Localization and Mobility of Underwater Acoustic Sensor Nodes

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Abstract—The Underwater Acoustic Sensor Network (UASN) is a network which consists of underwater wireless sensor nodes distributed randomly over the certain area of observation and communicate with each other using acoustic signals. UASN can be used in a wide variety of underwater applications, ranging from marine biology surveillance to earthquake and tsunami alert applications. Despite the fact that sensor networks are meant to collect data, in some applications, collection of data without a location of the occurrence becomes incoherent. Hence, localization for UASN has become an enthralling research topic in the recent years. However, there are several disadvantages of acoustic channel like propagation delay, limited energy sources, high bit error rate, and limited harvesting techniques underwater make the localization of UASN very challenging. Therefore, in this paper we have proposed a distributed localization scheme which employs two-way time of arrival estimation method to calculate distance and avoid the requirement of time synchronization.

Keywords- Underwater Acoustic Sensor Network, Acoustic Signals.

I- INTRODUCTION

Research on the Underwater Acoustic Sensors has seen rapid growth in recent years because of their wide prospects of potential applications ranging from exploration of rare minerals situated in the deep oceans, environmental monitoring, disaster warning systems, target monitoring systems, underwater habitat monitoring and oceanographic data gathering. Underwater wireless sensor networks behave as a bridge between the virtual information technology and real world phenomena. Optimal performance of the networks requires a balance number of working nodes, energy efficiency of the network and lifetime of the network, so the number of functional nodes in the network are very crucial for the operation of the network as a whole.

Underwater Acoustic sensor nodes use acoustic signals to communicate with each other; they can be deployed in very large number in a particular area to accomplish the task by forming a network. They communicate with each other to complete the task in a distributed way. Every sensor node in the network behaves as a host as well as router to route packets to other nodes in the network; the sensed data is then sent to sink which is connected with high bandwidth link to internet or database for real time monitoring and analysis. Even though wireless sensor networks are data centric networks some applications of these networks require the exact position of the sensor in order to properly transmit and receive the information in high latency underwater sensor networks.

The process of locating the position of sensor nodes in the network is called sensor localization. Sensors are not equipped with Global-positioning system, because Radio Frequency signals do not work in water and cannot be used to determine coordinates of nodes. To address this issue, algorithms are needed to detect the position of the sensor node in that area, where each position of the distributed sensor can have been determined using distributed localization algorithm. There are many techniques to resolve localization problems in terrestrial wireless sensor networks as discussed by the authors in [1] [2]. Localization is a method which finds the coordinates of the sensor node and helps maintain good communication in the underwater networks. Attenuation in radio signals and scattering of optical signals are very high in water; therefore, acoustic signals are considered as the best means of communication for underwater wireless sensor networks. Not only do Underwater Wireless Sensor Networks not have GPS signal underwater, but they are also limited to low bandwidth, high propagation delay, acoustic channel bit error rate, unevenly distributed sensor nodes which affects the localization of underwater sensor nodes. Special care must be taken while designing the protocol for Underwater Wireless Sensor Networks. It should ensure low energy dissipation, because of finite energy harvesting techniques available underwater and since replacing batteries of underwater sensors is not a feasible idea.

In this paper we have proposed an event-driven localization scheme for underwater sensor networks. Usually, in normal underwater sensor networks there are two different types of nodes, Beacon nodes and ordinary nodes; beacon nodes generally sink and the position of the beacon nodes are assumed to be fixed. Beacon nodes, which are also called anchor nodes are localized already. Therefore, in this paper we discussed only about the localization of the ordinary sensor nodes whose positions are unknown because of their random distribution. In Section 2 of this paper, related work is shown, which discusses about some of the existing techniques in the localization of underwater sensor nodes followed by the problem definition and the conclusion of the paper.
The localization scheme concept is developed and centered mainly for applications of UASN. In [1], a recursive distributed localization scheme is considered in which all sensor nodes are placed randomly underwater. Anchor nodes are used to obtain the geographical information, also it is localized. These sensor nodes respond to the localization request message broadcasted by the ordinary sensor nodes and they are equipped with an acoustic transmitter and receiver. Ordinary sensor nodes perform the tasks assigned to it, which is known as an event-driven technique. The node are the parameters with which the performance is evaluated. Localization success ratio is defined as localized nodes by total number of ordinary nodes which rises as the beacon nodes within the network increases.

During the movement of nodes, the mobility prediction model’s coefficients are estimated by the anchor node to determine the location in the next close prediction period [2]. The model works well, or the model coefficients are re-estimated quickly with a localization message sent, if the distance between the real and estimated location is less than the prediction threshold. This message signal carries all of the information about the node. The received message is dealt with, with the help of the reference nodes. The node updates its reference list with the required information in message. If the entry of the reference node becomes full, a new reference node is created with the existing nodes. The localization scheme used here is a distributed process. The anchor nodes in the network perform self-localization, predicting the movement of nodes and also acts as a reference node for the nearby ordinary nodes.

The paper [3] uses two Reference points for localization purpose. When the nodes are near the collision of two anchor messages, the message transmission can be controlled by utilizing the vicinity of the sensor node. Positions are calculated based on the time of arrival of the two anchor messages. To obtain the vicinity, the collision has to take place in the center of a region where the transmission of anchor message should occur. This method coordinates the reception of anchor messages by the sensor nodes within a certain time interval. The time intervals are referred to as transmission patterns. In this approach, all possible transmission sequences are found, which are fixed lengths. Also anchor nodes are prevented from performing consecutive transmissions, to avoid any risk of colliding any transmission patterns. Their performance analysis considers a scenario in which all the anchor messages are transmitted at the same time. The time of arrival and the angle of arrival has to be considered for the nodes which needs more than three anchors for determining their location.

A scalable localization with mobility prediction model was developed in [4] for underwater sensor network which utilizes a hierarchical localization approach. There are two types of localization in this approach: anchor and ordinary node localization. For the ordinary nodes to find their location, they use recursive range-based schemes and the spatial correlation of the underwater object. Usually anchor nodes measure their future location with the help of previous measurement locations, since they have straight contact with the dive and rise nodes. On the other hand, ordinary nodes cannot perform this type of approach for their location identity due to their poor memory and the size of computation is less for them. Localization coverage increases with increase in the prediction window utilized in this method. It will improve its position with the aid of previous estimated location if the sensor node does not get any localization message and also considering its speed vector. This process helped in reducing the communication cost by using localization coverage and accuracy.

In Paper [5], localization design and joint time synchronization are implemented for the localization and synchronization of ordinary nodes in the mobile underwater sensor networks. In this approach, propagation delays and sensor node mobility is considered. The movement of nodes often increases the delay in the propagation period so time synchronization has to be done. A Rough estimation of position of nodes has been found using this approach and the data is collected to find the estimated position. The approach has been divided into three phases. In one phase, the rough position is identified and in the next phase synchronization is done. In the last phase, nodes are localized by utilizing the data from the other phases. This mechanism has also been used in multi-hops scenario where there are more nodes and the mean distance among the nodes are higher. In order to achieve high accuracy, an advanced tracking accuracy algorithm is used for synchronization and localization purposes. However, varying transmission rate and varying time clock skew affect this approach of localization and synchronization during mobility of nodes. A hybrid size estimation algorithm [6] in shows each node knows its unique identifier and performing the estimated size of the network, a node counting algorithm is used.

A cross-correlation technique for the estimation of nodes has been proposed in [7]. Correlation is obtained when the signals are received at two sensors at the same time in the network. These signals are added and then correlated. Nodes are fixed; they are independent in this process. Binomial distribution is followed by the correlation function to prevent the random signal correlation problem. Mean and standard deviation can easily be obtained by this process. The approach followed in this technique is statistical signal following. This process will be affected by the sampling rate and also by the distance between the sensors. However, the harshness of the underwater networks affects the use of this protocol. Number of nodes can be estimated by correlating the random signal. In
order to overcome the problem in the above method, a new method is established in [8] where three sensors are used instead of two sensors. This approach has proven that the accuracy and the estimation process in much higher compared to the method with two sensors. However, there are some limitations in using this method. Signals used here are Gaussian and also delays are integer. A silent positioning system is discussed in [9] which relies on the time difference of arrival of the broadcast messages. It uses four anchor nodes to calculate the time difference between sensors. This method overcomes the communication overhead and synchronization problem.

A multi-hop localization algorithm is proposed in [10], to overcome the unknown node problem which is isolated in underwater sensor networks. This process consists of five phases: obtaining distances of neighbors, reference node distance calculation, choosing the reference node, calculating the angles and then shortest path finding. This method is employed for enhancing the sensor nodes positioning precision. Also sensor localization algorithm was proposed in [11] to improve the accuracy of the sensor localization in accordance with the number of communication taking place. This method utilizes more sensors and localization is performed even though the sensor range is small. A hierarchical localization process for ordinary node localization in [12] uses distributed scheme to get high localization coverage and minimal localization error. However, different parameter requirements will be there for different networks which need to be addressed.

III. PROBLEM IDENTIFICATION

The Proposed Distributed localization scheme employs two-way time of arrival based estimation method to avoid the requirement of time synchronization. Only the ordinary nodes are localized since the beacon or anchor nodes are already localized. This method considers only the situations in which the nodes are idle, but node mobility is not considered during time synchronization.

The problem arises with the movement of the node during localization period. Hence a suitable underwater event-driven localization scheme based on mobility prediction has to be established to overcome the effects of mobility of nodes.

IV. METHODOLOGY

In this approach, we consider an underwater scenario in which we randomly place the ordinary nodes, the surface buoys and anchor nodes. The surface buoys are fixed with a GPS receiver to get the exact location with the help of a satellite. The surface buoys send their location data to the anchor nodes, which are also known as beacon nodes. They receive their location information with the help of surface buoys and localize themselves with the other anchor nodes.

Ordinary nodes are the sensing nodes which are also present in the underwater. All these ordinary nodes are non-localized. In order for the ordinary nodes to get localized, they must obtain location information from the anchor nodes, which is when they become reference nodes for the other non-localized nodes.

Sometimes the ordinary nodes move to a new location during the localization period. In that time, it is difficult to determine the new location, since it may be out the reference node localization area.

Here a mobility based localization scheme is explained. There are three types of nodes in this underwater wireless sensor network, namely anchor nodes, surface buoys and ordinary nodes which are spread randomly in water. Surface buoys receive their location information from GPS receiver. The information about the location of anchor nodes will be calculated with respect to the location information of surface buoys and information about the position of ordinary nodes is calculated in accordance to the location of anchor nodes. [13]

Underwater sensors are subject to continuous movement because of water currents and dispersion. Objects near seashore represents periodic pattern because of these tides and the underwater objects tend to have a group movement property as the motion of a single object is correlated to the motion of other objects. The mobility in underwater wireless sensors is emphasized by adopting a kinematic mobility model.
The proposed method is divided into two portions, in the first part anchor nodes localize and in the second part ordinary nodes are localized. In this network, surface buoys act as satellites and localize anchor nodes. The anchor nodes are superior to ordinary nodes because of their processing and computational properties. Therefore, the mobility tracking algorithm is to be implemented on them, but the ordinary nodes do not have such properties therefore recursive range based scheme can be used. An anchor node current location is calculated on basis on its past location and tracked mobility pattern, then anchor node makes comparison on its expected location with the calculated location. The mobility pattern is re determined to reduce the difference and broadcasts the localization message with its new location and new mobility pattern; unless the difference between the measured position and the estimated position is greater than the threshold value.

For every period of localization, the ordinary node seeks for the message(localized) from its network [14]. It makes assumption that the ordinary node becomes out of range if it does not receive the localized message for a long duration of time. It may function its location and mobility tracking to calculate its new location and mobility pattern if some localization message is received from the anchor nodes.

VI. CONCLUSION

In this paper, we have considered the mobility prediction algorithm for the localization of ordinary nodes and anchor nodes in underwater sensor network. The localization of ordinary nodes is done by estimating the path of the ordinary node and previous location. The location is estimated with the help of localization message from the anchor nodes. This approach overcomes the mobility problem, thus reducing the communication cost and the overall delay in the network.

REFERENCES


