

Sensor Node Localization and Visualization in Underwater Sensor Networks

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Abstract - The localization of non-localized nodes is a crucial task in the underwater communication. The significance of localization is largely due to its role as a basic building block of several other capabilities, including the tagging of the monitored data, co-ordination of a group of node's motion and the detection of the position of underwater targets. Moreover, the localization of nodes also helps to adjust the routing protocols and medium access and facilitates processes like geo-routing. On the whole, the localization of sensor nodes is an inevitable procedure to get useful location-aware data.

Keywords — **Non-Localized nodes, Localization, Tagging, Routing, Sensor Node**

I. INTRODUCTION

Node's localization in a real environment is not an easy task, as underwater sensor networks (USNs) suffers several challenges [1]. One of the major tasks is determining sensor node's 3D position coordinates [2] in real-time water environment. A proper visualization [3] tool can help to overcome this difficulty. In addition, visualization tool also permits researchers to easily observe and recognize the patterns and behaviors of networks [4]. Hence, the present study is proposing the application of a visualization tool, named as Aqua-3D, developed by Tran [5], for localizing the non-localized nodes in a 3D underwater environment. The study attempted to examine its efficiency by comparing it with GPS module. The subsequent titles will provide the description of Aqua-3D, localization using Aqua-3D and its performance efficiency.

II. LOCALIZATION USING AQUA 3D

The localization process using Aqua-3D is depicted in Fig 1.

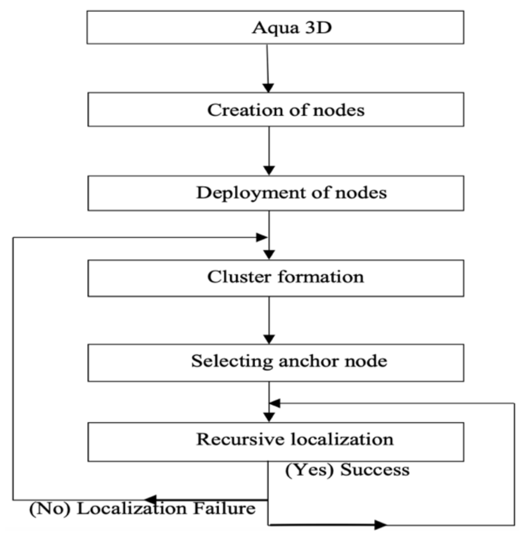

Fig 1. Flowchart

Nodes are deployed using tetrahedron deployment algorithm. Clusters in a deployed network comprises of an anchor node with highest battery power and has the prior understandings about its position coordinates. They are known as cluster head. The localization of the remaining non-localized nodes in the cluster are performed with the help of recursive localization considering the position of anchor node as reference. The ID numbers have provided to clusters on the basis of their location in the 3Dsurface. For instance, cluster with x,y,z polarity, which has the value +++ is identified as 1 or referred as ID 1. Similarly, if x,y,z polarity is ++- , then it is referred as ID 2 and so on. The simulation process consists of a top limit of 8 clusters. The position of each node is determined with respect to x,y,z coordinates. The data manager recursively preserves the position values of every sensor nodes that are visible in the node detail window. The entire localization process will be repeated from cluster formation, if there is any shift in the network topology due to the movements of nodes.

The stepwise description of localization process using Aqua-3D is provided in the subsequent paragraphs.

The first step in the localization process is setting the simulation and visualization environment. The study used network simulator-3 (NS-3) for the simulation of node deployment and Aqua-3D for 3D visualization of localized coordinates. The simulation parameters used by Aqua-3D are depicted in Table I. The study used a 3D simulated environment, having the area 400m*400m*400m. Acoustic medium is used for the data transmission. A total of 80 nodes is deployed under 8 clusters. The movement model is considered as static because, the anchor nodes, which perform an information exchange with other nodes in the cluster, maintain a static movement.

The model of the deployed UWSN is showcased in Fig 2 and the process of localization is described in the subsequent paragraphs.

Table I. Simulation Parameters

Parameter	Values
3D boundary	400m*400m*400m
Channel	Acoustic
Total number of nodes	80
Number of clusters	8
Node IDs	Node 0 to Node 79
Movement model	Static
Routing protocols	UW Flooding
Physical model	Underwater Phy
Mac protocol	Broadcast Mac
Initial energy nodes	1000J
Propagation model	Underwater propagation

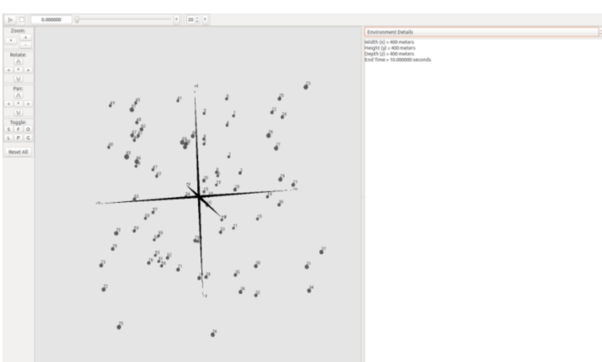

Fig 2. Environment details and Random deployment of sensor nodes

Once, the simulation environment has been set, the next step is the creation of water environment using data manager CCP tool. Fig 3 depicts the 3D network grid with deployed nodes. These nodes begin showcasing a random movement in the water environment during simulation.

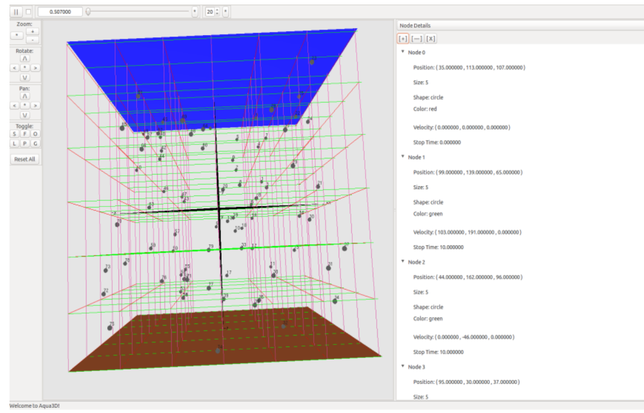

Fig 3. Network grid with deployed nodes

The nodes deployed in the water environment are assembled into 8 clusters, with all containing a fixed count of nodes. Within each cluster, the node having the maximum battery power is set as the anchor node and provides the numbers, such as 0, 10, 20, 30, 40, 50, 60 and 70.

Various nodes within the grid/cluster are differentiated the difference in its size, shape and colour. Figs 4(a), 4(b) and 4(c) provides the node ID details like node velocity, stop time of the simulation and node position.

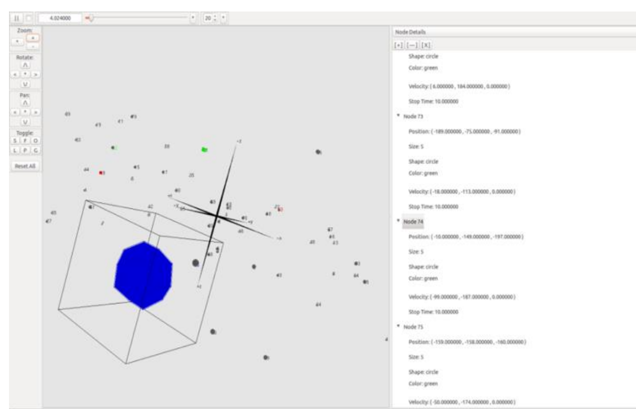

Fig 4 (a) Sensor node position

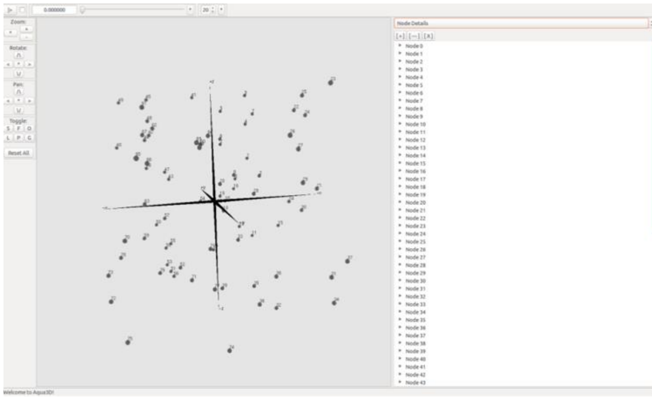

Fig 4 (b) Sensor node velocity

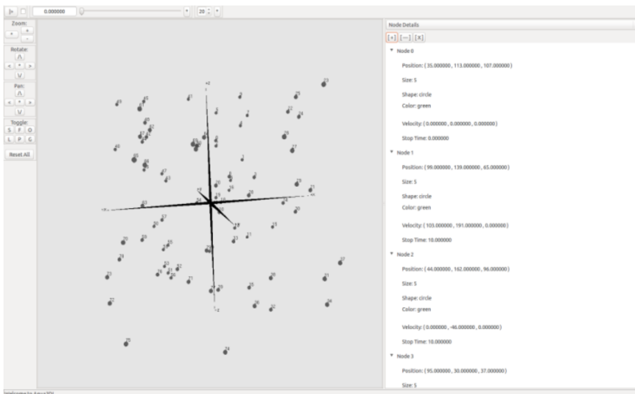

Fig 4 (c) Stop time of simulation

Node 0 having the coordinates (35.00,113.00,107.00), is the anchor node in the first cluster. Even though, the rest of the sensor nodes showcases random movement in the grid structure during simulation, the anchor nodes stay as staticand these anchor nodes perform an information exchange with remaining nodes in the cluster (Fig 5). The time data regarding the deployment of each node were also observed.

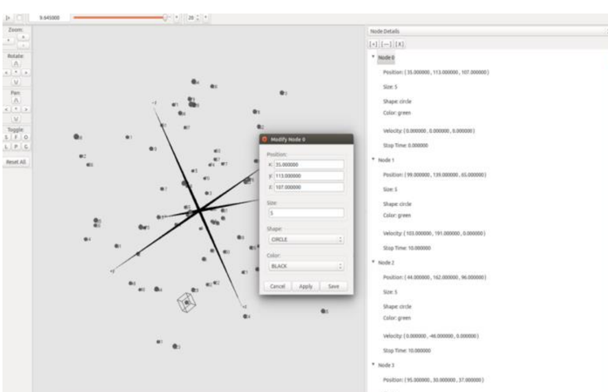

Fig 5 (a) Anchor node co-ordiantes and timing details

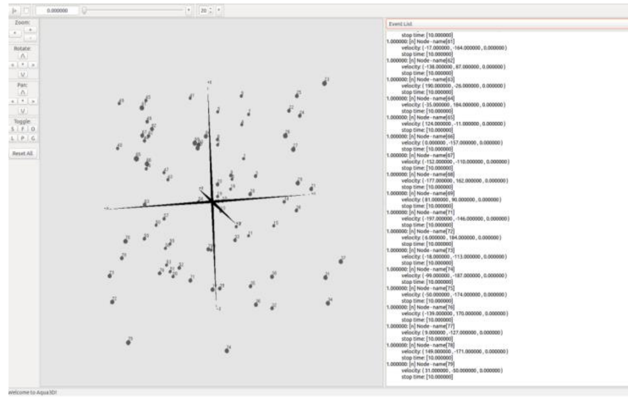

Fig 5 (b) Anchor node co-ordiantes and timing details

After the successful deployment of anchor nodes and the identification of anchor node co-ordinates, the localization of the non-localized nodes were performed with the help of a recursive algorithm and the co-ordinates were updated (Fig 6). As an example, the initial position of node 69, which was localized with the help of anchor node was (-48.00,-116.00,103.00), however, the position got updated after 30 seconds of simulation time and the co-rodinates became (296.22,220.14,54.00). Similar process continued with other non-localized nodes also and hence all non-localized nodes were successfully localized and visualized using its 3D coordinates.

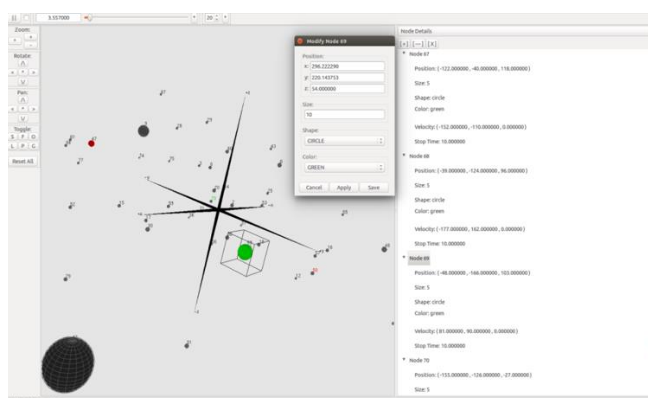

Fig 6. Non-localized node's Localization details

III. HARDWARE TOOLS AND EXPERIMENTATION

In this experiment, the study deployed the non-localized nodes which is developed was used in an underwater environment, which is 1to 4 meters deep and placed the anchor node on the water surface. A Linux operating system supported with the graphics card of 2GB, was used for the purpose of simulation. In addition, all the other requisite software, including VNC Viewer for observing the GPS values, was installed.

The non-localized anchor node used by the study comprised of the interconnected hardware components, including Raspberry Pi 3 b+, a TFT display for observing the output offshore, a GPS module to obtain the 3D co-ordinates, a DHT-11 Temperature sensor and the Battery. The pictorial display of hardware components used in the study is depicted in Fig 7.

Fig 7. Hardware components of the non-localized sensor node

The study placed whole set up in an electrically harnessed waterproof enclosure, rated as IP67. With the help of GPS, the anchor node fetched the coordinated of its position and interacted with the non-localized nodes. The 3D coordinates of 6 sensor nodes deployed underwater, were determined iteratively. The temperature sensors had been positioned in the non-localized node to get information about the data transmission in the network. Further, the measurement of temperature of water environment had been performed and transferred to anchor node. This temperature value is preserved in cloud and renewed in each hour. 3D localization was performed over the grid of non-localized nodes and routed the data.

The schematic explanation of the experimental setup is depicted in Fig 8. Fig 9 illustrates the UWSN test bed deployed in the pool of study institution.

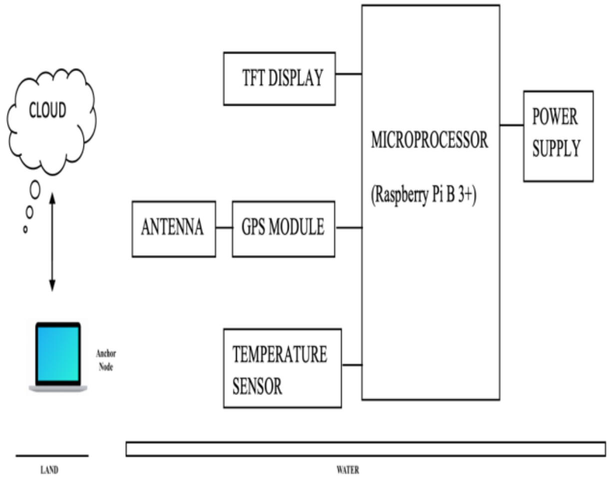

Fig 8. Block diagram of the experimental setup

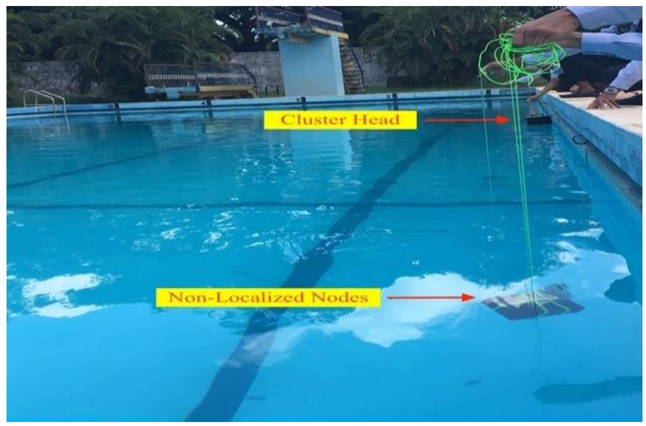

Fig 9(a) Hardware test bed of clusterhead and non-localized nodes

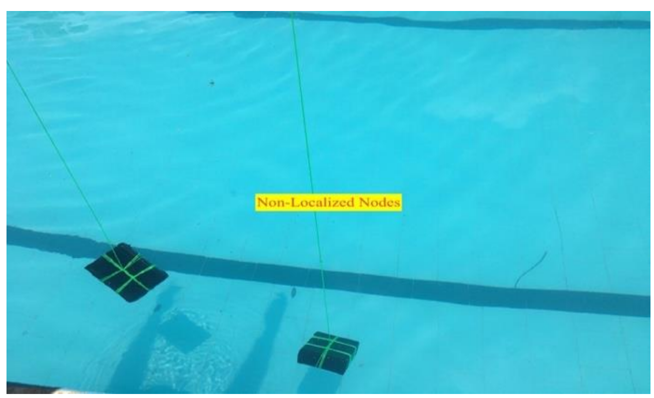

Fig 9(b) Hardware test bed of non-localized nodes

The Hardware associated with Aqua-3D

Table II provides the parameters taken by the present study for visualizing and localizing the non-localized nodes using Aqua-3D.

Table II. Hardware Implementation Parameters

Parameter	Values
3D boundary	400m*400m*400m
Total number of nodes	80
Number of clusters	8
Node IDs	Node 0 to Node 79

Experimental Procedure

The Flow chart (Fig 10), depicts the experimental procedure of the sensor network

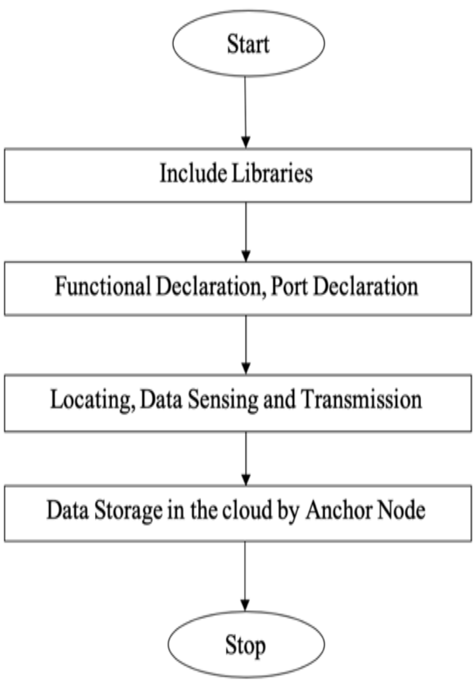

Fig 10. Work flow chart of the experiment

The process started with the inclusion of libraries, followed by the functional and port declaration. Then, data sensing and transmission occurred and stored in 'cloud' by anchor node. The study used Python programming language for storing the data in the 'Smartcore' cloud and also measuring the temperature and date. Header format of Smart core cloud is presented below (Fig 11).

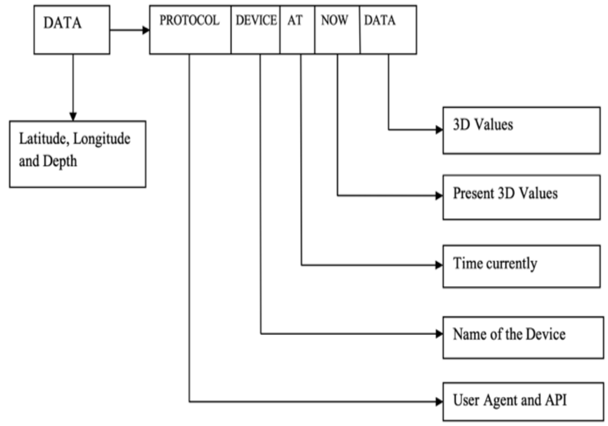

Fig 11. Data Structure for SmartCore Cloud

The responses of this experiment were recorded for the comparison between Aqua-3D and GPS in localizing the non- localized nodes. This is described in the following section.

IV. RESULTS

Performance parameters, such as latitude, longitude and depth were used to compare the localization efficiency of Aqua-3D with GPS. The findings were depicted in Table III. The longitude and latitude values were measured and the coordinates were rounded off to first decimal place for the convenience. The graphical representation of the comparison is depicted in Fig 12.

Table III. Latitude, Longitude and Depth Values of Aqua-3D and GPS

Node IDs	Latitude			Longitude			Depth		
	Aqua-3D	GPS	Difference	Aqua-3D	GPS	Difference	Aqua-3D	GPS	Difference
0	87.8	87.9	0.1	179.6	179.5	0.1	0.5	0.7	0.2
1	70.0	70.1	0.1	118.3	118.3	0	0.9	0.8	0.1
2	12.9	12.9	0	76.2	76.1	0.1	1.3	0.9	0.4
3	-36.6	-36.6	0	-67.3	-67.4	0.1	1.8	1.1	0.7
4	-55.5	-55.6	0.1	-95.4	-95.3	0.1	2.7	1.7	1
5	-80.6	-80.6	0	-163.9	-163.9	0	3.2	1.9	1.3

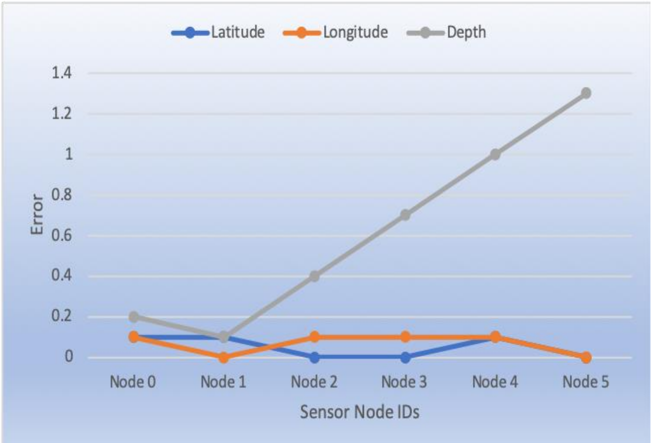

Fig 12. Comparative analysis of Aqua-3D and GPS values

Both the Table and the Figure demonstrated that with respect to the latitude and longitude, the difference in the co-ordinate values was minimal. However, the variation in the differences of values (also referred as error) was significant with respect to the depth of the environment. The findings (Table III and Fig 12) illustrated that the difference (error) in depth co-ordinate kept on increasing along with the increase in the depth of the environment. For example, the difference in depth co-ordinate of the localized nodes was only 0.1, if the nodes were placed at a depth of less than 1m (Table III). However, the difference became wider as the depth increased. The experiment showed that Aqua-3D was capable of localizing a non-localized node at a depth of 3.2 meters; meanwhile the localization capability of GPS was limited to a depth of 1.9 meters, showcasing a difference of 1.3 meters, a significant increase from 0.1. This clearly demonstrates that Aqua-3D is more efficient than GPS module in localizing the nodes which are placed in a deep water environment.

V. CONCLUSIONS

The present paper addressed the problems during the localization of non-localized nodes in 3D underwater environment. The study found out that the determination of sensor node's 3D position coordinates in real-time aquatic environment is the one of the major challenges faced during the localization of nodes and a proper visualization tool can help to overcome this difficulty. Hence the study proposed the application of Aqua-3D simulator to solve the problem. The experiments were conducted to achieve 3D coordinates of the non-localized nodes and also to illustrate the performance efficiency of the propose Aqua-3D. For this purpose, the study performed comparative analysis of Aqua-3D and GPS values using three performance parameters, such as latitude, longitude and depth. The findings demonstrated that Aqua-3D is more efficient than GPS module in localizing the nodes which are placed in a deep water environment.

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