Bio-Inspired Technique for Node Localization in Underwater Acoustic Networks

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Abstract - The networks that are designed by deploying sensor nodes in deep seas to monitor the activities in those regions are called the underwater acoustic networks. It is very easy to collect information in those regions and perform communication using such networks. Providing high-speed communication in the underwater acoustic channels is however difficult since the band width is limited and the multipath, fading and time-variations are high. Modification of such designed techniques is important so that appropriate underwater channels can be designed. For node localization, the previous approaches used fire fly algorithm such that an optimal value could be achieved. However, the proposed work used distance based technique. MATLAB simulator is used to implement both proposed and existing algorithms. It is seen through the conducted experiments that in terms of certain performance parameters, the performance of proposed algorithm is better.

Keywords - Node localization, butterfly, localization error

I. INTRODUCTION

To collect the data from a specific region several nodes are deployed in that region which gather and transmit the data to authorities using a wireless medium. This deployed network is called wireless sensor network (WSN). These nodes deployed in the networks are smaller in size. Due to this reason they have less power and processing capabilities. To sense the surrounding conditions and forward them to the base station, the sensor nodes are distributed randomly in the networks. The base station is deployed centrally to ensure that all the data from the network is aggregated towards it [1]. The sensor nodes deployed in WSNs are responsible for monitoring the environmental conditions that change. All such information can be collected by the centrally localized base station. There is very high computation power and storage capacity of the nodes. Therefore, the time required to process the information is very less. A gateway is responsible to provide an interface in between the internal and external scenarios. A base station is responsible to present the role of gateway [2]. The end users pass the information received to them from the base station, to the servers available. The deployment of sensor networks is done in large areas. Thus, it is very important to deploy more than one base station in the network since huge amount of information is being passed at regular time intervals. WSNs support both uni-directional and bi-directional types of communication. The sensor nodes are responsible for forwarding the data to the base station. A bi-directional type of communication is used here to forward the data to the base station. To monitor the surroundings using WSN, human surveillance is not required in these applications [3]. These networks have certain properties which distinguish them from other networks. WSNs are heterogeneous types of networks and their lifetime duration is also very small. Among the sensor nodes, there is very less mobility and flat grid based topology is provided in these networks. It is also possible to deploy these networks in applications like military regions or health applications. The sensor nodes can sense different conditions like pressure and temperature. WSNs are also deployed in regions that are highly prone to disasters such that they can be monitored regularly and in case of any emergencies, necessary actions can be taken. The deployment of sensor networks is done in large applications and the sensor nodes are distributed all across the regions.

1.1. Node Localization

Node localization is another major issue being faced because of the dynamic nature of WSNs. Node localization approach is used to share the location of sensor nodes such that efficient data communication can be performed. It is possible to resolve data aggregation issue by proposing efficient solution which can resolve the problem of node localization. Various applications are deploying WSNs in order to perform different tasks such as target tracking and monitoring the surrounding parameters. Node localization is an important requirement through which the various applications of WSNs can benefit. Node localization can be defined as the task that aims to recognize the unknown nodes by collecting their coordinates. In the coverage area where sensor nodes are deployed, the distance approaches are used for node localization. This technique needs to generate the queries for certain events such that the data forwarding and routing can be performed. To localize the position of sensor nodes, anchor nodes are deployed in the network. Therefore, for determining the localization distance in between the sensor and anchor nodes, an estimate value is calculated. The exact position of sensor

nodes is estimated by implementing various optimization techniques.

1.1.1. Importance of Node Localization

Estimating the position of a node is a major concern in most of the applications of UAN since they are deployed in large areas. Over the past few years, it has become common to design various node localization algorithms. Further, based on the efficient node localization algorithms the accurate positions of nodes are calculated. This helps in identifying the sensor nodes as well. When transmitting the data from sensor node to the base station, localization is considered as very important. When node location estimation is accurate, an efficient route is generated through which data transmission is performed by saving energy. These networks have certain very unique and critical applications and it is also important to maintain certain parameters like QoS, throughput, and etc. For applying data aggregation using sensor nodes a central authority called base station is used. The positions of the nodes are estimated here which also helps in increasing the security of these networks. It also provides solutions to various other issues commonly being faced in the UANs. It is possible to perform secure communication in the networks and minimize the chances of threat with the help of adjacent nodes that are available for every other node. Due to the problem of node localization, two major issues arise. A route establishment problem is being faced in the networks, which basically associates to generating a path from source to destination that is highly secure and efficient. A secondary issue being faced is the range of issue which defines the coverage area of sensor nodes. The solution to both of these issues is node localization.

II. LITERATURE REVIEW

Ranjit Kaur, et.al, (2017), studied that it is very important to include node localization in WSNs to ensure that their performances are improved. The localization technique aims to estimate the location of sensor nodes based on the distance. However, not real but approximate value of distance is calculated here. If there is incorrect estimation of the node's position, it is difficult to generate the important information from the base station. There is huge level of complexity in the networks since these networks are very large in size. Node localization is a commonly known optimization issue. The researcher here proposed a nature inspired optimization technique which could be applied to perform node localization [11]. For recognizing the appropriate mechanisms in terms of accuracy and computation time, several comparative analyses were made towards the end.

S.R.Sujatha, et.al, (2017), designed a novel dynamic weight based technique through which node localization could be performed for WSNs. To provide enhancements in the network, a hybrid technique was proposed in this research. There is reduction in the bit error rate in case when the positions of nodes are estimated and measured as equal. The anchor nodes are used to collect the accurate locations of nodes. To improve the localization accuracy, the author proposed DE algorithm in this research [12]. Improved simulation results were achieved by the proposed algorithm by implementing this proposed method.

Meng Joo Er, et.al, (2016), studied about the node localization which is necessary in WSNs to ensure better performance results. It is important to include high network density if highly accurate node position is required. Node density thus directly impacts the accuracy of node localization. If in any region, the node density is reduced this results in reducing the number of hops included in that region for communication. Therefore, it results in reducing the accuracy of network. The node density based estimation technique was designed to perform node localization [13]. For anchor nodes, the node density is calculated and based on the node density of anchor node, the sub-regions are generated. The distance that exists in between the anchor nodes and sensor nodes is calculated such that the nodes' positions can be estimated. Based on the simulation results it is seen that the performance of proposed approach is improved as compared to the previously designed approaches.

Eva Tuba, et.al, (2016), studied that the position of sensor nodes needs to be estimated for WSNs. Node localization method has been designed using which the location of unknown nodes was estimated. Based on the RSSI approach, the distance among anchor nodes and sensor nodes is calculated such that the location of sensor nodes can be predicted. This paper proposed a node localization method based on the firework swarm intelligence optimization scheme [14]. This algorithm helps in collecting the estimated data from different anchor nodes. The system is provided with input in the form of data. Algorithm is executed in three separate phases. The first phase is to compare the location of every node. In the second phase, the calculation of best location is done. The third and last phase estimates the value of MSE for node localization. The comparative studies proved that the proposed algorithm outperformed existing outputs in terms of execution time and accuracy.

Chin-Shiuh Shieh, et.al, (2016), studied about a major concern for WSNs that is node localization. When estimating the position and identity of sensor nodes is not provided, it becomes difficult to collect the data. Estimating the positions

of nodes is a major problem which results in causing issues in node localization and thus, optimization on WSNs [15]. For performing a comparative analysis of various algorithms and analyzing as to which algorithm is better than the other, certain evaluations were performed in this research using previously generated optimization algorithms. In terms of execution time and accuracy, the performances of different optimization algorithms were compared. It was seen that among all other parameters, the performance of firefly algorithm was better.

Suman Bhowmik, et.al, (2016), studied about the node localization issues being faced in WSNs. In case when the position of a node is unknown and the node is unidentified, it is difficult to aggregate the data across the networks. Another concern of this paper is dynamic nature of these networks which also makes it more difficult to perform node localization. Received signal strength is an important technique to be applied to perform node localization in these networks. In the RSSI approach, the node's position is estimated based on the received signal strength parameter. This research work aimed to propose a fuzzy logic based node localization approach [16]. In the fuzzy logic mechanism, fuzzy rules are generated by applying distance parameters. The calculation of distance among the anchor node and sensor nodes is done further. Using the calculated distance which runs by following the defined rule, the position of node is estimated. The simulations are performed using Omnet++ simulation tool and the evaluation of proposed algorithm is done based on the accuracy of node localization.

Saroj kumar Rout, et.al, (2016), studied that in WSNs, data aggregation related issues are also being faced commonly [17]. This paper proposed a novel approach named Fuzzy Based Eminence of Trilateration (FBEOT) to resolve this problem. This method helped in establishing relationship among the sensor nodes. It also helped in calculating the distance present in between the sensor nodes and the anchor node. The designing of this novel approach included the centric algorithm as base. This method generated the mandani fuzzy interface such that fuzzy logic could be generated. With respect to performance parameters like accuracy, the performance of proposed approach was compared with that of the previous weight based algorithms. It was concluded that the proposed approach outperformed the remaining algorithms.

III. RESEARCH METHODOLOGY

The process in which the coordinates of a node whose location is unknown, are identified using distance information and radius of wireless communications is called node localization. For reporting the origin of events, assisting the group querying of sensors, answering the queries on network coverage and performing routing, it is important to include node localization. There is no real value for the distance calculated in between an unknown node and anchor node. Thus, to identify the position coordinate of an unknown node, that node's estimated position can be considered as an optimization in which the anchor node's target function of the localization error is reduced. The location error of the unknown node is affected by ranging error. Also, the accuracy of localization is improved by reducing the maximum error.

The location is denoted as let (x,y) for any unknown node. Let the known location be (x_i, y_i) for an i^{th} anchor node receiver. The distance existing in between the i^{th} anchor node and target node is denoted as d_i for the unknown nodes. In the complete network, total number of anchor nodes deployed can be denoted by n. The formula for calculating the location that is in the range based localization is:

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

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

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

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

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

The location of sensor nodes is defined by the coordinates that are represented by P in the above equation.

IV. RESULT AND DISCUSSION

For performing numerical calculations that can also help in performing highly complex functions, a simulator known as MATLAB is used. For the simplified MATLAB, C programming language is used. Hundreds of built-in functions are included to provide an interactive environment. Depending on the type of version, the type of built-in function to be used can be changed. A matrix is the building block of MATLAB. There are various toolboxes and in-built tools in these tools.

(a) No. of nodes localised

TARGET NODES	NO. OF NODES LOCALIZED (BOA)	NO. OF NODES LOCALIZED (BOA-ABC)
25	23	24
50	38	40
75	55	57
100	80	82
150	130	131

Table 3: Comparison of nodes localized by BOA and BOA-ABC

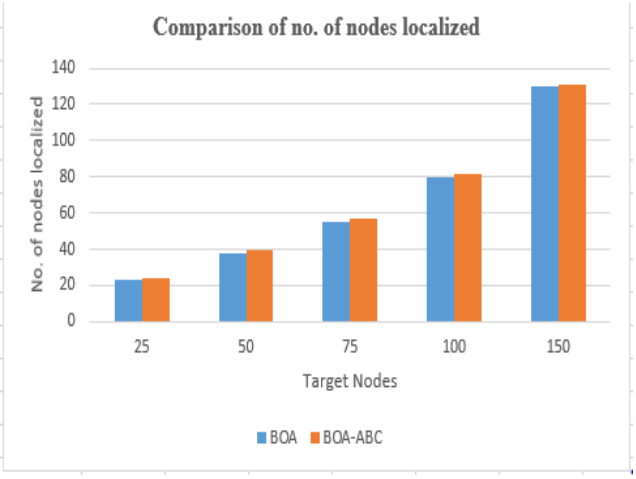

Figure 1: Number of nodes localised versus target nodes

The total number of nodes localized using the two algorithms proposed and existing individually, are shown in this graph. The results show that in comparison to exiting BOA algorithm, higher numbers of nodes are localized when applying improved algorithm.

(b). Localization error

TARGET NODES	LOCALIZATION ERROR (BOA)	LOCALIZATION ERROR (BOA-ABC)
25	20.22	8.84
50	19.58	16.93
75	17.74	15.81
100	20.16	19.73
150	19.72	16.29

Table 4: Comparison of localization error by BOA and BOA-ABC

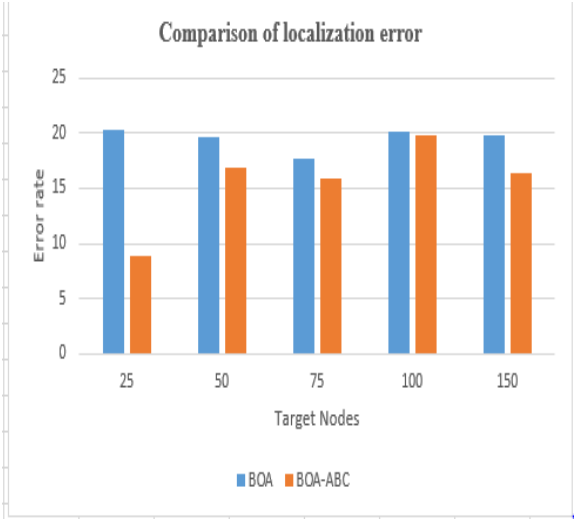

Figure 2: Error rate versus target nodes

The localization error achieved when applying the newly designed and exiting algorithms are compared in the graph shown above in figure 7. In comparison to the existing algorithm, the MSE value for proposed algorithm is reduced. Therefore, the node localization of network is improved.

(c) Execution time

TARGET NODES	EXECUTION TIME (BOA)	EXECUTION TIME (BOA-ABC)
25	1.85	1.03
50	2.38	1.03
75	2.12	1.03
100	3.01	1.04
150	2.25	1.06

Table 5: Comparison of execution time by BOA and BOA-ABC

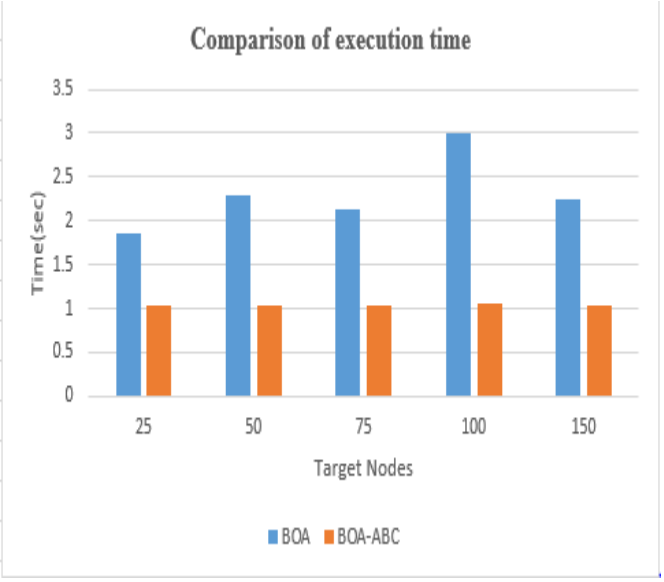

Figure 3: Execution time versus target nodes

For calculating the distance existing in between the anchor nodes and target nodes, determining the coordinate nodes and providing the best solution with minimized error value, the execution time consumed by proposed algorithm is very less as compared to that of previously designed algorithm. Also, there is a considerable variation in the execution time of BOA.

(d). Transmission Range

TRANSMISSION RANGE	NO. OF NODES LOCALIZED (BOA)	NO. OF NODES LOCALIZED (BOA-ABC)
20	23	94
40	49	115
60	96	120
80	116	131
100	130	131

Table 6: Comparison of number of nodes localized

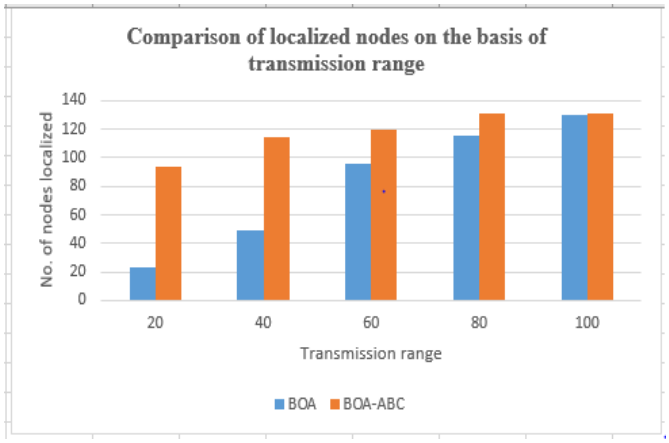

Figure 4: Number of nodes localized versus transmission range

The increment of transmission range results in increase of number of nodes localized as per the graphs. Also, there is an increase in the localization of target nodes with increment in the transmission range of anchor nodes.

V. CONCLUSION

Node localization can be defined as the task that aims to recognize the unknown nodes by collecting their coordinates. In the coverage area where sensor nodes are deployed, the distance approaches are used for node localization. The information related to distance and radius of wireless communications is used to identify the positions of coordinates of unknown nodes. The network coverage related queries are resolved, group queries of sensors are assisted and origin of events is reported through node localization. For node localization, the fire fly optimization algorithm is applied commonly. However, several iterations are required in

this algorithm. This research thus, uses the distance based technique to perform node localization. MATLAB simulation is used to implement the proposed approach and different parameters are used for comparative analysis.

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