LRCLE – LOCATION FINDING ALGORITHM TO REDUCE COMMUNICATION COST AND LOCALIZATION ERROR FOR ACOUSTIC SENSOR NODES IN UWSN

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Abstract: Underwater environment is the topic of great interest for many researchers. Underwater sensor networks replaced the disconnected, large and costly instruments and equipment to very small size, intelligent equipment which can connect with each other by acoustic signals. Among all researched technologies, localization is a critical task to do. One common solution for the localization is to install costly Global Positioning System (GPS) system, but due to increased cost one cannot install GPS in every sensor nodes. So, in this scenario localization scheme is needed that can track the position of the unknown sensor nodes in UWSN. Authors have proposed a localization scheme in this paper, along with it considers the error due in depth calculation, temperature, and salinity while calculating the location.

Key words: Underwater Acoustic Sensor Networks, 3D Localization, Euclidean Distance, Trillaration, Node density, Localization Error.

1. INTRODUCTION

More than ¾th area of geographical area is covered by water. That's why underwater environment is the topic of great interest for many researchers. A large number of underwater applications have been investigated in [4]. In this paper the authors explain monitoring environmental activities, life under sea, earth quake monitoring, disaster detection and prevention, mine investigation, etc. are main application of wireless sensor networks. Many technologies have been researched like routing in under water network, secure routing protocols, detection of clone node, localization algorithms. Localization is a critical task to do to get the location specific data. One common solution for the localization is the GPS system, GPS system installation can be done in some nodes. But one cannot install GPS in every sensor nodes that will be too costly. So, in this scenario localization scheme is needed that can track the position of the unknown sensor nodes in UWSN. Localization algorithm can be categorized in different ways as discussed in various papers, mainly Distributed Schemes, Centralized schemes.

2. LITERATURE REVIEW

In [6] authors describe LBL and the usage of Automatic underwater vehicle for locating distance and coordinates. One other classification of localization algorithms is based on signal strength measurement suggests by authors in [12]. These algorithms used approximate information of nodes and cost. One another algorithm named Three Dimensional Underwater Localization (3DUL) proposed by authors in [6], 3DUL uses minimum energy expenditure. In [2][3][4] authors explain multihop Underwater Sensor Nodes (USN) they are used to converse with the user at surface. These networks are installed with GPS receivers along with the modems. GPS installed buoys are a good choice to calculate position. But limitation is that, it can calculate the location of a node that must be in contact to at least three such buoys. So, by Trillaration centralized system it can compute the space between node to anchor nodes and approximate the location of node. Authors in [1] describes a location approximation technique based on Angular approximation algorithm. In [15] authors propose an underwater network with different nodes say anchor nods, nodes on surface and simple nodes. In [7] authors explain Fault-Tolerant Wireless Communication system for process control in wind power station. In this paper author used the ZigBee coordinator to create and maintain the wireless networks. This paper proposed algorithm which increases energy efficiency by properly deployed the nodes, selecting appropriate topology. This algorithm is also needed one location estimation algorithm. In [5] authors describe an energy efficient algorithm for routing in wireless sensor networks. This algorithm considers node mobility which in result decreases the network lifetime. Energy consumed in node mobility. Also, after every movement location need to be estimated for next data transfer. In [8, 10] authors proposed one algorithm for Localization of sensors by base station in wireless sensor networks. This algorithm uses a simple centroid model to approximate the nodes location. Authors in [12, 13] explains multi clustered energy efficient routing algorithm with randomly moving sink node. Again, this needs to have one algorithm to locate the positions of nodes and calculating errors.

3. PROPOSED ALGORITHM: LRCLE OVERVIEW

For finding the location of a Node authors used the concept of Projection. Before localization algorithm (LRCLE) network need to be deployed. Network can be deployed in any way it can be deployed by fixing the locations of sensor nodes or by deploying movable nodes.

Steps in Proposed Algorithm:
Step 1: Node deployment
Step 2: Distance Estimation and
Step 3: Location approximation.

3.1. Node Deployment

Three Dimensional environments for Underwater Sensor Networks. Here in this arrangement whole network is divided into equal size partitions in 3D. Each partition hes a cluster heads are installed with GPS receivers to determine their worldwide positions along with this they have medium range Radio Frequency transceivers to communicate with each other. These nodes have multiple functionality, installed with acoustic transceiver to communicate with UW sensors nodes. Cluster head at lower heights are equipped with a high range of Radio Frequency satellite transceiver to communicate with the sink node at water surface. Other nodes are deployed at various heights these nodes might be fixed at ocean bottom or with a float body. Fixed node is simple and accurate to work with. The challenges are with the movable body of sensor node which are called drogue. So here authors have to find the location of mobile nodes, cluster heads which are at higher depths. This can be finding out by two steps Distance Approximation and Location Estimation described in further sections. The distance between sink node and CH could be finding with the help of Distance Approximation.

After deployment location is estimated. LRCLE Distance approximation works in two steps. First step is Distance approximation and second is Projection.

3.2. Distance Estimation

Sensor nodes calculate its distance with the cluster heads. In underwater environment, mobile nodes move in the water due to water currents. Cluster heads broadcast a message containing its ID and location with its full transmission power. The nodes who listens to this message, reply by sending a message back to cluster head. Cluster head send acknowledge message to it. By this message propagation sensor nodes guesstimate their distance with the cluster head by checking the propagation delay. After calculating the propagation delay, one can calculate the distance by multiplying the propagation delay with the estimated speed of sound. Here paper say sink node is the anchor node whose location is known to all. Unknown node is that whose location has to find.

3.3. Location Estimation

For Location estimation each unknown node need at least three nodes to be in range whose locations are already known.

• **Anchor Node Selection.** Here cluster head are acting as the anchor nodes. Cluster head are equipped with GPS receiver. They can estimate their location worldwide by Trillaration method. Cluster nodes can act as anchor node to calculate the distance of unknown nodes. If unknown node is in the range of the cluster head. Then it could become anchor node by satisfying the equation of circle.

• **Intersection of planes.** In 3 Dimensional, planes can either be in parallel to other planes or can intersect by a straight line. The condition for two planes to be in line is the multiplication of two normal vectors n1 and n2 is zero. If n1*n2>0 then these planes are not parallel. Here given a directional vector formed by the cross product of the vectors for the intersection. It is used as a reference vector in the way of the line.

$$<a_1, b_1, c_1> \mathbf{x} <a_2, b_2, c_2> = <a_{12}, b_{12}, c_{12}> = k \qquad (1)$$

Here the vectors $n_1 = <a_1, b_1, c_1>$ is perpendicular to the plane $a_1x - b_1y + c_1z = k_1$, vector $n_2 = <d_1, e_1, f_1>$ is perpendicular to the plane $d_1x - e_1y + f_1z = k_2$ *and* $n3 = <g_3, h_3, i_3>$ is perpendicular to the plane $g_1x - h_1y + i_1z = k_3$. Where 'k' is known as directional vector to line which is created by connection of two planes.

• **Intersection of a line and a plane.** In three dimensional areas, line can intersect the plane or can be in parallel to the plane. To check this condition where line is parallel, or intersecting can be done by the dot product of normal vector of plane with directional vector

k. If n2*k=0 then this means that the k is vertical to plane having normal vector n3. If line is parallel, then it will not intersect with the plane also if line is not parallel then it will intersect with the plane at some point.

3.4. Location Estimation Algorithm

In this location estimation scheme, the formula to estimate the error is given below:

$$\text{Location error } \S = \sum_i^n (X - xi)2 + (Y - yi)2 + (Z - zi)2 - di^2 \quad (2)$$

Where (X, Y, Z) are the estimated location coordinates of the unknown sensor node Ni, (xi, yi, zi) are the coordinates of i's location of anchor node, di is the distance in between the unknown node Ni and the anchor node i.

This technique is suitable for locating the new nodes when have knowledge of location of at least more than two anchor nodes. But in case of very first node to be an anchor node. Paper have defined a normalized value of § denoted by €. If the node is first anchor node, one threshold value of € value is defined. If €>threshold value only then unknown node can become anchor node.

$$€ = 1 \text{ if the node is first anchor node} \quad (3)$$

$$€ = 1 - \S / \sum (X - x_i)^2 + (Y - y_i)^2 + (Z - z_i)^2 \text{ for other nodes} \quad (4)$$

Algorithm LRCLE

Input: Nodes of various categories, Sink nodes, Cluster nodes, Simple sensor in UWSN Environment.

Output: Find location of unknown node.

1. Node deployment: It can be done using any predefined algorithm or Random algorithm. In Random algorithm, nodes are
2. Distance Estimation is done in second step by sending messages to other nodes.
   For (i=0; i<n; i++)
   {
   Nodes SN_i send signal to SN_{i+1} at a particular time say t1.
   SN_{i+1} receives this signal at t2.
   }
3. For (i=0; i<n; i++)
   {
   SN_{i+1} send a reply message with its id at time t3.
   SN_i receives this reply message at time t4.
   }
4. Consider $t_2 = t_1 + t_p + T_{error}$……….. (5) and
   $t_4 = t_3 + t_p - T_{error}$……….. (6)
   T_{error} is the error caused due to inaccuracy in clock of node.
5. Calculate t_p (propagation delay).
   $$t_p = (t_2 - t_1) + (t_4 - t_3) \ldots\ldots\ldots(7)$$
6. Calculate Distance= $t_p * c$………… (8)
7. Repeatedly Select Anchor Node for all unknown nodes.
8. Calculate Location of node using techniques described in section 4.4.
9. Calculate Localization error as per equation (2).

4. ERROR CALCULATION IN LOCALIZATION ALGORITHM

4.1. Average Error Estimation with Effect of ocean parameters

This error is caused by the error in calculating the distance between node whose location is to be estimated and the anchor node. If there is no error in distance than our technique works fine. Distance measurement is inclined by speed of sound which again depends on the temperature, salinity and depth8.

Now the formula to calculate distance is depends on speed. So for calculating the erroneous distance8 a matrix is formed of distance Dij (distance from i to j). Dij will be equal to Dji.

$$D_{ij}= D_{ij}\ ((d_2/d_1)-1)\ when\ D_{ij}<=R \quad (9)$$

$$D_{ij}= -1\ when\ D_{ij}>R \quad (10)$$

Here R is the communication range. D2 and d1 is the distance calculation in two ways by varying speed due to temperature, salinity, latitude and depth.

4.2. Effect of Depth measurement on Average Error

Second error is the calculation of depth. Authors are assuming that depth of any node can be calculated by the pressure measurement.

5. PERFORMANCE ASSESSMENT

For calculating the performance, authors have deployed 500 nodes in the area of 100m* 100m *100m region. Cluster head are acting as the anchor nodes. Authors are evaluating the performance of this paper in terms of Localization exposure, Average communication cost and Localization error and simulating this work in MATLAB.

Standard communication cost: This is calculated by taking the Ratio of Overall messages transmitted and received in the network by the number of localized nodes. Here, we are showing two scenarios, first when anchor percentage is 5% and second is when anchor percentage is 20%. Four algorithms named Euclidean Distance, Recursive Estimation and R1 has been compared with LRCLE. Cost for Recursive Estimation is constant throughout; in comparison to that LRCLE have varying Average communication cost in various node density levels. Having less cost among all algorithms (fig. 1).

Localization error: It is calculated by checking the difference between the real locations of the nodes to the estimated positions of all nodes. Graph showing the data for Localization error with respect to (w.r.t) the node density in two scenarios, anchor percentage 5% and 20%. It is shown in the figure 2 that LRCLE have the minimum error w.r.t node density compared to other algorithms.

Fig. 2 is showing that Localization error increases with the increase in the density. LRCLE is showing higher error in comparison to other two schemes in case of low density levels, but it decreases when density is increases after an interval.

Coverage: It is defined as the ratio of the nodes localized to the total nodes. Fig. 3 shows the Localization Coverage v/s Node Density. It is compared with the algorithms which proposed location approximation by Euclidean Estimation and the Recursive estimation Technique. LRCLE is giving better results as compare to algorithms proposed by algorithm proposed in [14] and [15]. It is shown in the figure 3 that LRCLE have the maximum location coverage w.r.t node density, compared to other algorithms.

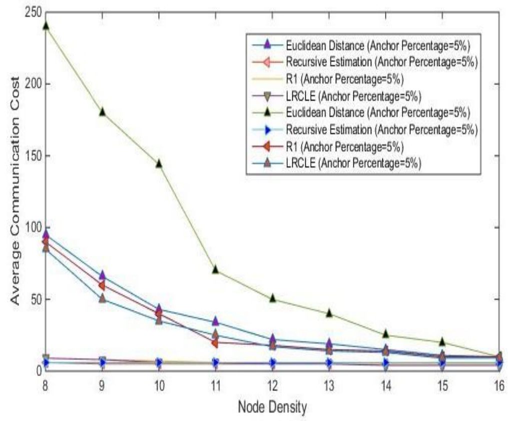

Figure 1. Average Communication Cost v/s Node Density

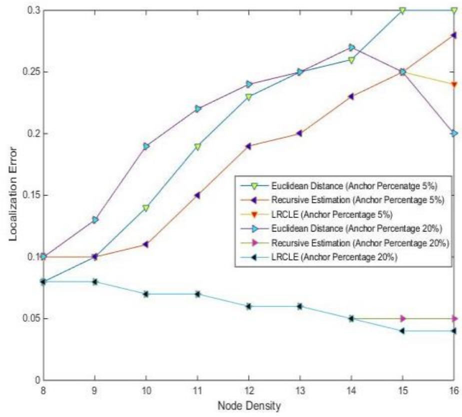

Figure 2. Localization Error v/s Node Density

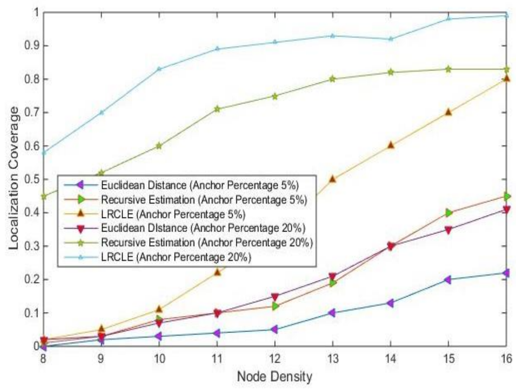

Fig. 3. Localization Coverage v/s Node Density

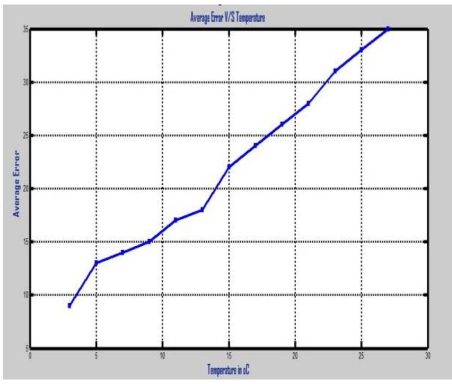

Fig. 4. Localization error v/s Temperature in ^{O}C

Paper has also examined LRCLE in various conditions which can lead to the increase in Localization error8, 12 (fig.4). The parameters papers have considered are assumed to be errors prone are Temperature, Sound Speed and difference in depth measurement (figures 5 and 6). Temperature range is between (3 to 27oc). Latitude and Salinity are kept as constant. Salinity =30%, Latitude=60%. Also calculated Localization error with respect to the difference in depth measurement. Depth is measured by pressure level. So, depth is not having any active role in distance approximation, but it will affect the Location estimation13. The error comes out by applying all these parameters are very low and can be negligible. Simulations are taken by varying depth estimation by pressure level from 0.03 to 0.24m/s.

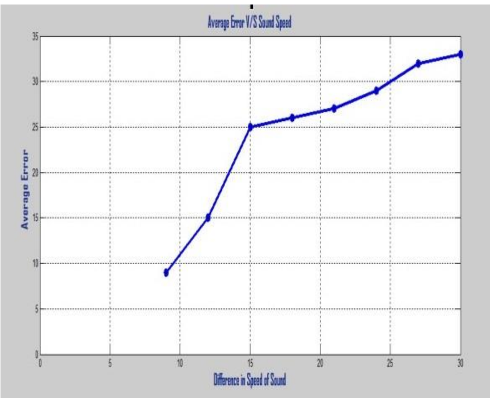

Fig. 5. Localization Error v/s Sound Speed

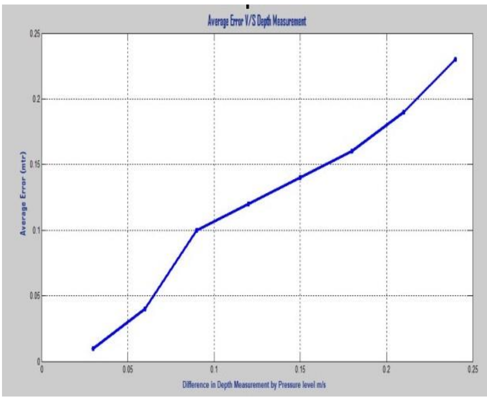

Fig. 6. Localization error v/s Difference in Depth Measurement

6. CONCLUSION

Authors have proposed a Localization algorithm LRCLE, which can be used for estimating the location of unknown nodes. It has been compared to various known algorithms in previous section. Tabular and graphical representations of results have been shown. It is clear that LRCLE is having improvements in terms of various chosen parameters, like Localization Coverage, Localization Error, and Average Communication Cost. Three parameters like sound speed, temperature and depth measurement has been taken and showed their influence on LRCLE in graphs. This is very less and can be negligible. Overall performance of LRCLE is better from compared algorithms.

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