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Distributed Networked Localization and Time Synchronization using Seawater Movement Pattern in Underwater Sensor Networks

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ABSTRACT

Time synchronization and localization issues in underwater sensor networks, where more challenges are introduced due to the unique properties of the water environment. These challenges include long duration and transmission delay, low bandwidth, energy restriction, mobility, etc., we recommend the time synchronization and localization based on the semi-periodic nature of sea water movement, SLSMP called. First, we analyze error factors in time synchronization and localization, and then propose a method to deal with this error. For a more precise synchronization SLSMP controls the time of transmission by the pattern of movement and seawater node providing exploits. Then SLSMP gradually decreases averaged localization error by the Kalman filter application or filter. Finally, INS (Inertial Navigation System) was adopted by the node mobility and error propagation problem caused localization error relieve. The simulation results show that SLSMP time synchronization error of 2.5 ms and 0.56 ms compared to TSHL and MU-Sync or reduced. Also localization error of 44.73% reduced compared to the single multilateration system.

Keywords: SLSMP, Synchronization, Localization, Sensor Node.

1. INTRODUCTION

Ocean infrastructures such as offshore installations have been garnering a lot of attention on major potential benefits of marine resources due to [1, 2]. The need for real-time monitoring of the marine environment is growing to deal immediately with critical accidents, etc. may be caused by unforeseen events such as the high temperature of the sea water, red tide, oil spills, and. According to this trend, recently, many researchers from academic and industry to study UWSN (underwater sensor networks). UWSN applications can remotely control and monitor marine architectures marine ecosystem. However, UWSN has some challenges due to the nature of the underwater communication channel by error-prone and long propagation delay. In addition, a constant motion has to be considered by underwater sensors for network protocol design. So it is impossible that we accept well refined terrestrial communication mechanisms in the underwater world directly. Although the time synchronization for various applications such as localization and low-power sleep scheduling MAC protocols is crucial, existing synchronization schemes have not fully take into account practical issues, such as channel access delay. The delay can be ignored in a terrestrial scenario where propagation speeds are extremely high, but not in the water. Due to the low velocity of the acoustic signal Furthermore, competition-based MAC protocols such as CSMA can cause high channel access delay, in a large gap between the time recorded results at a time stamp and the actual time of transmission. As a result, increases the synchronization error, because it is based on the exact time of measurement. Finally, does the node movement, the synchronization performance, but it is still a challenge remained. This paper proposes an enhanced time synchronization and localization SLSMP designated (synchronization and localization using seawater movement patterns). A SLSMP control the transmission time through reflects the fact that the node mobility caused by seawater movement as tidal and wave half-periodic patterns follows. Moreover SLSMP compensates for the airtime on timestamp recorded by the channel access delay of timestamps to remove a further transmission. Moreover mitigates the adoption of INS (Inertial Navigation System) to assess the impact of node mobility on the synchronization and localization.

The contributions of this paper are listed as follows.

(i) SLSMP accomplishes time synchronization and localization simultaneously and then it can be applied to many applications and other layers like MAC or network.

(ii) SLSMP considers node mobility in real-time by using INS and seawater movement pattern.

(iii) SLSMP deals with the issues of reference inaccuracy and the time measurement error that have not yet been addressed in previous researches on localization. Also, channel access delay, which significantly affects the synchronization, is removed by using application layer timestamp.

2. RELATED WORK

An OFDM Based MAC Protocol for Underwater Acoustic Networks

OFDM based MAC protocols for underwater acoustic networks. Due to the severe multi-path effects of underwater acoustic channels, the guard time between OFDM blocks becomes significant, which greatly degrades the system rate. In addition, the highly dynamic nature of underwater acoustic channels makes it hard to choose the optimal transmitting power and modulation mode. Furthermore, the bandwidth of most current OFDM modems is only around tens of kHz, which is much less than the available bandwidth in a network with short range communication links. All these challenges make existing OFDM based MAC protocols for designed terrestrial wireless networks unsuitable. In this work, we propose a new MAC protocol called TDM with FDM over OFDM MAC protocol (TFO-MAC), which smoothly couples TDM with FDM/OFDM for the uplink traffic in a cellular like underwater acoustic network. In TFO-MAC, the acoustic channel is divided into multiple sub-channels in frequency via FDM technology, and OFDM modulation is used in every sub-channel. In addition, time is partitioned into slots and every node can use different channels in different slots. Powerful base stations in the network are responsible for the dynamic channel assignment, power optimization and modulation method selection for all nodes in every slot. We formulate the problem as a mixed integer programming problem and propose an efficient greedy algorithm to solve it. Simulation results show that TFO-MAC can achieve high throughput with good fairness.

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. The novel networking paradigm poses inter-disciplinary challenges that will require new technological solutions. In particular, in this article, we adopt a top-down approach to explore the research challenges in mobile UWSN design. Along the layered protocol stack, we roughly go down from the top application layer to the bottom physical layer. At each layer, a set of new design intricacies are studied. The conclusion is that building scalable mobile UWSNs is a challenge that must be answered by inter-disciplinary efforts of acoustic communications, signal processing, and mobile acoustic network protocol design.

A Survey of Practical Issues in Underwater Networks

Underwater sensor networks are attracting increasing interest from researchers in terrestrial radio-based sensor networks. There are important physical, technological, and economic differences between terrestrial and underwater sensor networks. Previous surveys have provided thorough background material in underwater communications, and an introduction to underwater networks. This has included detail on the physical characteristics of the channel [1], on underwater acoustic communications and surveys of underwater acoustic networks. In this survey, we highlight a number of important practical issues that are not emphasized in the recent surveys of underwater networks, with an intended audience of researchers who are moving from radio-based terrestrial networks into underwater networks. We focus on issues relevant to medium access control (MAC) protocols, which are an area of continuing work both in terrestrial sensor networks and especially in underwater networks. Underwater networks are often characterized by more expensive equipment, higher mobility, sparser deployments, and different energy regimes when compared with terrestrial sensor networks. We discuss the role of these factors in the different set of challenges that face underwater networks.

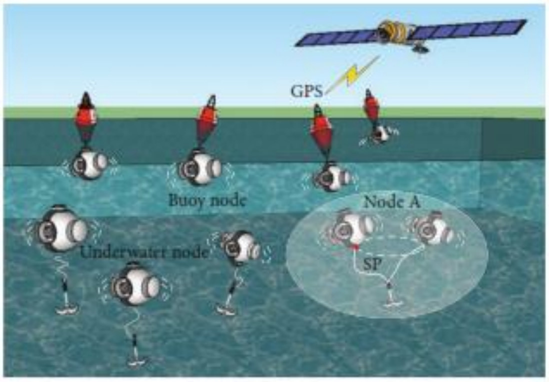
Underwater acoustic sensor networks: research challenges

Underwater sensor nodes will find applications in oceanographic data collection, pollution monitoring, offshore exploration, disaster prevention, assisted navigation and tactical surveillance applications. Moreover, unmanned or autonomous underwater vehicles (UUVs, AUVs), equipped with sensors, will enable the exploration of natural undersea resources and gathering of scientific data in collaborative monitoring missions. Underwater acoustic networking is the enabling technology for these applications. Underwater networks consist of a variable number of sensors and vehicles that are deployed to perform collaborative monitoring tasks over a given area. In this paper, several fundamental key aspects of underwater acoustic communications are investigated. Different architectures for two-dimensional and three-dimensional underwater sensor networks are discussed, and the characteristics of the underwater channel are detailed. The main challenges for the development of efficient networking solutions posed by the underwater environment are detailed and a cross-layer approach to the integration of all communication functionalities is suggested.

Research Challenges and Applications for Underwater Sensor Networking

It explores applications and challenges for underwater sensor networks. We highlight potential applications to off-shore oil fields for seismic monitoring, equipment monitoring, and underwater robotics. We identify research directions in short range acoustic communications, MAC, time synchronization, and localization protocols for high-latency acoustic networks, long duration network sleeping, and application-level data scheduling. We describe our preliminary design on short-range acoustic communication hardware and summarize results of high-latency time synchronization.

3. SYSTEM DESIGN



The reference nodes are attached to buoys and can get the global time from GPS and GPS provides a real-time location to the references. We assume that sensor nodes deployed in underwater are equipped with tiny gyro and acceleration sensors thanks to MEMS (micro electro mechanical systems) technology. Those sensors act as INS (inertial navigation system) to trace the node's trajectories in real time.

4. PROPOSED WORK

The aim waters our protocol is offshore with a depth of less than 400 m. In this application, we assume that transmission range is within 100 meters, even if the currently developed transmitter module to send a packet more than our assumption. This is due to the fact that multi-hop communication is more reliable than the direct communication because multipath fading, the packet delivery ratio in the offshore drops dominant. The reference nodes are attached to buoys and can get the global time of GPS and GPS provides a real-time location to the references. We assume that used in the underwater sensor nodes are equipped with tiny gyro and acceleration sensors thanks to MEMS (microelectromechanical systems) technology. These sensors act to follow trajectories in real time as INS (Inertial Navigation System) of the node. Nodes use in underwater is another challenge and how the sensors to implement is determined primarily by the use of the features. However, in general, scenario take underwater investigations that each node attached to the ocean floor or sea infrastructures with a wire or an anchor. Therefore, our target system is followed by the way, and then the node mobility is permitted only in a certain limit. Even after the ocean hydrodynamic and real experiments, ocean currents periodic force apply to floating objects. In other words, node move is not accidental but semi-regular basis. Based on this knowledge, we insist that all nodes have semi-periodic patterns of mobility.

5. METHOD

SLSMP Protocol

SLSMP consists of three phases, namely, SAP (position) selection based on tracking, messaging and time synchronization / localization. Especially underwater sensors their semi-periodic patterns of mobility record for some interval with INS and then decide SP. SP is the only place where the destination node to the destination node stationary makes even this effort sends a timestamp, although the nodes permanently actually moved. Consequently, by node mobility causes error synchronous / localization much easier. It will be explained later in more detail. To extract the SP from the recorded tracks, the sensor divides evenly the range of motion into several small cubes and examines how often it is at each cube during the tracking phase. The highest hit ratio means that the node has arrived at the position often, and it will reach the cube periodically in the future.

Time Synchronization

The synchronization phase consists of three main steps: propagation delay estimation, linear regression and propagation delay Update.

Propagation Delay Estimate: To increase the accuracy of the propagation delay estimation when the aqueous medium is not homogeneous, it is necessary to cope with the bias of the rectilinear propagation adoption.

Linear Regression: During this step, the ordinary node updates its estimates of the timing offset u and offset b of the ordinary least squares estimation (OLS) method using based on the collected time stamp and the calculated propagation delays in all previous rounds of message exchange.

Propagation Delay Update: If the synchronization process is complete, the ordinary sensor node is synchronized, and a new design clock skews u and estimated offset b. The propagation delay T1 and T2 can then be updated. Since the synchronization procedure is an optimization process, the propagation delays tend to be more accurate than the estimated in step.

Localization

Meanwhile, after selecting the SP, destination node monitors their location in real time and sends a time stamp to references only if it is in the SP for localization. At a time stamp received that record references the receiving location and time and respond to the target y to transfer the recording of information. If the number of references is greater than or equal to four, discovered the object of his position to them by reference. SLSMP takes multilateration system.

Kalman Filter

The Kalman filter is used in many fields; a recursive data processing algorithm to estimate unknown variables contains random errors. The unknown values mean target position (x, y, z) in underwater space. It is already implemented and used in some underwater localization as JSL, the representative localization protocol utilizing the Kalman filter. The JSL uses IMM filter, a mixture of Kalman filter and EKF (extended Kalman filter) to estimate the target location, and approximate the node trajectory with state transition matrix. However, it is impossible that the state transition matrix describing exactly all possible node mobility patterns due to their nature by probabilistic and described static. As a result, isolation performance could get worse significantly. Also smooth the EKF, linearize the nonlinear system has a possibility of divergence when initial estimate is wrong or system design is not appropriate. Unlike the JSL, the proposed method is independent of any mobility patterns on the use of the Kalman filter by the time stamp sending only to the specific areas, SP. In other words, we make the system linearly impractical to avoid modeling. we make the system linearly impractical to avoid modeling. State variables V, state transition matrix A and matrix H represents change in the states are determined as $V = (x\ y\ z)$ H = (100 010 001), A = (100 010 001) initial parameters also Kalman gain setting is as $Q = (000)$ designated $R = (400\ 040\ 004)$.). Estimated location by ith iteration is called P and final estimate of the node is completed by N times iteration.

6. EXPERIMENTAL RESULTS

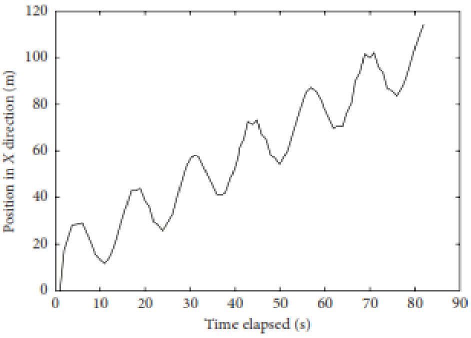


Fig 1: A Node Trajectory (a) Without Boundary Restriction

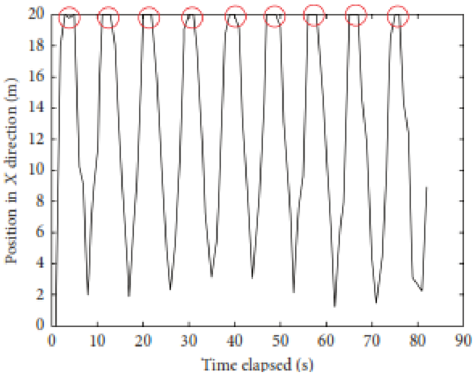


Fig 2: A Node Trajectory With Boundary Restriction

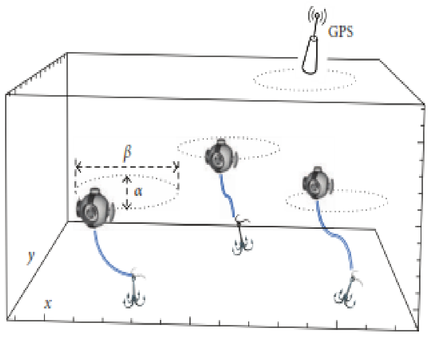


Fig 3: Node Deployment and Mobility Design

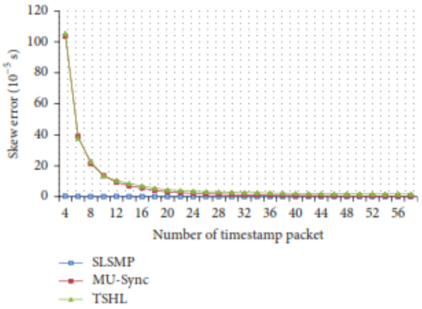


Fig 4: Effect of the Number of Timestamps on Skew Estimation

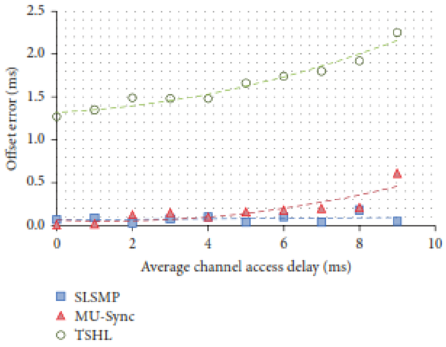


Fig 5: Effect of Channel Access Delay on Offset Estimation

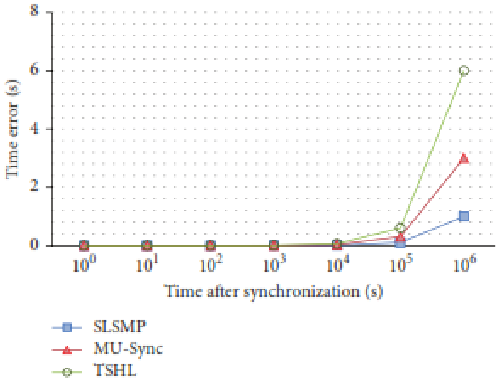


Fig 6: The Error in Time Estimation Since Synchronization

7. CONCLUSION

We proposed an improved time synchronization and localization, called SLAMP, with characteristics of seawater motion and sensor deployment. We define error factors influencing the accuracy of the synchronization and localization with mathematical and experimental analysis. The adjustment of the transmission timing and the weighted least squares regression relieved skew estimation error caused by variation of the propagation delay. Moreover, SLSMP provides more practical and accurate synchronization since the unpredictable channel access is removed by the application of the application layer timestamp. In addition, location accuracy is significantly improved with the knowledge of sensor deployment, INS and filter technology. An interesting fact is that the Kalman filter and averaging filter have similar performance. The simulation results show that SLSMP the previous well-known time synchronization protocols, TSHL and MU-Sync, in terms exceed the timing accuracy and SLSMP also shows a better performance in a practical environment includes network time measurement error and unreality of the reference node as a single compared multilateration.

8. FUTURE WORK

In future, we plan to improve our work to locate mobile objects such as AUV (Autonomous Unmanned Vehicle). For this purpose, we will investigate and develop the prediction algorithm for the mobile pattern, how to combine SLSMP with them.

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