VELOCITY ESTIMATION OF AN OBJECT MOVING IN UWSN USING REVERSE LOCALIZATION SCHEME

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ABSTRACT

Underwater sensor networks (UWSNs) has drawn considerable attentions from both academy and industry areas. Traditionally, the time synchronization algorithms are used for UWSNs to identify the localization and mobility of objects in under water as well as terrestrial. The algorithms such as TSHL, MU-Sync, and D-Sync are used in terrestrial and also in underwater sensor networks to address the long propagation delays but they all exhibits particular shortcomings because those algorithms assumes only negligible propagation delays among sensor nodes, the velocity of an object is not estimated and the efficiency is not up to considerable level. Hence, in UWSN, a new method called novel time synchronization is used to overcome the above said short comes. This method is more suitable for time synchronization, propagation delay analysis and improving mobility of objects. In Novel time synchronization, an scheme called Reverse Localization Scheme is used with Mobi-sync for the sensor nodes to calculate the velocity and mobility of an object and time synchronization. With this method, very high accuracy with relative low message overhead and high efficiency can be achieved.

***Keywords:* TSHL, MU-SYNC, RLS, D-SYNC, MOBI-SYNC**

I. INTRODUCTION

UWSNs facilitate or enable a wide range of aquatic applications, including coastal surveillance, environmental monitoring, undersea exploration, disaster prevention, mine reconnaissance and so on. On the other hand, due to the high attenuation of radio in water, UWSNs have to mainly reply on acoustic communication. The unique characteristics of underwater acoustic communications and networking, such as low communication bandwidth, long propagation delays, high error probability, and sensor node (passive or proactive) mobility (in mobile networks) pose grand challenges to almost every layer of network protocol stack[1] [6] [10]. In this paper, we tackle the time synchronization problem, which is very critical to many UWSN design issues. In fact, most UWSNs applications either benefit from or require time synchronization services. For instance, data collected by underwater sensor nodes need global time stamps to make data fusion and processing meaningful. TDMA, one of the commonly used medium access control (MAC) protocols, often requires good synchronization among nodes.

In the literature, a large number of time synchronization protocols have been proposed for terrestrial wireless sensor networks. Most of them claim to be able to achieve high accuracy with reasonable energy expenditure.

However, these algorithms cannot be directly applied to UWSNs. Recently some time synchronization algorithms, such as TSHL [20] and MU-Sync [5], have been proposed for UWSNs. In these algorithms, the issue of long propagation delays is often well addressed. However, they often ignore one issue or another. For example, TSHL assumes that nodes are fixed, which makes it not suitable for mobile networks. While MU-Sync is designed for mobile underwater networks, it is not very energy efficient. In this paper, we propose a scheme, called "Reverse Localization Scheme", with Mobi-Sync which is specifically designed for mobile UWSNs, with high energy efficiency as one major goal.

Underwater Wireless Sensor Networks (UWSNs) provide new opportunities to observe and predict the behavior of aquatic environments. In some applications like target tracking or disaster prevention, sensed data is meaningless without location information. In this paper, we propose a novel 3D centralized, localization scheme for mobile underwater wireless sensor network, named Reverse Localization Scheme or RLS in short. RLS is an event-driven localization method triggered by detector sensors for launching localization process. RLS is suitable for surveillance applications that require very fast reactions to events and could report the location of the occurrence. Reverse Localization Scheme does not suffer from mobility. Instead it novelly utilizes the spatial correlation of mobile sensor nodes to estimate the long dynamic propagation delays among nodes.

RLS extends three phases: Phase I, delay estimation; Phase II, linear regression; and Phase III, calibration. In phase I, the spatial correlation of mobile sensor nodes is effectively employed to help the estimation of the propagation delays. In phase II, based on the MAC layer time stamps and corresponding propagation delays, sensor nodes perform the first linear regression to get the draft clock skews and offsets. And some draft results are applied as input parameters for Phase III, "calibration", which is designed to further improve the synchronization accuracy. During calibration, by updating certain initial parameters and re-performing delay calculation and linear regression, the final clock skews and offsets are obtained. We conduct extensive simulations. And our results show that Reverse Localization Scheme outperforms existing schemes in both accuracy and energy efficiency.

II. EXISTING AND PROPOSED SYSTEM

The time synchronization algorithms for UWSNs, such as TSHL, MU-Sync, and D-Sync are used here. These algorithms address the long propagation delays but them all exhibit particular shortcomings. Because, TSHL is designed for static networks hence it does not consider sensor node mobility. MU-Sync confronts the mobility issue, but it is not energy efficient. D-Sync overlooks the effect of the skew when estimating the Doppler shift. MU-Sync utilizes the spatial correlation of underwater mobile sensor nodes to estimate the long dynamic propagation delays but not effective. This is because most of these approaches assume negligible propagation delays among sensor nodes and the batteries of sensor nodes are difficult to recharge and it is often impractical to replace due to their relative inaccessibility. This lack of serviceability imposes even more stringent requirements.

2.1 Proposed System

A high energy efficient time synchronization scheme specifically designed for mobile UWSNs. The distinguishing attribute of Reverse Localization Scheme which extends Mobi-sync is how it utilizes information about the spatial correlation of mobile sensor nodes to estimate the long dynamic propagation delays among nodes. We investigate other approach to estimate node moving velocity and further examine how the accuracy of Reverse Localization Scheme will be affected.

2.2 Advantage of Proposed System

The Proposed system, estimate node moving velocity and further examine how the accuracy of will be affected. The results indicate that RLS outperforms existing schemes with respect to both accuracy and energy efficiency.

III. ESTIMATING NODE MOVING VELOCITY

The collection of closest point of approach time stamps is used to calculate the velocity of the object moving through the sensor field. The time stamps are combined with a position estimation vector which contains the approximate location of each of the sensor nodes. A linear regression is the performed on the data to fit a constant velocity trajectory to the sensor data. In order to update the location of the individual sensors, a the linear regression is used to determine the relative positioning of the individual sensor nodes. Over time, the position estimation vector will be updated to reflect reality.

Temporal and spatial correlation is always inherent in mobility. This characteristic has very positive impact on Mobi-Sync as it can be used for an ordinary node to calculate its own moving velocity. In ach node a specific time period is represented with $\boldsymbol{V = [v(1); v(2); : : : v(i); : : : ; v(k)]}$. Where $v(i)$ is the average speed to a short time period[3][4][7]. If a node j wants to estimate its velocity of a node j its velocity can be represented as, its speed has to be known first. Hence the speed of an ordinary node j is said to be in the form of x/y axis, then the own velocity of j becomes as $\boldsymbol{[v_x(j); v_y(j)]}$, **where** $\boldsymbol{v_x(j)/v_y(j)]}$

where $v_x(j) = {}_{i=1}\sum^{m} c_{ij} v_x(i)$ and $v_y(j) = {}_{i=1}\sum^{m} c_{ij}\, v_y(i)$ (1)

where m is the number of neighbors, and the interpolation coefficient c_{ij} is calculated as

$$cij=(1/rij)/({}_{i=1}\sum^{m} 1/rij) \quad (2)$$

The process of propagation delay estimation consists of three steps, message exchange, delay calculation and multiple requests. And several time intervals occurs in propagation delay estimation. Hence Response time t_r consists of t_{r1} and t_{r2}, the first and the second response time, and t_{r1} is considerably short comparing with t_{r2}. t_i is a short period of time for super nodes to record a new sub-speed vector $v(i)$.

3.1 Message Exchange

As the synchronization procedure starts, an ordinary node initializes the synchronization process by broadcasting the synchronization request (SR) message to its neighbor super nodes. SR contains the sending time-stamp , right before it departs from the ordinary node. Super nodes mark their local time as upon receiving SR. Simultaneously, they start to record their moving velocity with the frequency.

SR contains the sending time-stamp *T*1 obtained at the MAC layer, right before it departs from the ordinary node and they mark their local time as *T*2 upon receiving *SR*. *Now it starts to record their moving velocity with frequency* $1/t_i$. After suspending for a fixed time interval *tr*1, each super node sends back the first response message *RS*1 with a MAC layer sending time-stamp *T*3.2 *RS*1 informs ordinary node about *T*2 and *T*3. *RS*2 informs the ordinary node about the speed vector super node has recorded from time *T*2 to *T*5 and MAC layer time-stamp *T*5. With other time period *tr*2, super nodes send back the second response message *RS*2. [2][5][10]

*RS*2 informs the ordinary node about the speed vector super node has recorded from time *T*2 to *T*5 and MAC layer time-stamp *T*5. Now the ordinary node listens for *RS*1 and *RS*2, and records the receiving time *T*4 and *T*6 for each super node.

Here $fr(T)$ as the ordinary node corrected time and $fa(T)$ as the super node corrected time.

$$fr(T) = (T - b)/a \text{ and } fa(T) = T \qquad (3)$$

3.2 Delay Calculation

At the beginning of each run, the ordinary node calculates the initial distance to a super node upon receiving message from it. At this stage, due to lack of information, half of the round trip time is employed to compute one way propagation latency between each pair. Some errors are introduced. Since the pre-defined first time interval is very short the errors are supposed to be acceptable at this time.

Considering the two round trips *T1 to T2 to T3 to T4* and *T1 to T2 to T5 to T6*

$$fr(T1) + d1/Vp = fa(T2),\ fa(T3) + d2/Vp = fr(T4) \qquad (4)$$

and

$$fr(T1) + d1/Vp = fa(T2),\ fa(T5) + d3/Vp = fr(T6) \qquad (5)$$

where *Vp* represents the propagation speed of acoustic wave in underwater environment, which is assumed to be constant during one time synchronization period.

Let *h*1 stand for round trip distance of *T1 to T2 to T3 to T4 and h*2 for *T1 to T2 to T5 to T6*

Now using (3) $h1 = d1 + d2 = (T2 - T3 + T4 - T1/a) \times VP$

$$h2 = d1 + d3 = (T2 - T5 + T6 - T1/a) \times VP \quad (6)$$

By knowing $h1$, the initial distance r can be calculated as:

$$r = h1/2 = [(T2 - T3 + T4 - T1/a) \times VP]/2 \quad (7)$$

By using this super nodes start to record their speeds upon receiving *SR*.

3.3 Multiple Requests

Next step, the ordinary node asks for multiple runs of synchronization process based on its accuracy requirement. For each time, the ordinary node and super nodes follow the same routine to calculate propagation delays. By doing so, the ordinary node can collect a set of time stamps for each neighbor super node and corresponding propagation delays for each exchanged message. After this, it gets ready for the linear regression.[1][6][10]

3.4 Linear Regression

The ordinary node performs linear regression to estimate the draft clock skew and offset. It is possible that in some bad cases sample points are far away from what they are expected. In order to reduce the impacts from those outliers, instead of OLSE, an advanced Weighted Least Square Estimation (WLSE) specific for Reverse Localization Scheme is proposed and adopted.[1][3][5]

3.5 Calibration

For one run, the ordinary node first updates the initial distance. Then with the same speed vectors gathered from super nodes, the ordinary node re-calculates its own speed vector. Next, with new estimated speed vector and the same routine first 3 modules, the ordinary node rebuilds the relative motion relationship with each super node to get updated triangles. Then with the same way in above modules, the ordinary node gets updated. Meanwhile, via updating initial skew, the ordinary node obtains updated round trip distance. With all the updated parameters, the ordinary node re-calculates propagation delay for each exchanged message. By keep performing above for each run, the ordinary node obtains a set of updated propagation delays for exchanged messages. Then with the same time stamps gathered in phase I and the updated propagation delays, the ordinary node re-runs linear regression with WLSE to gain the final skew and offset.[1][5][6][10]

Finally by calculations we get

$$V_x = k_1 \lambda v \sin(k_2 x) \cos(k_3 y) + k1 \lambda \cos(2k1t) + k_4$$

$$V_y = -\lambda v \cos(k_2 x) \sin(k_3 y) + k5$$

IV. FIGURES

ARCHITECTURE DIAGRAM **DATA FLOW DIAGRAM**

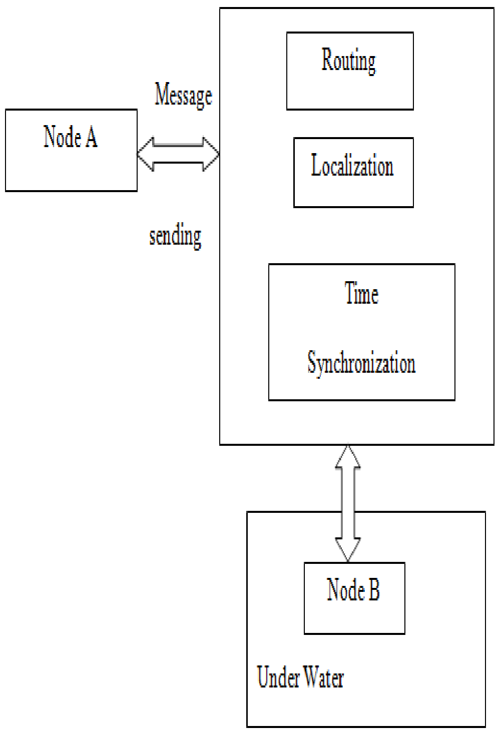

Fig 1.1 Architecture Diagram

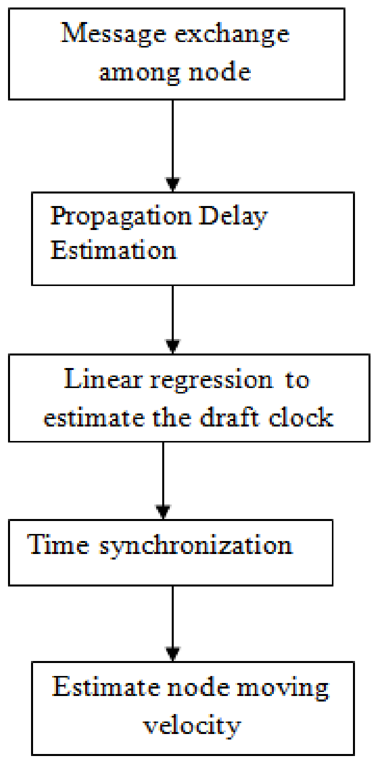

Fig1.2 Data Flow Diagram

V CONCLUSION

In this paper, we presented Reverse Localization Scheme, a time synchronization scheme for mobile UWSNs. Reverse Localization Scheme is the first time synchronization algorithm which does not suffer but benefit from sensor node mobility and it is also the first one which resorts to geometry knowledge to do time synchronization. Our simulation result shows that this new approach can achieve to estimate node moving velocity and further examined how the accuracy of Reverse Localization Scheme will be affected.

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