A Recursive Localization Approach for Distributed Networks in UWSN

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Abstract - *Underwater acoustic sensor network (UASN), is a network of wireless sensor nodes distributed over a certain area in an underwater environment, communicating with each other via acoustic signal. It can act as an assisting technology for a variety of underwater applications. In spite of the data centric nature of the UASN, sometimes the collected data without its location of occurrence become meaningless. Thus, localization for UASNs has become a very interesting topic of research. This paper proposes an event-driven distributed localization scheme for small scale 2D UASN. The Proposed scheme employs a recursive localization process in which successfully localized nodes can act as reference node to aid in localization of the other ordinary sensor nodes. The simulations are done using MATLAB, Aqua-Sim Network Simulator 2.30 and Xilinx ISE 14.7.*

***Key Words*: Acoustic Signal, Anchor Node, Localization, Ordinary Node, UASN.**

1. INTRODUCTION

Ocean covers almost 2/3rd area of the total earth surface. Most of the areas are unexplored even as on today. The oceans are rich with a numerous valuable resources which takes attention of the human being to study ecological environment. Conventional oceanographic exploration devices are large and expensive. Relatively small and less expensive underwater sensor nodes can communicate with each other using the acoustic signal. Large numbers of sensor nodes are deployed for a particular task to accomplish. These nodes essentially form a network. They coordinate each other to perform sensing of environmental phenomena in a distributed way. WSN makes a bridge between the real world phenomena with the virtual sphere of information technology. In recent few years, a growing interest in underwater acoustic sensor network has been reported.

Underwater Wireless Sensor Networks (UWSNs) that is constituted by wireless sensor nodes distributed over a large area can be used for a broad range of applications that include ocean sampling, monitoring environmental activities, ocean exploration for scientific as well as commercial purposes, navigation assistance, disaster management etc. Even as on today, many issues remain unresolved in UWSN. Localization is a technique to know the physical coordinate of an ordinary underwater node. The acoustic signal is considered as the best way of communication between the objects within the underwater environment because the radio signal attenuates very high and the optical signal scatters. Thus, UWSN is redefined as underwater acoustic sensor network (UASN).

1.1 Related Work

To the best of our knowledge, however, there is no complete packet level underwater sensor network simulator published yet. There are several widely used packet level network simulators such as NS-2 and OPNET. But they were developed for terrestrial radio wireless and/or wired networks, not for underwater sensor networks. They cannot be used for the simulation of underwater sensor networks without significant modifications. Aqua-Sim, for underwater sensor networks has been developed [1]. Here NS-2 is chosen as the development platform since NS-2 is a very powerful, widely used, and open source simulator. NS-2 provides efficient and convenient methods to configure network and nodes. Two languages are used in Network Simulator-2 (NS-2) NS-2, C++ and Object oriented tool command language (OTCL). Aqua-Sim can effectively simulate acoustic signal attenuation and packet collisions in underwater sensor networks. Moreover, Aqua-Sim supports three-dimensional deployment. Further, Aqua-Sim can easily be integrated with the existing codes in NS-2.

In WSNs, the major challenge is the deployment of the nodes in the deployment region to satisfy continuous sensing with extended network lifetime while maintaining uniform coverage. Various architectures and node deployment strategies have been developed for wireless sensor network, depending upon the requirement of application. There are various deployment schemes for sensor networks environments, random deployment, grid deployment, group-based deployment, and grid-group deployment. Random deployment means setting positions of wireless sensor nodes randomly and independently in the target area [2]. Random deployment method is fast in practice though costs a relatively larger number of nodes to achieve the same deployment goal. When practical application scenarios are considered, random deployment is a feasible and practical method, and sometimes it is the only feasible strategy.

Localization has been widely explored for terrestrial wireless sensor networks, with many localization schemes being proposed so far. Generally speaking, these schemes can be classified into two categories: range-based schemes and range-free schemes. Range-based protocols [3] can provide more accurate position estimates; they need additional hardware for distance measures, which will increase the network cost. On the other hand, range-free schemes do not need additional hardware support, but can only provide coarse position estimates.

2. PROPOSED LOCALIZATION TECHNIQUE

The proposed scheme is aimed for event-driven UASN [4] applications. It is a recursive distributed localization scheme. All of the underwater sensor nodes are randomly distributed. An underwater acoustic sensor network is considered to be completely distributed in nature and there is no central control point. This will make the scheme more robust as it is not failure prone.

The proposed scheme consists of the following types of nodes:

- Anchor Nodes: These are already positioned nodes which acts as initial reference for estimating the position of ordinary nodes. For simulation purpose the location of these nodes are provided manually and these nodes consumes more power when compared to that of ordinary nodes.
- Reference Nodes: When some ordinary nodes get localized they can be considered as reference for estimating the position of other unlocalized ordinary nodes. These nodes are called as reference nodes.
- Ordinary Nodes: The main motive of this project is to locate these nodes. Initially anchor nodes provide the location reference and then reference nodes location is used for finding the location of these nodes. These nodes consume less power when compared to that of the anchor nodes.

2.1 Localization Scenario

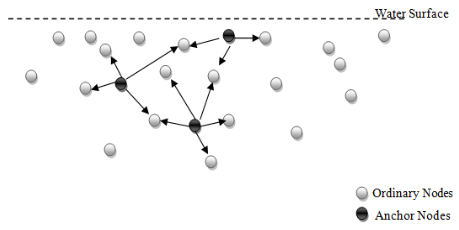

Fig-1: Proposed Localization Scenario

The entire localization is shown in Fig-1. There are two types of nodes during initial random deployment stage: ANCHOR NODES and ORDINARY NODES. ANCHOR NODEs are called KNOWN NODES since they know their positions and ORDINARY NODES are called UNKNOWN NODES since their positions have to be still find. They are equipped with acoustic transceivers which help in communication.

2.2 Implementation Details

According to the flowchart shown in Fig-2. The first task is to randomly deploy the nodes at any random position just by throwing the nodes into the water using MATLAB. After random deployment of nodes the task is to calculate the energy associated with each node and selecting three nodes having highest energies. Energy is calculated using,

$$\text{Energy} = \frac{\text{Sum of x and y co-ordinates}}{\text{Total No. of nodes}} \qquad (1)$$

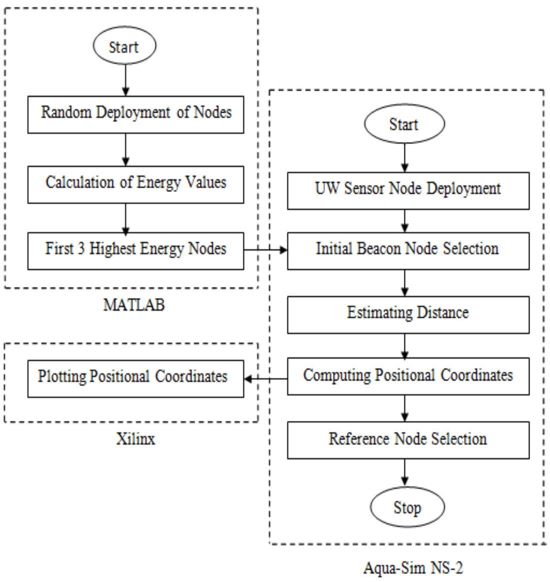

Fig-2: Flowchart for proposed localization process

After random deployment of nodes using Aqua-Sim NS-2, select the anchor nodes as the initial reference. After finding the anchor node i.e. known nodes, the ordinary nodes uses anchor node's location reference to find the location by enabling packet transfer. As soon as the ordinary node gets its location, distance to each anchor node will be calculated. Distance is calculated using 2-D (Two-Dimensional) Euclidean technique. Euclidean distance can be computed by using the below equation,

$$d(p,q) = \sqrt{(x_q - x_p)^2 + (y_q - y_p)^2} \qquad (2)$$

Where p is the anchor node and q is the ordinary node, $d(p, q)$ is the 2-D Euclidean distance between p and q, (x_p, y_p) are the x

and y co-ordinates of node p and (x_q, y_q) are the x and y co-ordinates of node q.

Each localized node is associated with a localization error and confidence value μ. Confidence value for each localized node is given by,

$$\mu = 1 - \frac{\sum_{p=0}^{n} |(a-x_p)^2 + (b-y_p)^2 - d^2|}{\sum_{p=0}^{n} \sqrt{(a-x_p)^2 + (b-y_p)^2}} \quad (3)$$

Where μ is the localization confidence value, (a, b) are the estimated co-ordinates of ordinary nodes, (x_p, y_p) are the x and y co-ordinates of anchor node p, d is the distance between anchor and ordinary node and n represents total number of anchor nodes in the network.

In order to reduce the energy consumption of the anchor nodes some of the localized nodes are considered as REFERENCE NODES based on localization confidence value.

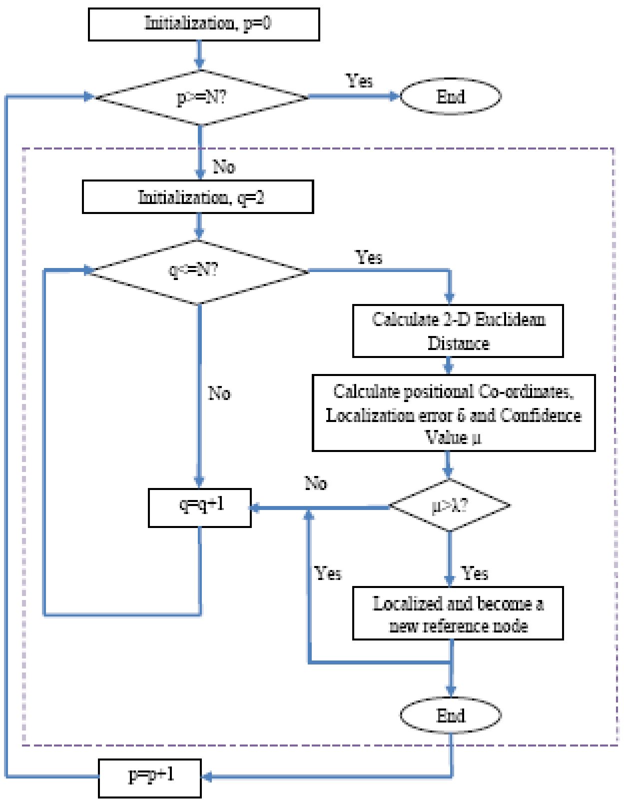

Fig-3: Ordinary node localization process

Fig-3 gives the detailed description of ordinary node localization process in an RPE algorithm. The procedure is as follows:

1. Anchor node value is initialized according to the designer.
2. If p>=N then the process will be aborted.
3. If p< N then ordinary node values will be initialized.
4. If q<=N, then distance to the initialized anchor node is computed.
5. And the positions are estimated using trilateration method.
6. The localization confidence value computed using eq^n (3) and it is compared with the predefined threshold λ.
7. If $\mu>\lambda$ then that particular node status is changes as REFERENCE NODE.
8. If $\mu<\lambda$ then that particular node cannot be regarded as reference node and the ordinary nodes will be incremented and the steps 4 to 6 are again repeated until all the ordinary nodes are checked with reference to a considered anchor node.
9. Now the anchor node gets incremented and steps from 2 to 8 are again repeated.

The localized nodes with confidence value of 1 are considered to be absolutely localized.

After getting the x and y co-ordinate of the ordinary nodes they are represented as a simulation waveform using Xilinx ISE.

3. SIMULATION RESULTS

Table-1: Different simulation settings for the proposed work

Parameter Description	Value
Total number of nodes	23
Area of the sensing field	100*100 m^2
Number of beacon nodes	3
Number of ordinary nodes	21
Simulation time	50ns
Confidence threshold	0.9

The proposed work has been simulated using Aqua-Sim NS-2.30. Table -1 represents the different simulation settings used in this work.

Simulation is carried out using 3 anchor and 20 ordinary nodes. Recursive localization process requires at least three anchor nodes. Simulation area is 100*100 m^2. Simulation is done for 50 ns. The predefined threshold value λ is set to 0.9.

Fig-4 shows the random deployment of nodes in MATLAB where the total number of nodes is 23 which are spreaded unevenly.

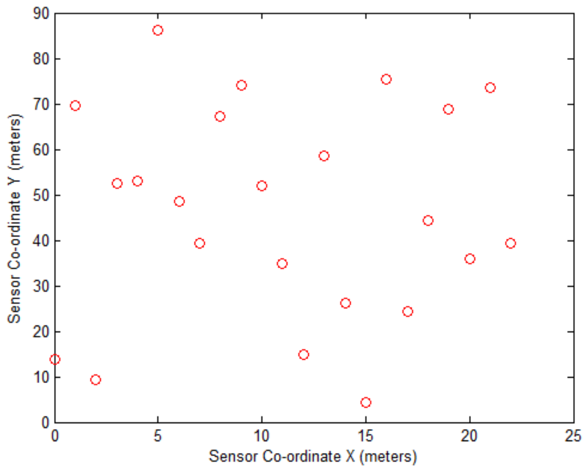

Fig-4: Simulation result in MATLAB

Fig-5 shows how energy can be calculated by entering the x and y co-ordinates. The table in the left side represents the energy value for the given co-ordinates.

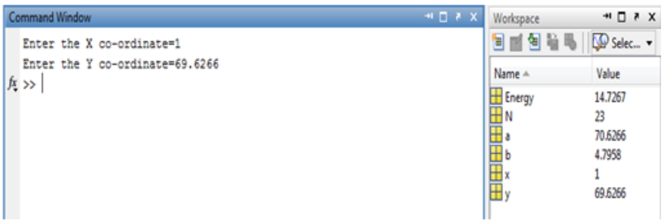

Fig-5: Energy Calculation in MATLAB

Energy for all the nodes is calculated and entered in Table-2. Here the x and y co-ordinates of nodes simulated in MATLAB is also entered.

Fig-6 shows the random deployment of nodes in Aqua-Sim network simulator-2.Here also the nodes are dispersed at uneven positions in a given simulation area. Here node 21, 5 and 16 are considered has anchor nodes having highest energy in MATLAB.

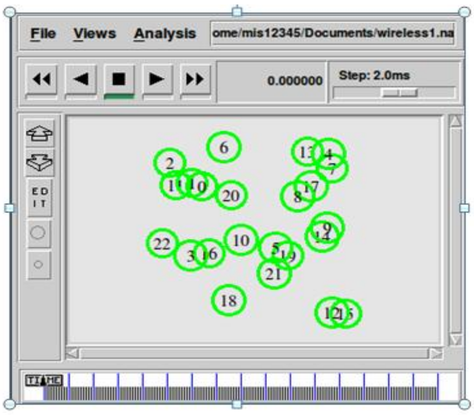

Fig-6: Random Deployment of nodes

Table-2: x and y co-ordinates and energy entries obtained from MATLAB

Nodes	x co-ordinates in meters	y co-ordinates in meters	Energy
Node0	0	13.8874	2.8957
Node1	1	69.6266	14.7267
Node2	2	9.382	2.3733
Node3	3	52.5404	11.5810
Node4	4	53.0344	11.8925
Node5	5	86.114	18.9986
Node6	6	48.4853	11.3610
Node7	7	39.3456	9.6637
Node8	8	67.1431	15.6684
Node9	9	74.1258	17.3329
Node10	10	52.0052	12.9290
Node11	11	34.7713	9.5440
Node12	12	14.9997	5.6298
Node13	13	58.6092	14.9316
Node14	14	26.2145	8.3853
Node15	15	4.4454	4.0546
Node16	16	75.4933	19.0777
Node17	17	24.2785	8.6072
Node18	18	44.2402	12.9780
Node19	19	68.7796	18.3033
Node20	20	35.9228	11.6607
Node21	21	73.634	19.7326
Node22	22	39.4707	12.8175

Fig-7 shows the ubuntu terminal displaying the x and y co-ordinates of the ordinary nodes and the distance of ordinary nodes from each anchor nodes. Confidence value of each located nodes is also calculated. These values are entered in Table -3.

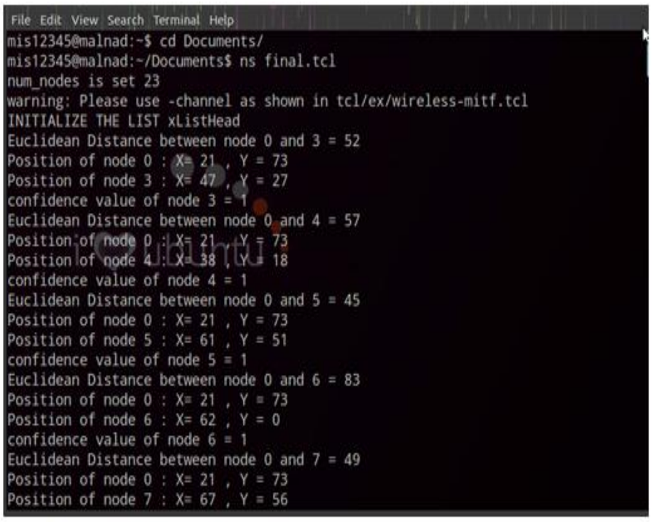

Fig-7: Terminal displaying the x and y co-ordinates and distance between the nodes.

Table-3: Distance and confidence value entries

Ordinary Nodes	Estimated Positional Co-ordinates in m*m	2-D Euclidean Distance in Meters			Confidence Value µ
		B0	B1	B2	
Node3	x=47 y=27	52	57	72	1
Node4	x=38 y=18	57	61	75	1
Node5	x=61 y=51	45	51	66	1
Node6	x=62 y=0	83	87	103	1
Node7	x=67 y=56	49	54	68	1
Node8	x=23 y=31	42	44	57	1
Node9	x=72 y=92	54	58	67	1
Node10	x=74 y=0	90	94	110	1
Node11	x=97 y=64	76	81	94	1
Node12	x=23 y=17	56	58	71	1
Node13	x=29 y=49	25	29	44	1
Node14	x=8 y=40	35	35	46	1
Node15	x=87 y=49	70	75	89	1
Node16	x=85 y=35	74	79	94	1
Node17	x=35 y=25	50	53	67	1
Node18	x=89 y=47	72	78	92	1
Node19	x=89 y=81	68	73	84	1
Node20	X=26 y=88	15	16	21	1
Node21	x=25 y=56	17	21	36	1
Node22	x=59 y=66	38	43	57	1

Fig-8 shows the simulation results of x and y co-ordinates when input is not defined i.e. for a general case.

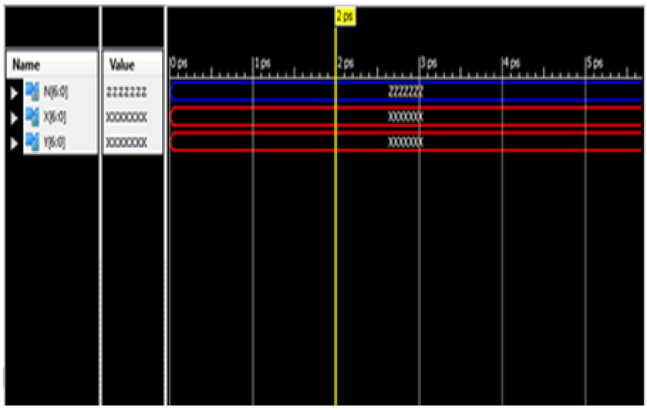

Fig-8: Simulation result in Xilinx

When input is given the corresponding x and y co-ordinates are displayed. Fig-9 shows the simulation result for node 5.

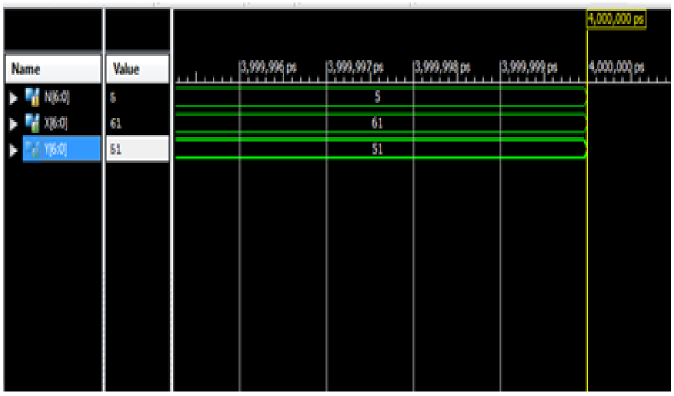

Fig-9: Simulation result for node 5

4. CONCLUSIONS

An Event Driven Localization Scheme for distributed underwater wireless sensor network is proposed which evaluates its performance based on the values of mean localization ratio. Since anchor nodes are already localized, therefore emphasis is put for ordinary node localization.

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