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Node Movement Prediction & Node Location Algorithm in Underwater Acoustic Sensor Networks

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Abstract: Underwater Wireless Sensor Networks (UWSNs) are finding different applications for offshore exploration and ocean monitoring. In most of these applications, the network consists of significant number of sensor nodes deployed at different depths throughout the area of interest. The sensor nodes located at the sea bed cannot communicate directly with the nodes near the surface level; they require multi-hop communication assisted by appropriate routing scheme. However, this appropriateness depends not only on network resources and application requirements but also on environmental constraints. In our project, node location phase has proposed with the help of, a TOA (time of arrival)-based ranging strategy to reduce communication overhead and energy consumption. Then, after dimension reduction processing, the grey wolf optimizer (GWO) is used to find the optimal location of the secondary nodes with low location accuracy.

Keywords: UWSN, GWO, sensor network, node prediction

1. INTRODUCTION

The ocean is vast as it covers around 140 million square miles; more than 70% of the Earth's surface, and half of the world's population is found within the 100 km of the coastal areas. Not only has it been a major source of nourishment production, but with time it is taking a vital role for transportation, presence of natural resources, defense and adventurous purposes. Even with all its importance to humanity, surprisingly we know very little about the Earth's water bodies. Only less than 10% of the whole ocean volume has been investigated, while a large area still remains unexplored. With the increasing role of ocean in human life, discovering these largely unexplored areas has gained more importance during the last decades. On one side, traditional approach used for underwater monitoring missions have several drawbacks and on the other side, these inhospitable environments are not feasible for human presence as unpredictable underwater activities, high water pressure and vast areas are major reasons for un-manned exploration. Due to these reasons, Underwater Wireless Sensor Networks (UWSNs) are attracting the interest of many researchers lately, especially those working on terrestrial sensor networks. Sensor networks used for underwater communications are different in many aspects from traditional wired or even terrestrial sensor networks (Akyildiz et al., 2005; Heidemann et al., 2006).

Firstly, energy consumptions are different because some important applications require large amount of data, but very infrequently. Secondly, these networks usually work on a common task instead of representing independent users. The ultimate goal is to maximize the throughput rather than fairness among the nodes. Thirdly, for these networks, there is an important relationship between the link distance, number of hops and reliability. For energy concerns, packets over multiple short hops are preferred instead of long links, as multi-hop data deliveries have been proven more energy efficient for underwater networks than the single hop (Jiang, 2008). At the same time, it is observed that packet routing over a greater number of hops ultimately degrades the end-to-end reliability function especially for the harsh underwater environment. Finally, most of the time, such networks are deployed by a single organization with economical hardware, so strict interoperability with the existing standards is not required. Due to these reasons, UWSNs provide a platform that supports to review the existing structure of traditional communication protocols. The current research in UWSNs aims to meet the above criterion by introducing new design concepts, developing or improving existing protocols and building new applications (Fig. 1).

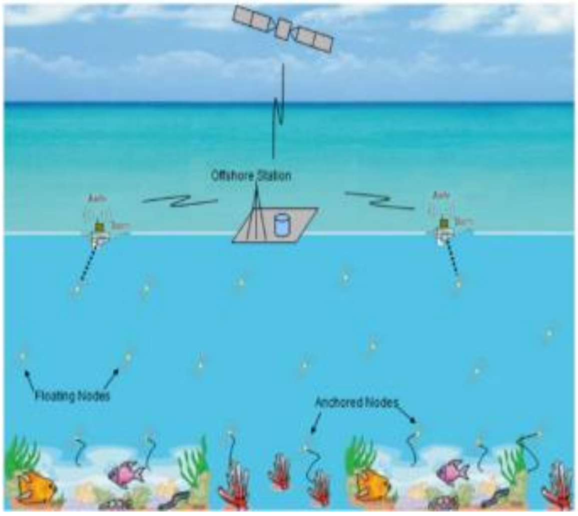

Figure 1. Underwater mobile sensor node scenery

Further, some of the underwater applications, including detection or rescue missions, tend to be ad hoc in nature, some requiring not only network deployment in short times, but also without any proper planning. In such circumstances, the routing protocols should be able to determine the node locations without any prior knowledge of the network. Not only this, the network also should be capable of reconfiguring itself with dynamic conditions in order to provide an efficient communication environment. Moreover, a significant issue in selecting a system is establishing a relation between the communication range and data rate with the specific conditions. A system designed for deep water may not be suitable for shallow water or even when configured for higher data rates when reverberation is present in the environment (Chitre et al., 2008). Manufacturer's specifications of maximum data rates mostly are only useful for establishing the upper performance bound, but in practice these are not reachable with specific conditions. Users who are well funded have resorted to purchasing multiple systems and testing them in particular environment to determine if they will meet their needs. An international effort for standardizing the tests for acoustic communications is required, but it is not so simple as private organizations or even government institutes performing such comprehensive tests tend not to publish their results.

II. LITERATURE SURVEY

Cheng et al. (2018) proposed a target-scale localization scheme (LSLS) algorithm as a static localization algorithm of UASNs. This algorithm solves the problem of the locations of large-scale network nodes and improves the location coverage; however, a large amount of communication between nodes will increase node energy consumption, leading to the premature death of nodes. Song et al. (2016), proposed a self-healing localization algorithm (SHLA) for UASNs [13]. This algorithm can effectively improve the location coverage, reduce the impact of the anchor node faults, and prolong the network life. However, it cannot meet the requirements of some environments because it improves the location coverage while ignoring the problem of node location accuracy. Cheng et al. proposed a passive underwater positioning scheme (UPS) without time synchronization. This scheme fixes the anchor node to the seafloor and requires its communication distance to cover the entire network. Its disadvantage is that the location of the three-dimensional underwater network needs to obtain at least four beacon nodes from a distance, resulting in relatively high node traffic. In addition, the algorithm has a limited communication distance, and can therefore only be applied to small underwater networks.

Chang et al. (2019), proposed a new approach to the RSS-based underwater acoustic localization problem based on the convex relaxation technique in underwater wireless sensor networks (UWSNs). This method improves the location accuracy of the underwater acoustic RSS, but only considers the simplified model, rather than the general model. Nguyen et al. (2019) established an RSS-based location scheme that can accurately predict the location of the sensor by studying the change depth and random fluctuation of dynamic propagation in the water. However, to effectively apply the UWSN location scheme, it is necessary to combine the characteristics and challenges of underwater acoustic signals with the location design. Sun et al. (2019) proposed a mobile anchor node-assisted RSSI localization scheme for use in UWSNs. However, the error between the vertical distance obtained by this method and the actual parameters is large, and its location accuracy is not ideal. Xu et al. (2019) proposed a localization algorithm using a mobile anchor node based on region determination in UWSNs;

Xu et al. (2019) proposed a localization algorithm using a mobile anchor node based on region determination in UWSNs; however, it only considers the wind speed and salinity environment, and does not consider the noise and sea water flow in the process of moving anchoring nodes. Chang et al. (2018) proposed a target location scheme based on the received signal strength measurement. This algorithm is a simple method for solving the problem of underwater RSS location. However, there is still much room to improve its estimation accuracy. Luo et al. (2017) proposed a localization algorithm called the Two-Phase Time Synchronization-Free Localization Algorithm (TP-TSFLA).

A multi-step localization method based on mobility prediction and the PSO algorithm was proposed by Zhang et al. (2016) However, the range-based PSO algorithm may consume a considerable amount of energy, and its computation complexity is high

III PROPOSED METHODOLOGY

A. TOA-based ranging strategy

Based on the TOA ranging method, this paper designs a ranging strategy that is considered a time backoff strategy. This policy only requires the packet switching of a pair of messages; one occurs in the starting node of a known sensor node, and the other occurs in the node to be located. The other known sensor nodes only need to listen to broadcasts, and the European distance of a node to be located to all known sensor nodes in its communication range can be measured. A backoff time is added for the node to be located to avoid collisions with other request information. The data transmission process of this strategy is obviously reduced, and consequently the energy consumption of nodes is reduced and the network life cycle is prolonged. The ranging method takes place in the communication range of a node to be located. Only two transmission processes can measure the distance between all known nodes and the node to be located; one is in the starting node, and the other is in the node to be located. The other known nodes only need to listen to broadcasts. This strategy can reduce energy consumption because the process of receiving data consumes less energy than the transmission process. Additionally, when the node to be located receives the range request, the response message is not required to be fed back immediately, and a backoff time is experienced. This can prevent the information delay or failure caused by message collision, and the energy consumption of the node can be further reduced by reducing the message retransmission process. A ranging strategy between a known sensor node and a node to be located P is illustrated in Figure 2.

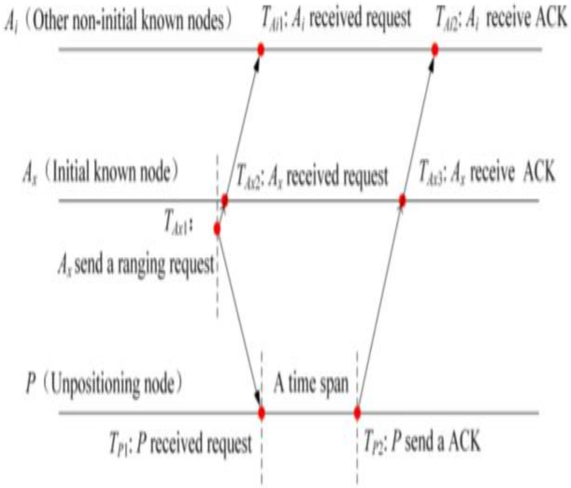

Figure.2. ToA Based Ranged Strategy

The buoy collects all the above data packets and sends them to the base station, which performs distance calculation. Based on the above description, the following equations are derived.

$$T_{p1} = T_{A_x1} + d_{A_xp}/v$$

$$T_{A_x2} = T_{A_x1} + D/v$$

$$T_{A_x3} = T_{p2} + d_{PA_x}/v$$

$$T_{A_i1} = T_{A_x1} + d_{A_xA_i}/v$$

$$T_{A_i2} = T_{p2} + d_{A_ip}/v$$

In the above equations, TA is the timestamp when the event occurs, d is the physical distance between nodes, v is the underwater sound velocity, and D is the distance between the node receiver and transmitter.

$$d_{A_xp} = \frac{v}{2}[T_{A_x3} - T_{A_x1}] - (T_{p2} - T_{p1})$$

$$d_{A_ip} = d_{A_xp} + d_{A_xA_i} - D + v(T_{A_i2} - T_{A_i1}) - v(T_{A_x3 - T_{A_x2}})(i \neq x)$$

B. Calculation of node position

The main idea of the MPL algorithm is to use the hierarchical method to locate the first node location, the secondary node location, and supplementary locations. As shown in Fig.5, the node located by the buoy is a first-level node, and the remaining nodes are secondary nodes. In the process of location, the unknown under water sensor node (i.e., the node to be located) communicates with the known underwater sensor node (i.e., the known node) to obtain the time stamps of the transmitted data and the received data. Then, the base station collects the time stamp data, calculates the distance between the nodes, and finally calculates the coordinates of the node to be located. Based on the existing location information, the future mobile models are predicted, and the future location is estimated by these mobile prediction models.

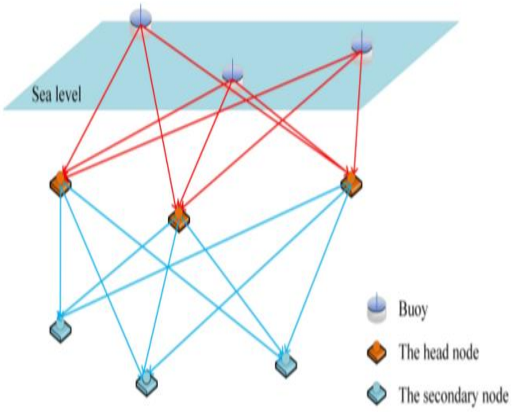

Figure. 3. Three-dimensional model of underwater communication network

C. Secondary level node location:

Limited by the communication distance between network nodes and the timeliness of node location, the first level nodes are used to locate the secondary level nodes. However, In order to reduce the transfer error and improve the location accuracy, the optimal first level nodes are selected as the location reference points and the Grey Wolf Optimizer (GWO) is used to locate the position of the secondary level nodes. In the GWO algorithm, for the function optimization problem, the individual with the highest fitness value is represented by the symbol α, the two suboptimal individuals are represented by β and δ, respectively, and ω represents the other individuals excluding the three individuals above them in the hierarchy. As shown in Fig.8, when grey wolves conduct group hunting, the whole population is led by α, β and δ are responsible for assisting with the work, and ω obeys commands and follows α, β, and δ for hunting and predation, including following the three steps for encircling, hunting, and attacking, and eventually capturing prey. The optimal solution in the population is wolf α, and the second and third optimal solutions are β and δ as candidate solutions. It is assumed that there are m known nodes to be located in P, and when m is greater than 10, the 10 known nodes closest to the target node are selected to locate it. When m is less than 3, it cannot be positioned. Each of the m (10 > m > 3) known nodes is a group of triangular positioning units, and there are C3 m (set k = C3 m). In addition to the unqualified triangular positioning unit, the coordinatevaluesof3pointscanbecalculated by using trilateral measurements in the first three groups,

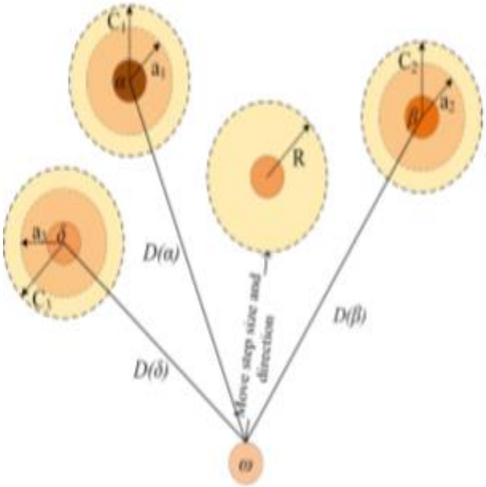

Figure 4. Grey Wolf Optimization

IV. SIMULATION TOOL

MATLAB is a simulation software, which can be applied to sensor networks, data analysis, deep learning, image processing, computer vision, risk management, control systems, communications, signal processing and so on. It is an abbreviation of matrix and laboratory and it is developed by MathWorks. The MATLAB settles the high-tech computing problems such as scientific computing, visualization, and interactive programming. It integrates many powerful functions like numerical analysis, matrix calculation, scientific data visualization, and nonlinear dynamic system modeling and simulation in an easy-to-use software environment. It provides a comprehensive solution for scientific research, engineering design, and many scientific problems that require effective numerical calculations. Moreover, it gets rid of the editing mode of traditional non-interactive programming languages, such as C and Fortran, to a large extent, and it provides many feature-rich practical tool boxes such as signal processing toolboxes and communication toolboxes.

V. RESULT AND DISCUSSION

In this section, the result of the project has explained with respect to Cost function, Underwater sensor node deployment, and mobility of node.

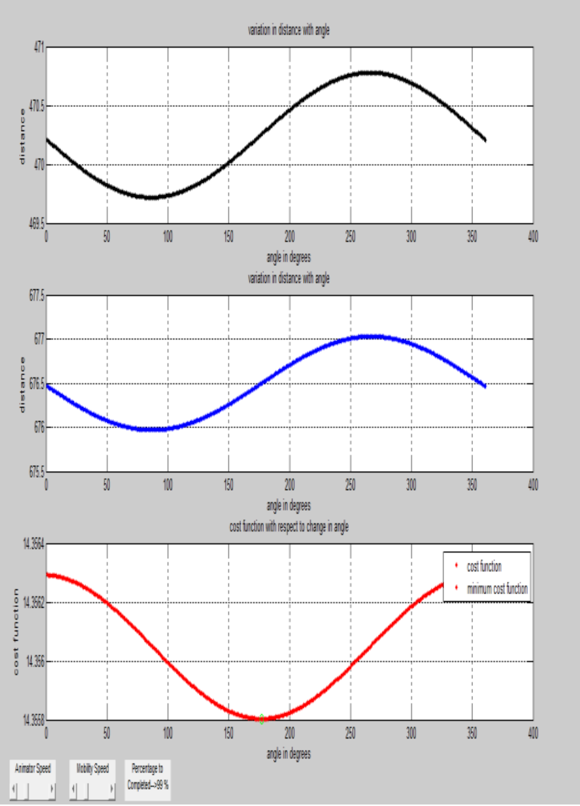

Figure. 5. Cost function and cost angle

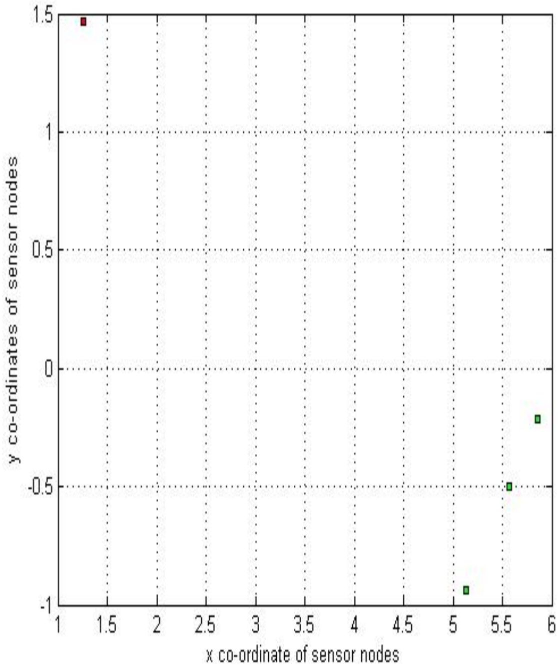

Figure 6. Sensor node deployment

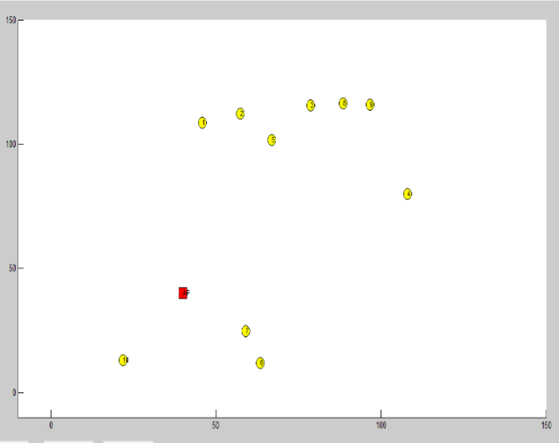

Figure. 7. Prediction of Moving node

VI. CONCLUSION

In this paper, we have presented an overview of state of the art of locating the nodes in underwater wireless sensor network. Localization for UWSN is an important issue, which is attracting significant attention from the researchers. The design of any localization protocol depends on the goals and requirements of the application, as well as appropriateness, which depend on the availability of network resources. The development of localization of node suitable for these environments is therefore regarded as an essential research area, which will make these networks much more reliable and efficient.

Conflict of Interest:

The authors confirm that there is no conflict of interest to declare for this publication.

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