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Efficient Time Synchronization and Localization for Mobile Under Water Sensor Networks

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Abstract— In distributed network systems the time synchronization plays a critical role. This time synchronization is investigated in the underwater sensor networks. The protocols used in the existing system do not consider long propagation delays and sensor node mobility. Our proposed system introduces the STSL (Synchronized Time Synchronized Location) algorithm which provides the accurate result. This approach is the use of relative speed and direction information available at the mobile UL node to compensate for node mobility. The STSL algorithm uses a two-step approach, in which first nodes are time-synchronized and then location is estimated. In addition, we used the applicable CRLBs as references for the performance of STSL. Considering the problem of establishing a faithful simulation environment for the underwater acoustic channel, Both simulations and sea trial results demonstrated that our algorithm can cope with time-synchronization and propagation speed uncertainties in a dynamic environment, and achieves a reasonable localization accuracy using no more than two anchor nodes.

Key Words-STSL,CRLB

I. INTRODUCTION

Underwater acoustics is the study of the propagation of sound in water and the interaction of the mechanical waves that constitute sound with the water and its boundaries. The water may be in the ocean, a lake or a tank. Typical frequencies associated with underwater acoustics are between 10 Hz and 1 MHz the propagation of sound in the ocean at frequencies lower than 10 Hz is usually not possible without penetrating deep into the seabed, whereas frequencies above 1 MHz are rarely used because they are absorbed very quickly. Underwater acoustics is sometimes known as hydro acoustics.The field of underwater acoustics is closely related to a number of other fields of acoustic study including sonar, transduction, acoustic signal processing, acoustical oceanography, bioacoustics, and physical acoustics

Under Water acoustic localization (UWAL) has recently attracted much attention due to advances of technology enabling reliable and efficient underwater acoustic communication (UWAC). Applications such as environmental monitoring, navigation or command and control systems typically include several autonomous nodes with UWAC capabilities and require accurate localization of these nodes. Localization also improves routing capabilities and scheduling in UWAC networks. Since GPS signals are highly attenuated underwater, UWAL is a difficult task with similarities to indoor localization.

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The need for underwater acoustic telemetry exists in applications such as data harvesting for environmental monitoring, communication with and between manned and unmanned underwater vehicles, transmission of diver speech, etc. A related application is underwater remote control, in which acoustic telemetry is used to remotely actuate a switch or trigger an event. A prominent example of underwater remote control are acoustic releases, devices that are used to return sea floor deployed instrument packages or other payloads to the surface per remote command at the end of a deployment. Acoustic communications form an active field of research with significant challenges to overcome, especially in horizontal, shallow-water channels. Compared with radio telecommunications, the available bandwidth is reduced by several orders of magnitude. Moreover, the low speed of sound causes multipath propagation to stretch over time delay intervals of tens or hundreds of milliseconds, as well as significant Doppler shifts and spreading. Often acoustic communication systems are not limited by noise, but by reverberation and time variability beyond the capability of receiver algorithms. The fidelity of underwater communication links can be greatly improved by the use of hydrophone arrays, which allow processing techniques such as adaptive beam forming and diversity combining.

Acoustic propagation is best supported at low frequencies, and the bandwidth available for communication is extremely limited. For example, an acoustic system may operate in a frequency range between 10 and 15 kHz. Although the total communication bandwidth is very low (5 kHz), the system is in fact ultra-wideband, in the sense that bandwidth is not negligible with respect to the center frequency. Sound propagates underwater at a very low speed of 1500 m/s, and propagation occurs over multiple paths.

II. LITERATURE SURVEY

Chaotic Behavior and Pollution Dispersion Characteristics in Engineered Tidal Embayments:

A Numerical Investigation: This paper presents a numerical investigation of approaches to enhance the mixing and dispersion processes in tidal areas by effecting changes in the natural estuary system. It compares the impact of various estuary modifications stemming from human intervention to pollutant dispersion and chaotic flow within the estuary including the implications of alteration of the original channel shape, change of the channel bathymetry, and modification of the tidal signal.

Localization in Underwater Sensor Networks - Survey and Challenges:

In this paper, we study the localization problem in large-scale Underwater Wireless Sensor Networks (UWSNs). Unlike in the terrestrial positioning, the global positioning system (GPS) cannot work efficiently underwater. The limited bandwidth, the severely impaired channel and the cost of underwater equipment all makes the localization problem very challenging. The new scheme mainly consists of four types of nodes, which are surface buoys, Detachable Elevator Transceivers (DETs), anchor nodes and ordinary nodes.

Aloha-Based MAC Protocols with Collision Avoidance for Underwater Acoustic Networks:

Unlike terrestrial networks that mainly rely on radio waves for communications, underwater networks utilize acoustic waves, which have comparatively lower loss and longer range in underwater environments. However, the use of acoustic waves pose a new research challenge in the networking area. While existing network schemes for terrestrial sensor networks are mainly designed for negligible propagation delay and high data rate, underwater acoustic communications are characterized by high propagation delay and low data rate.

Challenges: Building Scalable Mobile Underwater Wireless Sensor Networks for Aquatic Applications:

Large-scale mobile Underwater Wireless Sensor Network (UWSN) is a novel networking paradigm to explore aqueous environments. However, the characteristics of mobile UWSNs, such as low communication bandwidth, large propagation delay, floating node mobility, and high error probability, are significantly different from ground-based wireless sensor networks.

D-Sync: Doppler-Based Time Synchronization for Mobile Underwater Sensor Networks:

Time synchronization is an essential service in underwater networks, required for many functionalities such as MAC, sleep-scheduling, localization, and time-stamping of sensor events. However, there exist two fundamental challenges to underwater synchronization, namely, large propagation delays and substantial node mobility during the synchronization process.

III. EXISTING SYSTEM

In existing system we assume that UL nodes are equipped with means to self evaluate their speed and direction such as accelerometer and compass. While inertial systems could also be used for self-localization, inertial-Doppler navigation and Tactical Underwater Navigation systems often suffer from low accuracy due to accumulated errors when used stand alone. Therefore, UWAL is often based on ranging using packet exchange. In existing system, pair wise, cross layer and time synchronization scheme is called as DA-sync which is used to achieve time synchronization, reduce propagation delay and increase energy efficiency. In this algorithm first calculate the velocity of each node using the Doppler Scaling factor estimation algorithm. These velocities are further refined using the Kalman filter. In existing system, first data is collected then estimate velocity and propagation delay finally it performs linear regression and calibration.

The algorithm used in the existing system increases the energy and also increases the propagation delay which results in liner regression and calibration. However, due to unpredictable multiple access control (MAC) delays, an anchor node might not be able to respond immediately upon detecting a localization packet, thus significantly decreasing the accuracy. By applying mobility prediction, these approaches consider node movements as an undesired phenomenon.

The proposed system should perform a self-evaluation of localization accuracy, by estimating the propagation speed and checking its validity, relying on known model boundaries for it. Then it should provide the accurate localization of un-localized node. The number of iterations used in the system should be reduced in this proposed concept.

IV. PROPOSED SYSTEM

To overcome the problem of existing system here we introduce new algorithm called STSL (sequential time synchronization and localization) algorithm). The intuition behind our approach is the use of relative speed and direction information available at the mobile UL node to compensate for node mobility. The STSL algorithm uses a two-step approach, in which first nodes are time-synchronized and then location is estimated. In both steps, the measured time of flight of packets exchanged between anchor and UL nodes and self localization data obtained at UL nodes are linked to the unknown location, synchronization (clock skew and offset), and propagation speed parameters through liner matrix equations. Our algorithm is modular in the sense that both time-synchronization and localization steps can be readily replaced with alternative solutions (as we do in this paper to benchmark the STSL performance).

1) Topology formation
2) Un-localized node
3) Anchor node
4) Performance evaluation

Topology Formation:

In underwater acoustic communication the topology formation is the first step. In which there are number of nodes are contributed. In communication networks, a topology is a usually schematic description of the arrangement of a network, including its nodes and connecting lines. There are two ways of defining network geometry: the physical topology and the logical (or signal) topology. There are two types of nodes are in this topology. One is Un-localized node another is Anchor node. The Un-localized nodes do not know the nearest node's location in order to communicate. The Anchor nodes are the nodes they know the location of the nearest nodes present in the network. So, the un-localized nodes are first connect with nearest anchor node and then the anchor node sends the information about the nearest un-localized nodes to that concern node. Then the Un-localized node starts communication with that nearest localized nodes.

The nodes are grouped with each other in order to make cluster. The cluster consists of more number of anchor nodes and un-localized nodes. The topology defines the routing of data in a network. Localization of un-localized node is achieved by means of contacting with anchor node.

Unlocalized Node :

The un-localized nodes don't know the location of the nearest node in order to make communication. So, the un-localized nodes first connect with nearest anchor node and then the anchor node sends the information about the nearest un-localized nodes to that concern node. Then the Un-localized node starts communication with that nearest localized nodes.

The localization of un-localized nodes is difficult task. Because the nodes are mobile in nature so it causes unpredictable location changes. But in this proposed system we use a specific algorithm. Un-localized nodes are here localized by the anchor nodes by using an algorithm STSL. For example if we take the cellular communication in which each nodes are mobile in nature. So the user want to communicate with any other user is done by means of Base station and Mobile switching center. First the call is connected to the corresponding Base station of the user's location, and then base station enables the communication if the other end user is also within that base station. Otherwise the call is forwarded to the nearest mobile switching center and that enables the proper communication with desired user.

Likewise the localization of un-localized nodes is done by anchor node. The anchor node enables the communication between any two un-localized nodes, by sending the nearest localized nodes location to the un-localized node.

Anchor Node:

Anchor node knows the location about it. But un-localized node doesn't know the location. So the localization of un-localized nodes is done by using STSL algorithm. The localization technique follows the upcoming procedure.

1. Anchor node sends the packets to the nearest un-localized node.

➔ Calculate the distance between the Mobility nodes.
➔ Then calculate the angle between the mobility nodes
➔ Calculate the transmission rate between the mobility nodes
➔ Calculate the speed between the mobility nodes.

2. After find out this values, then anchor node sends the following details to the unlocalized node

➔ Location of the un-localized node.
➔ Distance between all the nearest un-localized node.
➔ Angle between the nearest un-localized node.

Then the communication became enabled between any two un-localizes nodes.

Performance Evaluation:

The performance evaluation is done by drawing graph for time consumption. Compare to existing system the time consumption is considerably reduced by using an algorithm named as STSL.

V. IMPLEMENTATION AND RESULTS

Time synchronization is an important requirement for underwater acoustic communication, for delivering packets at specified time. A lot of time synchronization protocols have been proposed for terrestrial Wireless Sensor Networks (WSNs). A synchronization algorithm for UWSNs must consider additional factors such as long propagation delays from the use of acoustic communication and sensor node mobility. Time Synchronization in wireless networks is extremely important for basic communication, but it also provides the ability to detect movement, location, and proximity.

The synchronization problem consists of four parts: send time, access time, propagation time, and receive time. Ranging in wireless networks is usually performed by measuring the time of arrival (ToA), time difference of arrival (TDoA) and angle of arrival. The main objective of time synchronization is to provide estimates the propagation delays. This can be accomplished by sending packet though two way transmission. Due to the permanent motion of nodes the delay obtained may not be same. There should allow quantization mechanism to allow for difference in propagation delay of separate packet.

The STSL algorithm uses a two- step approach, in which first nodes are time-synchronized and then location is estimated. In both steps, the measured time of flight of packets exchanged between anchor and UL nodes and self localization data obtained at UL nodes are linked to the unknown location, synchronization (clock skew and offset),and propagation speed parameters through liner matrix equations. The STSL algorithm uses a sequential approach in which first nodes are time-synchronized and then location is estimated. We start with quantizing the spatial domain by representing the continuous motion of nodes as a series of discrete locations.

Time synchronization algorithms can be classified according to different properties, such as:

• Global versus local algorithms:

A global algorithm tries to keep all sensors in the network synchronized, while a local algorithm only synchronizes sensors locally (some logical part of the network, a broadcast domain...)

• Hardware- versus software-based algorithms:

Some algorithms require specific hardware such as a GPS module, a dedicated radio channel, or high precision clocks in order to perform as expected, while software-based algorithms only use the standard radio and message exchange.

The relationship between two clocks by the addition of clock skew. In practice, the time synchronization problem in WSNs generally involves two steps: synchronizing the nodes in the network to one common absolute time by adjusting clock phase offset (clock offset) among the nodes, and correcting the clock frequency offset (clock skew) relative to a certain standard frequency. The second step is required because the imperfections in quartz crystals and environmental conditions induce different clocks to run at slightly different frequencies.

Fig5.1.Node Distribution Undersea

Actually, the effect of clock skew is the main reason why clock offset keeps drifting apart. Hence, adjusting clock skew guarantees long-term reliability of synchronization, and therefore reduces network-wide energy consumption in synchronization procedures. Indeed, developing long-term and network-wide time synchronization protocols that are energy-efficient represents one of the key strategies for the successful deployment of long-lived WSNs.

VI. CONCLUSION AND FUTURE ENHANCEMENT

The approach proposed in our paper is increases the relative speed and direction information available at the mobile UL node. Our proposed algorithm makes use of the permanent movements of underwater nodes. It also performs a self-evaluation of localization accuracy. According to the structure of the proposed algorithm we refer to it as sequential time synchronization and localization (STSL) algorithm.

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