

Advancement in range based scheme for node localization of underwater acoustic networks

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Abstract

The underwater acoustic network is the type of network which is deployed under the deep sea or ocean to gather underwater information. The sensor node position estimation is a major issue of the underwater acoustic network. The process of estimating node position is called node localization. In the existing RSSI based approach for the node localization has a high delay which reduces its efficiency. The technique needs to be designed which localize a number of nodes in less amount of time. This research is based on the advancement of the range-based scheme for node localization. In the proposed scheme mobile beacons are responsible for the node localization. The beacon nodes send beacon message in the network and sensor nodes respond back with a reply message. When two beacons receive the reply of a sensor node that is considered as a localized node. The sensor nodes which are already localized will not respond back to the beacon messages which reduce delay in the network for node localization. The simulation of proposed modal is performed in MATLAB and it shows that proposed scheme performs well in terms of a number of nodes localized.

Keywords: Mobile Beacons; Range-Based Scheme; Node Localization; Time Synchronization

1. Introduction

The numerous unexplored applications can be sensed using the underwater networks and their environments can be observed and predicted. For exploring the natural undersea resources and collecting important scientific data from them [1], the underwater sensors are equipped with deployment of Unmanned or Autonomous Underwater Vehicles (UUVs/ AUVs). Amongst the underwater devices, communications are enabled in order to make the applications more potential. The sensors and vehicles are deployed underwater and with the help of acoustic links, they are networked with each other such that the monitoring tasks can be collaborated within Underwater Acoustic Sensor Networks (UW-ASNs) [2]. Within the UWSNs, there are mainly three different sensor nodes deployed which are the anchor nodes, unknown nodes as well as reference nodes. The surroundings data is sensed with the help of unknown nodes [3]. In order to localize the unknown nodes, anchor nodes are deployed which can utilize the GPS systems or artificial arrangement in order to acquire the positioning of nodes in advance. There are localized unknown nodes as well as initial anchor nodes present within the reference nodes [4]. The manner, in which a node determines its position using only particular localization technologies and limiting communications amongst the anchor nodes or reference nodes, is defined by the localization process of an unknown node. The positions of the sensor nodes are important to be known within the three dimensional topology such that the potential gains of underwater applications can be realized efficiently [5]. The capability of the underwater sensor network can be enhanced by associating the sampled data with three-dimensional position information [6]. In order to raise the alarm, the best node that can be used is the sensor reading which crosses by and does not include within it the location information about

the possible submarine. The submarine can be tracked and more efficient precautions can be taken by combining the data along with the location information [7]. The geographical routing protocols which ensure scalability and availability of required signaling features use positional information for underwater scenarios [8]. There are three broader classifications of the localization algorithms. All the sensor nodes are static within the stationary localization algorithms within first classification. To the surface buoys or ocean floor units that have fixed locations, the sensor nodes are attached [9]. All the sensor nodes are mobile within the mobile localization algorithms which is the second classification. In order to control the movements, the water currents are freely drifted or the propelled equipment's are utilized [10]. There is co-existence of stationary and mobile sensor nodes within the third category which is the hybrid localization algorithms. Some of the localization algorithms are explained below:

1.1. Area localization scheme (ALS)

It is not feasible to recognize the exact location of each unknown node within the large scale UWSNs [11]. Thus, in order to estimate the position of each unknown node present within a specific area instead of recognizing the exact location, the efficient Area Localization Scheme (ALS) is proposed [12]. In order to localize the unknown nodes, signals need to be sent to various levels of power which is done by the anchor nodes. The signals need to be listened to and the IDs of the anchor nodes need to be recorded along with their relevant power levels by the unknown nodes. Towards the sink node, the recorded information is transmitted along with the gathered data [13]. The map of areas that are partitioned by all the transmitting signals generated through anchor nodes is generated by the sink node with the help of appropriate signal propagation algorithms.

1.2. Hyperbola-based localization scheme (HLS)

In order to localize the nodes and model and calibrate the normal distribution for estimation of error [14], the Hyperbola-based Localization Scheme (HLS) technique is proposed [15]. This technique avoids the utilization of circle-based detection and least squares algorithm based location estimation that is commonly used.

1.3. Asymmetrical round trip based localization (ARTL) algorithm

Within this proposed technique, it is assumed that packets are received by the anchor nodes differently which is however not possible in case of the unknown nodes [16]. The distances amongst the anchor nodes and unknown nodes can be determined with the help of basic ranging mechanism.

1.4. Node discovery and localization protocol (NDLP)

The localization of large numbers of unknown nodes through continuous selection of seed nodes an anchor-free and GPS-less algorithm is proposed here which is known as NDLP [17]. There are various issues also which arise due to the deployment of this technique. There is higher communication overhead required during the node discovery phase. In order to choose the seed nodes within the message exchange, each node requires its participation due to which the energy consumption also increases [18]. There is huge time required in order to select the seed node which results in increasing the localization time.

2. Related work

Yuhan Dong, et.al proposed an event-driven technique for underwater surveillance which was named as Reverse Localization Scheme (RLS) [19]. As direct path, the strongest arrival or the first arrival is selected by RLS approach. Due to severe multipath effect present within the underwater acoustic channels, this mechanism does not provide accurate results. By assignment of each path with a possibility that it can be a direct path, median RLS (MRLS) is proposed here which helps in choosing median path and weighted RLS (WRLS). The proposed schemes have been validated as per the simulation results and it is seen that in comparison to MRLS and several other traditional techniques. Md. Farhad Hossain, et.al proposed and investigated the various tree-dimensional cluster-based underwater wireless sensor network architectures that are applied to identify the intruders within underwater applications [20]. The intruder that enters the network area is identified by the sensor nodes as well as cluster heads present within the architectures. In order to estimate the 3D location of intruder, the important information is forwarded to the base station from the sensor nodes and cluster heads. In order to evaluate the proposed network performance within the salty seawater scenario, extensive simulations are performed here. In terms of error in the distance and the direction estimations, the performance of localization accuracy is compared within different mechanisms. Sergej Neumann, et.al proposed a novel localization technique with respect to the attitude estimation namely deep net localization [21]. There is no active data exchange required in this approach and in order to perform localization, regular communication is used within the network. It is seen through the simulation results that the attitude estimations on simulation and real data are good in comparison to other techniques. Amongst the elevation angle and attitude error there is a strong correlation seen which shows that for small elevation angles, the proposed technique outperforms other techniques. Jing Yan, et.al presented that within the clock synchronization and node mobility constraints, the UASNS face localization issues [22]. Thus, by including active as well as passive sensor nodes within the network a hybrid AUV architecture is proposed here. Comparisons are made against the synchro-

nous localization algorithms and proposed mechanism and it is seen that there is enhancement in the accuracy of localization. Also, there is reduction in localization time within the proposed mechanism in comparison to other search-based localization techniques. Yashwanth N, et.al proposed a localization scheme for the underwater acoustic networks. Node mobility is considered and the localization of unknown nodes is done within this work [23]. Within the localization procedure, the nodes participate large number of nodes participate since the positioning scheme is recursive in nature. With the help of proposed approach, the battery power of beacon nodes is conserved and the lifetime of the network is increases as per the simulation results.

3. Research methodology

3.1. Range based scheme for node localization

As shown in Figure 1, an underwater sensor network is deployed by distributing the sensor nodes randomly. In order to monitor the specific region, the sensor nodes are deployed at different depths. There is fixed communication range provided to the special sensors along with assignment of particular monitoring tasks in this scenario. In order to localize the other sensors nodes which are called anchor nodes [24], there is a need to know the location of some special nodes in advance as per the proposed localization technique. Within the anchor nodes, some mobile nodes are utilized which are also known as mobile beacons. Utilizing extra weight, the mobile nodes can dive and rise within the sea level in a vertical direction. The mobile nodes rise again in order to reach the sea surface after touching the deepest point of deployment. When the nodes float over the surface of sea, they receive their coordinates with the help of GPS receiver. The nodes dive within the water towards the monitoring area after this step. When the node goes to the depth, there is a change in only the z-coordinate of the mobile beacon. In order to measure the depth, there is pressure sensor present within both mobile beacons and sensor nodes. Within the water, the diving speed and communication range are fixed for all the mobile beacons. When the nodes dive within the sea, acoustic transceiver is utilized in order to broadcast the localization messages. At fixed beacon interval (b_i), the localization messages are broadcasted by these nodes. The fixed time interval in which the messages are broadcasted by the mobile beacons is known as the beacon interval. At the time of instance, there is a mobile beacon id, message number as well as coordinates of mobile beacon present within the localization message. The broadcast messages that are transmitted by the mobile beacons are listened passively by the sensor nodes. In order to identify the distance between sensor nodes and the mobile beacon, broadcast messages are utilized by them [25-28]. Within the underwater network, sensor nodes are assumed to be static in nature. In order to identify the location of sensor nodes, their distance from three mobile beacons is calculated. There is a need to identify the coordinates of x and y only since the depth of each sensor node is already known. With the help of communication range and the beacon interval of mobile beacon, the coverage of monitoring area is known [26]. In order to ensure that the maximum numbers of sensor nodes are covered, there is a need to provide large coverage of the mobile nodes.

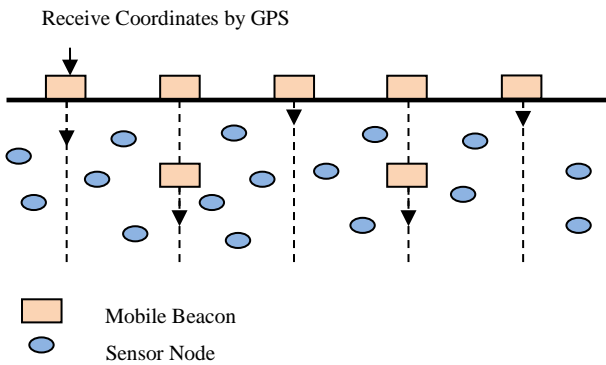


Fig. 1: Node Localization Scenario.

3.2. Advance range based scheme for node localization

The advance range based scheme is the improvement of the range based scheme for node localization. In the advance range based scheme only the distance parameter is considered for the node localization. As shown in figure 1, the beacons are deployed to localize position of the sensor node. The beacons send beacon messages in the network and sensor nodes respond back with the reply message [27]. When the beacons receive reply message, it will check the time of interval. On the basis of time of interval, beacons estimate distance of the sensor nodes. When the two beacons receive reply from same sensor node, that sensor node is considered as localized node. Beacon exchange information (distance) to find coordinates of node [28]. The beacon sends the control message to the localized node and localized node change its color. The nodes which get localized by beacon list of that nodes will be passed to other beacon. The other beacons also flood beacon messages in the network and nodes are already localized will not respond back to mobile nodes. The defined process is repeated after defined amount of time. After the threshold time, all the sensor nodes which hold the flag of localized will leave the flag and marked as non-localized [29-30]. The advance range based scheme for node localization required clock synchronization in the network.

3.3. Proposed flowchart

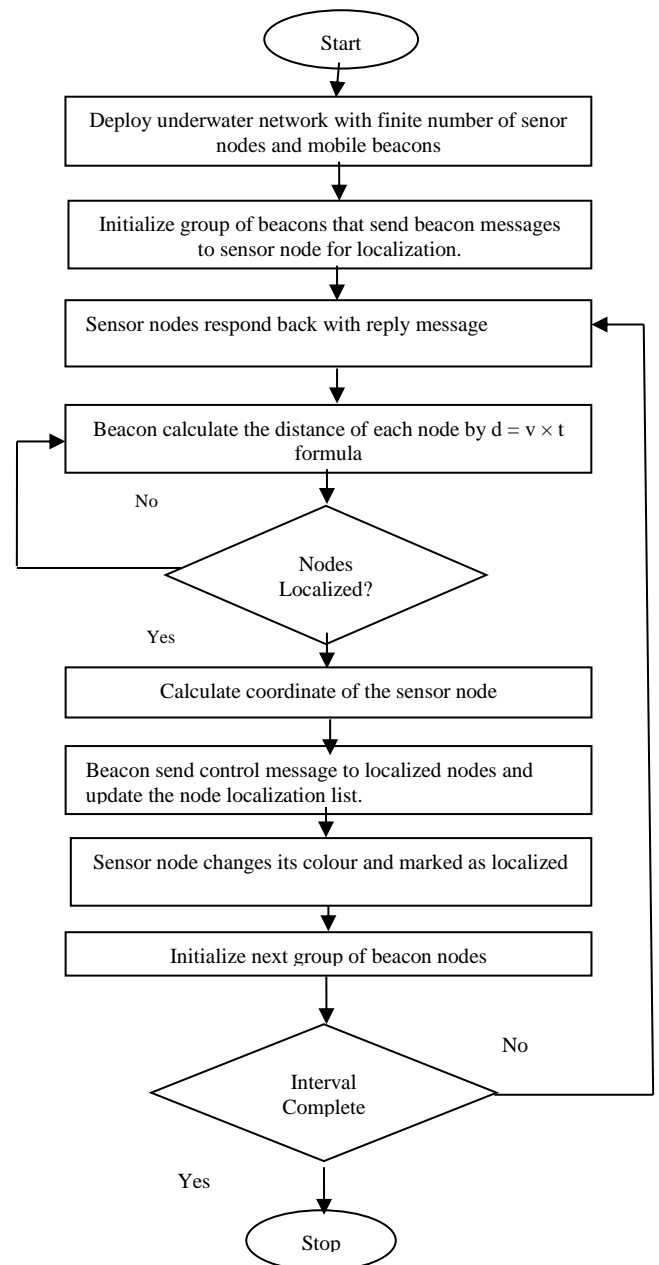


Fig. 2: Proposed Flowchart.

4. Implementation and result evaluation

MATLAB simulator is utilized here in order to perform evaluations on the proposed technique. Within the underwater network, around 250 sensor nodes are deployed and static nodes are deployed here. At constant rate, 1500 m/s of speed of sound is sent here. Beacon interval (bi) is the transmission range for which the sensor nodes vary from the range of 20 to 250 m. The anchor nodes are fixed in the network and some extra weights are tied with these nodes to fix their locations. The anchor nodes are GPS enabled to find its exact location. In terms of various parameters such as coverage, beacon interval and localization ratio and so on, the performance of proposed technique is analyzed. In this research work, the range based scheme is improved for the node localization. In the existing range based scheme sensor nodes get localized when the beacons send the beacon message in the network and node receive reply message from the sensor nodes. In the proposed approach, the beacons do not move in the network and one's node sensor node get localized, it don't respond back when it receive beacon message. When the anchor nodes send beacon message to the sensor nodes then sensor nodes will respond back to the anchor nodes and linear equation is solved to

estimate location of sensor node. The technique of time of interval is applied for the location estimation.

In this technique given equation is applied for the distance estimation.

$$d = v \times t$$

Where d is distance, v is speed of the signal and t is time taken by the signal to travel the distance d. Therefore, if the time taken by a signal to propagate from the beacon node to the dumb node, which is called time of arrival or time of flight is measured and speed of propagation of the signal is known, the distance and hence position of the dumb node can be calculated. To calculate distance between the anchor nodes and sensor nodes, clock synchronization of the sensor nodes is required. When any event occurs, the sensor nodes send data with the time on which event occur. After gathering such information, the time lay technique is applied for the clock synchronization [20]. The beacon receives reply message and calculated distance using Euclidian distance. This reduce overhead in the network and when overhead reduce it directly reduce delay. To estimate the coordinates of the sensor node, inverse distance is measured. For unknown node D, let (x, y) is the location. For i'th anchor node receiver, let (x_i, y_i) be the known location. For unknown nodes, let d_i be the i'th anchor node. Further, let n be the total number of anchors deployed in the network. To calculate the location within range free localization, the formula is:

$$\begin{cases} \sqrt{(x-x_1)^2 + (y-y_1)^2} = d_1 \\ \sqrt{(x-x_2)^2 + (y-y_2)^2} = d_2 \\ \vdots \\ \sqrt{(x-x_i)^2 + (y-y_i)^2} = d_i \end{cases} \quad (1)$$

$$A = -2 \times \begin{pmatrix} x_1 - x_n y_1 - y_n \\ x_2 - x_n y_2 - y_n \\ \vdots \\ x_{n-1} - x_n y_{n-1} - y_n \end{pmatrix} \quad (2)$$

$$B = \begin{pmatrix} d_1^2 - d_n^2 - x_1^2 + x_n^2 - y_1^2 + y_n^2 \\ d_2^2 - d_n^2 - x_2^2 + x_n^2 - y_2^2 + y_n^2 \\ \vdots \\ d_{n-1}^2 - d_n^2 - x_{n-1}^2 + x_n^2 - y_{n-1}^2 + y_n^2 \end{pmatrix} \quad (3)$$

$$P = \begin{pmatrix} x \\ y \end{pmatrix} \quad (4)$$

Here,

$$P = (A^T A)^{-1} A^T B$$

Here, P defines the coordinates of the sensor nodes.

- a) Coverage: The measurement as to how good or to what extent each point present in the deployed network is under vigilance of a sensor node is known as coverage. For a mobile beacon, let R be the transmission range. Let, S₂ be the speed of a mobile beacon which is must to be known previously for every sensor node and is constant. D_b is the distance that a mobile beacon travels before sending any message further. Thus, equation (1) defines the computation of coverage of a mobile beacon as:

$$Coverage = \frac{\pi}{12} (4R + D_b)(2R - D_b)^2 \quad (1)$$

- b) Localization ratio: The number of sensor nodes that can be localized is defined by the localization ratio.

- c) Number of localized nodes: The measure of number of nodes that a mobile beacon can localize is represented by 'N1' and equation (2) denotes is calculation as:

$$N1 = \frac{N}{V} * \frac{\pi}{12} (4R + D_b)(2R - D_b)^2 \quad (2)$$

Here, the total number of nodes present in a network are represented by N and the volume in which the nodes are deployed is presented by V.

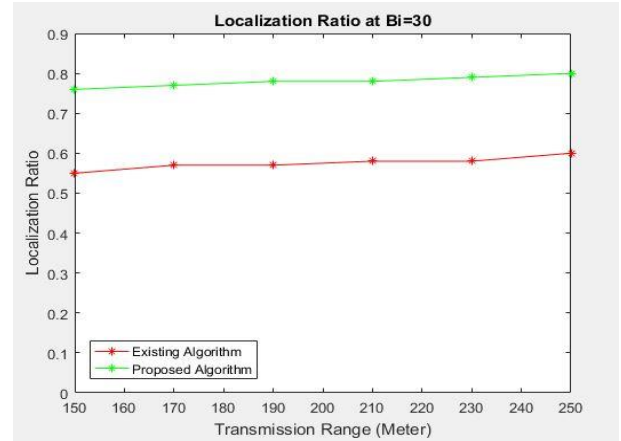


Fig. 3: Localization Ratio Comparison.

As shown in figure 3, the proposed and existing algorithms are compared in terms of localization ratio. In the proposed technique beacons cover more area as compared to existing technique due to which localization ratio is increased at steady rate.

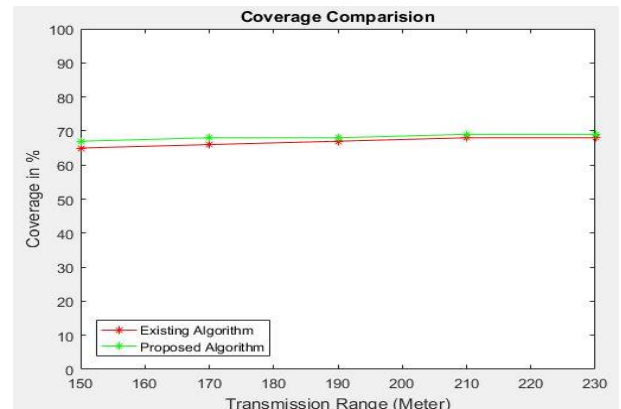


Fig. 4: Coverage Comparison.

As shown in figure 4, the proposed and existing algorithms are compared in terms of coverage area. The proposed algorithm has high coverage area due to use of more beacons as compared to existing algorithm. In the proposed technique with the increase of transmission range the coverage is increased at constant rate

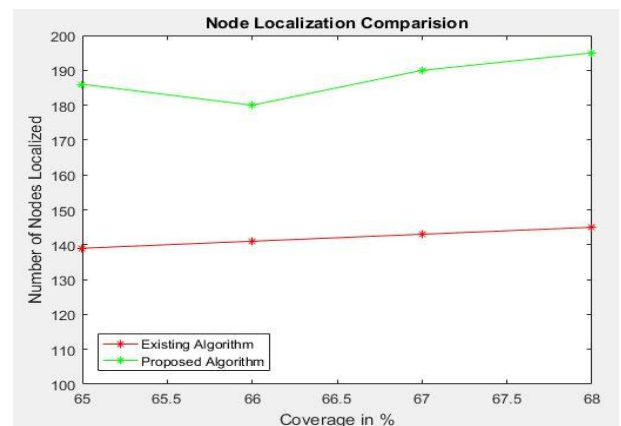


Fig. 5: Number of Nodes Localization Comparison.

As shown in figure 5, the existing and proposed algorithms are compared in terms of number of nodes localized versus coverage area. In the both existing and proposed technique number of nodes localized increased with the coverage area. In the proposed technique number of nodes localized in high as compared to existing technique.

Table 1: Range and Localization Ratio

Range	Existing Algorithm	Proposed Algorithm
150	0.57	0.77
170	0.57	0.78
190	0.58	0.78
230	0.58	0.79
250	0.60	0.80

As illustrated in table 1, the comparison is made between the existing and proposed techniques in terms of ratio of localization. In the proposed technique node localization is high as compared to existing when range is increased at same rate.

Table 2: Coverage and Number of Nodes Localized

Coverage %	Existing Algorithm	Proposed Algorithm
65	139	186
66	141	180
67	143	190
68	145	195s

As illustrated in table 2, the existing and proposed algorithms are compared in terms of number of nodes localized versus coverage area. The proposed algorithm has high number of nodes localized than existing algorithm.

Table 3: Range and Coverage Area

Range(m)	Existing Algorithm	Proposed Algorithm
150	65 %	67 %
170	66 %	68 %
190	67 %	68 %
210	68 %	69 %
230	68 %	69 %

As shown in table 3, proposed and existing algorithms are compared in terms of coverage area. It is analyzed that in the proposed algorithm cover more area than existing algorithm with the increase of range

5. Conclusion

The node localization is the scheme which is applied to estimate sensor positions in under water acoustic networks. In this research paper, advancement in the range-based scheme for node localization is proposed. In the proposed scheme, mobile beacons flood beacons messages in the network and nodes which respond back is marked as localized. The localized nodes do not respond back again when second time it receives beacon message from mobile beacons, which eventually reduce the delay in localization. Energy is also saved as localized nodes not respond back again to beacon messages. The proposed scheme is implemented in MATLAB and proposed schemes shows improvement in the results in terms of node localization verses coverage area of mobile beacons and node localization ratio.

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