Bio-inspired Techniques for Node Localization of Underwater Acoustic Networks

Manisha Kapoor[1], Anurag Rana[2]
[1]*Research Scholar,* [2]*Assistant Professor*
Arni University, Indora, Himachal Pradesh, India

Abstract - The underwater acoustic network is the type of network which is deployed under the deep sea to sense ocean conditions like pressure etc. The networks are deployed underwater for providing communication such that the important information can be easily transmitted across regions. Due to the presence of limited bandwidth, higher multi-path, higher fading, huge time-variations as well as Doppler shifts, it is difficult to perform high-speed communication within underwater acoustic channels. Within the sea waters, the propagation of electromagnetic waves is very poor. Originally for the terrestrial wired and wireless channels, the communication techniques were designed. Thus, in order to make them appropriate for underwater channels, there is a need to modify these techniques. In this research work, distance based technique is applied for the node localization. The proposed and existing algorithms are implemented in MATLAB. The simulation results show that proposed algorithm performs well in terms of certain parameters.

Keywords - Node Localization, Bio-inspired Techniques, Range-based

I. INTRODUCTION

A network that consists of various sensor nodes and base station for collecting data from surroundings is known as a wireless sensor network. The power, memory as well as computational capacity of sensor nodes in these networks is very less. The networks are deployed underwater for providing communication such that the important information can be easily transmitted across regions. Due to the presence of limited bandwidth, higher multi-path, higher fading, huge time-variations as well as Doppler shifts, it is difficult to perform high-speed communication within underwater acoustic channels. Within the sea waters, the propagation of electromagnetic waves is very poor [1]. Originally for the terrestrial wired and wireless channels, the communication techniques were designed. Thus, in order to make them appropriate for underwater channels, there is a need to modify these techniques. There has been huge research proposed in last few centuries on underwater acoustic communication. The development of underwater phone for US navy at the time of World War II was one of the initial discoveries of underwater communication devices. Further, various scientific, military and commercial applications have been utilizing this technology within them to provide better communication [2]. The electromagnetic waves, optical waves as well as the acoustic waves are used within the underwater acoustic sensor networks. Each of these has their own merits and demerits. For example, the high attenuation of water affects the radio frequency waves due to which the high transmission power and large sized antenna is required. Although high data rate communication is achieved due to the utilization of optical waves, the scattering and absorption issues will cause huge affects on them. Thus, only within short distance links, the optical waves can be efficient and reliable [3]. Long distance communications can be possible due to the utilization of acoustic waves. However, the absorption under water causes less affects on them. Thus, the reliable UWSNs can provide reliable results and are preferred more in these networks. Due to the dynamic nature of WSNs, one of the major issues that arise is known as node localization. For ensuring efficient data communication, the location of sensor nodes is shared through node localization mechanism. By proposing efficient solution to the node localization issue, the data aggregation issue is resolved [4]. For performing several tasks like tracking of target, monitoring the environmental conditions, WSNs are deployed in various applications. To fulfill the various applications of WSN, an important requirement is node localization. Due to the dynamic nature of these networks, node localization is known to be the major issue. The task in which the coordinates of nodes are collected for identifying unknown nodes is known as node localization. The distance approaches can be utilized to perform this technique along with the coverage area in which sensor nodes are deployed. For generating queries from sensor nodes for several events, forwarding data within the groups, and routing the data, the generation of queries is important within this technique [5]. Anchor nodes are deployed within the network for localizing the position of sensor nodes. Thus, an estimated value is calculated to determine the localization distance amongst the sensor node and anchor. Several optimization approaches are implemented on anchor nodes for estimating the exact position of sensor nodes. Ranging errors is the major issue of node localization in which the exact position estimation of unknown nodes is to be minimized. There is reduction of mean square error due to the identification of position of unknown nodes. For estimating the exact location of sensor nodes, there is a need to minimize the optimization issue using the fitness value known as mean square error [6]. Several node localization techniques have been proposed by various researchers. On the basis of mobility and nature of swarms, a stochastic mechanism is proposed that has high flexibility. It is known as Particle swarm optimization (PSO). The basic concept of social interaction is utilized to solve the basic issues in PSO. James Kennedy (social-psychologist) and Russell Eberhart (electrical engineer) were the researchers that developed PSO in 1995. The best solution was identified due to the mobility within search space within several numbers of particles that has the presence of swarm in them. An algorithm that is used for optimizing the functions through the enhancement of candidate solution in stochastic and repeated manner is known as Biogeography-based optimization (BBO). For the meta-heuristics class, BBO is used and there are several variations present in this approach. Any assumptions related to the situation are not provided here and thus, several classes of situations utilize it. For localization, the trilateration is utilized widely [7]. The utilization of three or more numbers of anchor nodes is the major principle of this approach. The radiuses of circles are known as the computed distances from known points to the unknown object. The sensor nodes of WSNs are localized using Bee Optimizations Algorithm (BOA). The normal allocation of Time of Arrival (TOA) measurements and received signal strength (RSS) measurements are used for various topologies by conducting various tests. A range based methodology which is consumed in Received signal strength Indicator (RSSI) circuitry in which the transceivers chipsets of the sensor are included is known as RSSI-based localization algorithm.

II. LITERATURE REVIEW

Ranjit Kaur, et.al, (2017), presented a study related to node localization which plays a very important role within wireless sensor networks. On the basis of distance, the location of sensor nodes is estimated within the localization approach. The value of estimated value is just an approximation and not real. The important information from base station is very difficult to be generated in case if the estimation of position of node is not correct. Because of huge sizes of the sensor networks, the complexity of node localization is very high also. An optimization issue caused here commonly is node localization. For node localization, a nature inspired optimization approach is proposed by author [8]. Comparisons are made amongst various optimization algorithms in order to identify appropriate mechanisms with respect to accuracy and computation time they provide.

S. R. Sujatha, et.al, (2017), proposed in this paper a novel dynamic weight based mechanism for node localization in WSN. Mainly, a hybrid approach is proposed here through which the improvements are achieved. When there is equality of the estimated and measured positions of nodes, the bit error rate is minimized. For gathering the accurate locations of nodes, the anchor nodes are utilized. For localization, DE algorithm is proposed by author here, with which the accuracy of localization is increased here [9]. With respect to accuracy and execution time, the proposed algorithm provides better simulation results.

Meng Joo Er, et.al, (2016), presented research related to node localization within WSNs. To provide highly accurate position of nodes, the density of network needs to high. The accuracy of node localization is directly affected due to the node density. There is minimization of number of hops of network when the density of nodes is minimized in the area. Thus, the accuracy of network is also minimized here. For providing node localization, node density based estimation approach is proposed [10]. The node density is calculated for anchor nodes and regions within sub-regions are divided on the basis of node density of anchor node. To estimate the position of nodes, the distance amongst the anchor node and sensor node is computed. In comparison to already existing approaches, the performance of proposed approach is shown to be better as per the simulation results.

Eva Tuba, et.al, (2016), presented that an important part of WSNs is the estimation of position of sensor nodes. A mechanism in which the location of unknown nodes can be estimated is known as node localization. In order to predict the location of sensor nodes, the distance amongst the anchor nodes as well as the sensor nodes is computed as per the RSSI approach. On the basis of firework swarm intelligence optimization algorithm, the node localization mechanism is proposed in this paper [11]. From several anchor nodes, the gathering of estimated data is done using this algorithm. In the form of input, this data is provided to the system. There are three different phases in which this algorithm performs. The location of each node is compared within the initial phase. Further, the best location is computed within the second step. Further, for node localization, the value of MSE is estimated within the final phase. It is seen through the comparisons that with respect to accuracy and execution time parameters, the performance of proposed algorithm is better that already existing approach.

Chin-Shiuh Shieh, et.al, (2016), presented study related to node localization which is a major issue. The gathering of data from the network becomes difficult in case when the position as well as identification of sensor nodes is not estimated. The optimization issue faced within WSNs is node localization which is mainly caused due to the estimation of positions of nodes [12]. Several optimization algorithms that are proposed for node localization are compared within this research to evaluate the performances of each other in comparison to each other. The various optimization algorithms are compared with respect to accuracy as well as execution time. It is seen as per the simulation results that the firefly algorithm performance better in comparison to other algorithms.

Suman Bhowmik, et.al, (2016), presented the study related to node localization issue within WSNs. The aggregation of important data within the network is very difficult in case when there is no knowledge about the position or no identification of node. Because of the dynamic nature of network, the localization of node is another optimization issue. For node localization, an efficient technique to be applied is the received signal strength. On the basis of received signal strength, the position of node is estimated within RSSI technique. A fuzzy logic based node localization approach is proposed in this research work [13]. Using distance parameters, fuzzy rules are generated within the fuzzy logic approach. Amongst the anchor node and sensor nodes, the distance is computed. The position estimation is done using the calculated distance that follows the define rule. Within Omneet++, the simulation of proposed algorithm is done and the accuracy of node localization is also evaluated when proposed algorithm is applied.

III. RESEARCH METHODOLOGY

Node localization is required to report the origin of events, assist group querying of sensors, routing and to answer questions on the network coverage. The measured distance between unknown node and anchor node is not the real value. So unknown node position estimation can be treated as a kind of optimization which minimizes the target function of localization error of anchor node to find out the position coordinate of unknown node. The major factor is a ranging error that affects the location error of the unknown node, and decreasing the maximum error which can meritoriously improve the accuracy of localization. Butterfly optimization algorithm (BOA) is a new nature inspired meta-heuristic algorithm. It is based on food-foraging strategy of butterflies. Butterflies use sense receptors to locate the source of their food/nectar. The main strength of BOA lies in its mechanism to modulate fragrance in the algorithm. The whole concept of sensing and processing the modality is based on three important terms viz. sensory modality (c), stimulus intensity (I) and power exponent (a). Sensor ymodality is the concept related to measuring the form of energy and processing it. Stimulus intensity is the magnitude of the physical/actual stimulus. In BOA, the stimulus intensity is correlated with the fitness of the butterfly/solution. This means that when a butterfly is emitting greater amount of fragrance, the other butterflies in that surrounding can sense it and gets attracted toward it.

Pseudo code for Butterfly Optimization Algorithm (BOA)

1. Objective function $f(\mathbf{x})$, $\mathbf{x}=(x_1 \ldots\ldots x_{dim})$
2. Generate population of n Butterflies **x**i= (i=1,2,…n)
3. Define c, a and p
4. **while** stopping criteria not met **do**
5. **for each** butterfly *bf* in population **do**
6. Calculate fragrance for *bf* using Eq. (1)
7. **end for**
8. Find the best *bf*
9. **for each** butterfly *bf* in population **do**
10. Generate a random number r from [0, 1]
11. **if** $r < p$ **then**
12. Move towards best butterfly using Eq. (2)
13. **Else**
14. Move randomly using Eq. (3)
15. **end if**
16. **end for**
17. **end while**
18. Output the best solution found.

IV. EXPERIMENTAL RESULTS

a) No. of nodes localised –

Table 1: Comparison of nodes localized by BOA and BOA-ABC

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

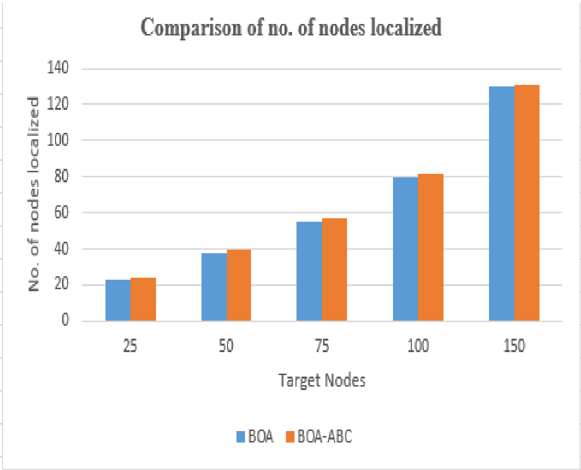

Figure 1: Number of nodes localised versus target nodes

The graph shows the number of nodes localized with the optimization algorithms (BOA and BOA-ABC). It shows that the nodes localized with the (BOA-ABC) are comparatively more than the BOA optimization algorithm.

b) Localization error –

Table 2: Comparison of localization error by BOA and BOA-ABC

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

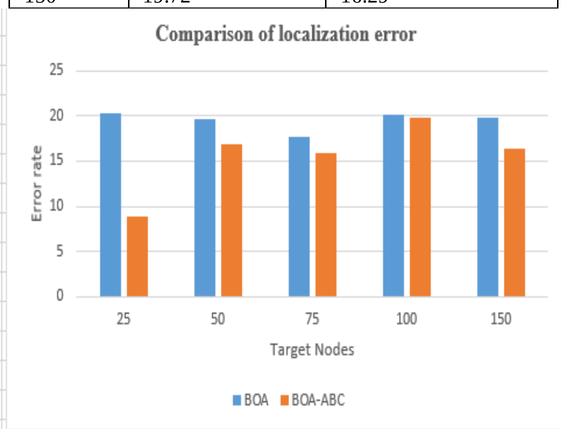

Figure 2: Error rate versus target nodes

The graph shows the results of localization error calculated by BOA and BOA-ABC. It shows that the hybrid optimization algorithm (BOA-ABC) reduces the Mean Square Error(MSE) to the greater extent as compared to the BOA optimization algorithm thus, improving the node localization in the network.

c) Execution time –

Table 3: Comparison of execution time by BOA and BOA-ABC

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

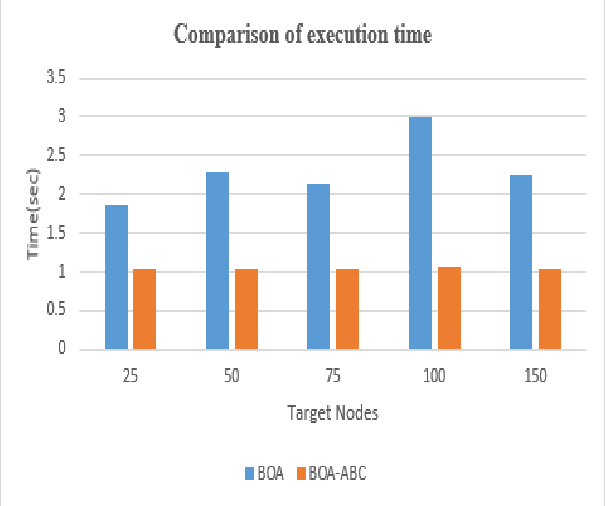

Figure 3: Execution time versus target nodes

The graph shows the computing time used by the optimization algorithms (BOA and BOA-ABC) to calculate the distance between the anchor nodes and the target nodes with the help of beacon messages, to calculate the co-ordinates of the nodes and finding the best solution by reducing the error value. It shows that the computing time of BOA-ABC is almost same and less in comparison to the computing time of BOA. Also, execution time of BOA varies considerably.

d) Transmission Range –

Table 4: Comparison of number of nodes localised

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

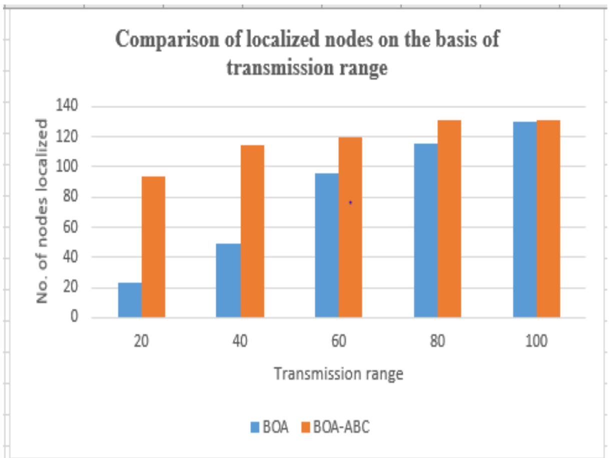

Figure 4: Number of nodes localized versus transmission range

The graph shows that the number of nodes localized increases with the increase in the transmission range that is with the increase in the transmission range of the anchor nodes the localization of the target nodes also increases.

V. CONCLUSION

In WSN location awareness is one of the important, critical and challenging issues. Knowledge of location among the participating nodes is one of the crucial requirements in designing of solutions for various issues related to wireless sensor networks. Node localization is also one of the problems in WSN. It is the process of identifying the position coordinates of unknown nodes which can be achieved by using the distance information, and radius of wireless communications. The fry fly algorithm is the optimization for the node localization. The fry fly algorithm need large number of iterations for the node localization. In this research work, distance based technique is applied for the node localization. The proposed algorithm is implemented in MATLAB and results are analyzed in terms of certain number of parameters.

VI. REFERENCES

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