes Settled (For range 200)

No of Nodes	Anchor based	Proposed Model
50	0.628	0.636
100	0.643	0.647
150	0.640	0.642
200	0.644	0.644

TABLE VI
Energy Remaining After Nodes Settled (For range 300)

No of Nodes	Anchor based	Proposed Model
50	0.625	0.661
100	0.640	0.663
150	0.643	0.667
200	0.646	0.669

VI. CONCLUSION

In this paper, an enhanced path planning model is proposed. The main objective of the model was to localize as more nodes as possible by removing linearity. The proposed model leads to enhance coverage implicitly by 0.082%. The mathematical analysis of the proposed model shows that the model forms by 0.082% whereas the simulation shows more than 2% better than SCAN model. The simulation model shows better result due to the randomness of the node deployment. Thus, it can be concluded that the proposed model will outperform minimum of 0.082% better than SCAN model. The other direction of the work mentions that the path covered by the beacon node is not considered. Further, accuracy of the localization is not measured which is calculated using trilateration method. Hence, the author claims that the proposed model will able to localize a greater number of nodes than SCAN model. Furthermore, the model will be applied on other models like, S-SCAN, HILBERT

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