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Time Synchronization in Mobile Underwater Sensor Network

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ABSTRACT

Time synchronization plays a critical role in underwater sensor networks (UWSNs). Sensor network consists of static and mobile underwater sensor nodes. Although many time-synchronization protocols have been proposed for terrestrial wireless sensor networks, none of them can be directly applied to UWSNs. This is because most of these protocols do not consider long propagation delays and sensor node mobility, which are important attributes in UWSNs. In addition, UWSNs usually have high requirements in energy efficiency. In this paper, time-synchronization scheme is proposed in mobile underwater sensor networks. The scheme proposes a framework to estimate the Doppler shift caused by mobility, more precisely through accounting the impact of the skew. The time delay and frequency are estimated accurately. To refine the relative velocity estimation, and consequently to enhance the synchronization accuracy, the Kalman filter is employed. Thus by estimating the velocity, the accuracy has been increased.

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INTRODUCTION

Underwater sensor networks are vast improving technologies in the field of ocean observation systems and these are responsible for the upcoming developments in the wireless information transmission networks through the oceans. An underwater sensor network consists of a number of underwater sensor nodes with sensing, data processing, and communication capabilities. The underwater sensing networks are defined as the system comprised of sensors and acoustic modems with the vehicles to perform the monitoring tasks over the prescribed area. The nodes can communicate with other nodes, and the sink node had two acoustic modems, these two modems are used for the communication of sensor network and gateway on the sea surface, the gate way is connected to the control station through which the data transmission takes place, the control station transmits the UWSN data globally through internet.

I.F. Akyildiz *et al* (2004,2005) has said the major challenges in the design of Underwater Acoustic Networks: Battery power is limited and usually batteries cannot be recharged, also because solar energy cannot be exploited; The available bandwidth is severely limited; Channel characteristics, including long and variable propagation delays, multi-path and fading problems; High bit error rates; Underwater sensors are prone to failures because of fouling, corrosion, etc.

Distinct from terrestrial sensor networks, an underwater sensor network has some unique characteristics that need to be particularly addressed such as low communication bandwidth, large propagation delay, cost, deployment, power, harsh geographical environment, and floating node mobility. Acoustic communications are the typical physical layer technology in underwater networks. In fact, radio waves propagate at long distances through conductive sea water only at extra low frequencies (30 -300 *Hz*), which require large antennae and high transmission power. Optical waves do not suffer from such high attenuation but are affected by scattering. Thus, links in underwater networks are based on acoustic wireless communications.

A reference architecture for two-dimensional underwater networks and three-dimensional underwater network.The stationary nodes are placed at the surface the water and the vehicle is used to collect the information from those stationary nodes. It is necessary to have a time synchronization between these nodes. Recently, some time synchronization algorithms, such as TSHL, MU-Sync, Mobi-Sync, and D-Sync have been proposed for UWSNs. In these algorithms, the issue of long propagation delays is often well addressed. However, they all ignore one issue or another.

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A.Syed *et al* (2006) proposed an method known as TSHL, where it assumes that nodes are fixed, which makes it not suitable for mobile networks and it is designed for high latency circuit, that can manage long propagation delays and remains energy efficient. It combines one-way and two-way message delivery. One-way is used to estimate clock skew and two-way is to compute clock offset.

MU-Sync method proposed by N.Chirdchoo *et al* (2008), While in MU-Sync is designed for mobile networks, and it is not energy efficient. It is used to synchronize nodes in a cluster based UWSN. The MU-Sync runs two times of linear regression. The first run allows cluster head to estimate the draft and the second run used to correct the estimate skew.

J.Liu *et al* (2012) said that the Mobi-Sync is used for dense network. The nodes will have spatial correlation and velocities to estimate the time varying delay.

F.Lu *et al* (2010) proposed an algorithm known as D-Sync, leverages the Doppler shift in underwater environment to do time synchronization. It does not consider the effect of skew during the process of estimation of Doppler shift estimation. It completely depends on the measured speed of the Doppler shift, which also may leads to error.

Consider the message exchange between two nodes, where the reference and the ordinary node. Ordinary nodes are the stationary nodes and the reference nodes are the nodes placed in the vehicle. When there is a motion between these nodes leads to the Doppler effect. In the physical layer, a well-designed preamble and a Doppler scaling factor estimation algorithm are adopted to measure the relative velocities of one sensor node to the others. These velocities are further refined using the Kalman filter. By incorporating relative moving velocities between the transmitter and receiver, the accuracy of the propagation- delay estimation is greatly improved.

System model:

Consider a OFDM preamble structure in Fig. 1, which consists of two identical OFDM symbols of length T_0 and a cyclic prefix T_c in front, with an embedded structure

$$x(t) = x(t + T_0), -T_c \leq t \leq T_0 \quad (1)$$

X	X

Fig. 1: Preamble structure.

Let B denote the system bandwidth, and define $K_0 = BT_0$ as the number of subcarriers. The baseband CP-OFDM signal is

$$x_c(t) = \sum_{k=-K_0/2}^{K_0/2-1} d[k] e^{j2\pi\frac{k}{2T_0}} q(t), t\epsilon[-T_c, 2T_0] \quad (2)$$

where $d[k]$ is the transmitted symbol on the $q(t)$ subcarrier, and is a pulse shaping window

$$q(t) = \begin{cases} 1, t\epsilon[-T_c, 2T_0] \\ 0, elsewhere \end{cases} \quad (3)$$

Consider a multipath channel which consists of N_{pa} path

$$h(t;\tau) = \sum_{p=1}^{N_{pa}} A_p(t)\ \delta\left(t - \tau_p(t)\right) \quad (4)$$

where $A_p(t)$ and $\tau_p(t)$ denote the amplitude and delay of the p th path, respectively. If all the paths in the channel have the same Doppler scale factor

$$\tau_p(t) = \tau_p - at \quad (5)$$

Then the received waveform becomes

$$\boldsymbol{y(t)} = \boldsymbol{e^{-j2\pi\frac{a}{1+a}f_cT_0} y\left(t + \frac{T_0}{1+a}\right), \frac{-T_c-\tau_{max}}{1+a} \leq t \leq \frac{T_0}{1+a}} \quad (6)$$

which has a repetition period $T_0/(1 + a)$ regardless of the channel amplitudes. The discrete time expression of the $\boldsymbol{y(t)}$ at the sampling rate of λB is

$$y[n] = y[t]|_{t=\frac{n}{\lambda B}} \quad (7)$$

where B is the signal frequency bandwidth. To estimate the Doppler scaling factor, a periodic property of the received preamble via a bank of autocorrelators is used as shown in Fig.2.

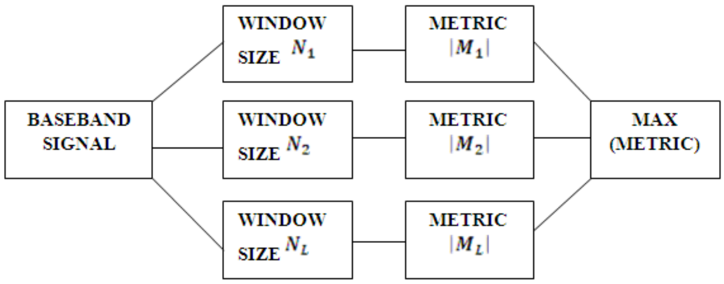

Fig. 2: Structure of parallel autocorrelators.

N_l is the autocorrelation window length, the autocorrelation is calculated using

$$M(N_l, d) = \frac{\sum_{i=d}^{d+N_l-1} y[i]y[i+N_l]}{\sqrt{\sum_{i=d}^{d+N_l-1}|y[i]|^2 . \sum_{i=d}^{d+N_l-1}|y[i+N_l]|^2}} \quad (8)$$

Where d is the index of the autocorrelation output. The Doppler scaling factor can be estimated based on the window length of the branch which has the maximum autocorrelation output

$$\hat{a} = \frac{\frac{T_0}{\lambda B} - \hat{N}}{\hat{N}} \; where \; \hat{N} = \arg\max|M(N_l, d)| \quad (9)$$

A linear interpolation can be adopted at the autocorrelation output to improve the estimation accuracy. where l is the index of the branch that has largest correlation output. Let $|X_l|$ denotes the maximum amplitude of the metric at the l branch and $|X_{l-1}|$ and $|X_{l+1}|$ as the neighbors from the $(l-1)$ th and $(l+1)$ th branch, respectively. Define Δa as the spacing of the Doppler searching grids. The offset of the Doppler scaling factor estimation can be interpolated as

$$\delta = \frac{|X_{l+1}| - |X_{l-1}|}{4\,|X_l| - 2\,|X_{l-1}| - 2\,|X_{l+1}|}\Delta a \quad (10)$$

which leads to $\tilde{\hat{a}} = \hat{a} + \delta$. Thus the estimation of the velocity is $\hat{v} = \tilde{\hat{a}}c$, where c is the speed of the sound.

Frequency estimation:

Taking a DFT or FFT of collected samples is arguably the most common method of making such frequency estimates. Various methods are being used for the estimation of frequency. Quinn (1994,1997) developed a simple and efficient method to closely estimate a signal frequency based on the three samples around the DFT output peak. Both methods provide efficient frequency estimators which perform well to SNRs as low as 0dB. Neither directly provides a corrected magnitude estimate, and both require division. Macleod (1998) proposed a similar frequency estimator, but the operating assumptions are restrictive and, again, division is required for the frequency estimate. Most contemporary DSPs do not have efficient divide instructions, so algorithms which minimize or eliminate the use of divides are advantageous. Thus Eric Jacobsen introduced a method with less computation. By using these methods, the frequency can be estimated.

Data collection:

An ordinary node initiates message exchanges by sending a “Sync-Req” message to a neighboring reference node. The ordinary node records the sending time stamp T_1, obtained at the MAC layer, before the message leaves. Upon receiving the Sync-Req message, the reference node estimates and records the ordinary node’s relative moving velocity v_0 with Doppler shifts. Meanwhile, it marks its local time as t_2. Then, after a time interval t_r (waiting for the hardware sending receiving transition and avoiding collisions), the reference node sends back a “Sync-Res” message which contains t_2, v_0 and its sending time t_3. When receiving the Sync-Res message, the ordinary node records its receiving time T_4 and its relative moving velocity to the reference node, v_1.Depending on the accuracy requirement from the application, the above message exchange process can run multiple times. After a couple of rounds of message exchange, the ordinary node collects a set of time stamps consisting of T_1, t_2, t_3 , and T_4 and relative velocities consisting of $v_0$and v_1.

Sensor node mobilty:

The message in the waveform $x_{AB}(t)$ is sent from sensor node A to sensor node B, with node A as the reference node. Denote a as the combined Doppler scaling factor of the waveform received at node B, and define v and θ as the speed and the clock skew of node B relative to node A, respectively. The Doppler scaling factor induced by the sensor mobility is thus $a_m \cong {}^{v}/_{n}$ where is the sound speed in water. The received waveform at node B can be formulated as the summation of signals arrived along multiple physical paths,

$$y_{AB}(t) = \sum_{p=1}^{N_p} A_p \, x_{AB}\left((1 + a_m)t - \tau_p\right) \quad (11)$$

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The given the clock skew θ, the sampling rate at node B is actually θf_s relative to node A, leading to discretized samples

$$y_{AB}[n] = y_{AB}(t)|_{t=n/\theta f_s} = \sum_{p=1}^{N_p} A_p\, x_{AB}\left[\frac{(1+a_m)}{\theta} n - \tau_p\right], \frac{(1+a_m)}{\theta} = 1 + a_{AB} \quad (12)$$

Similarly message $x_{BA}(t)$ sent from node B to node A, the received signal at node A is discretized as

$$y_{BA}[n] = y_{BA}(t)|_{t=n\theta/f_s} = \sum_{p=1}^{N_p} A_p\, x_{BA}[\theta(1 + a_m)n - \tau_p], \theta(1 + a_m) = 1 + a_{AB} \quad (13)$$

Due to the sensor mobility, a_m varies from transmission to transmission, and skew is unknown. Estimation of a_m and θ therefore cannot be obtained directly based on a single round-transmission in two directions. Since a_{AB} and a_{BA} can be gathered at this time, skew is assigned with an initial value "1", named as initial skew denoted by $\hat{\theta}$. In doing so, relative speed v can be estimated.

Velocity estimation:

Considering that multiple message exchanges occur in the synchronization process, estimation of the relative speed between the reference node and the ordinary node can be improved by incorporating the estimates obtained during the previous message exchanges. Assuming the relative motion between the reference node and the ordinary node follows the first-order kinematic model, we have the dynamic equation

$$x(k + 1) = F(k)x(k) + \Gamma(k)w(k) \quad (14)$$

Where $x(k)$ is the denotes the velocity, $w(k)$ denotes the discrete-time process noise, which is supposed to follow a Gaussian distribution where $F(k)$,$\Gamma(k)$ and $\Delta T(k)$ are,

$$F(k) = \begin{pmatrix} 1 & \Delta T(k) \\ 0 & 1 \end{pmatrix} \; and \; \Gamma(k) = \begin{pmatrix} \Delta T^2(k)/2 \\ \Delta T(k) \end{pmatrix} \quad (15)$$

$$\Delta T(k) = \begin{cases} \frac{\tau_1[i]-\tau_2[i]}{2} + t_3[i] - t_2[i], & (k = 2i - 1) \\ \frac{\tau_2[i-1]-\tau_1[i]}{2} + t_2[i] - t_3[i - 1], & (k = 2i) \end{cases} \quad (16)$$

The measurement equation can be formulated as

$$z(k) = Hx(k) + n(k) \quad (17)$$

Where,$H = [1 \quad 0]$, $n(k)$ denotes the measurement noise and is the $z(k)$ velocity measurement.

Simulations and results:

Orthogonal Frequency multiplexing modulation (OFDM) symbol with K_0 =128 subcarriers is used to generate preamble. The speed of sound in underwater is 1500 m/s. T_0 is the time duration of the waveform and the bandwidth B = 12KHz. The window size of the preamble is found in Fig.3.where it is used to know where the delay has been estimated. By using the Delay estimation, receiver can correlate the output. Fig.4. shows the autocorrelation output, where the maximum value is found. The Doppler Scaling factor can be estimated based on the maximum correlation output and the linear interpolation is performed to improve the estimated accuracy.

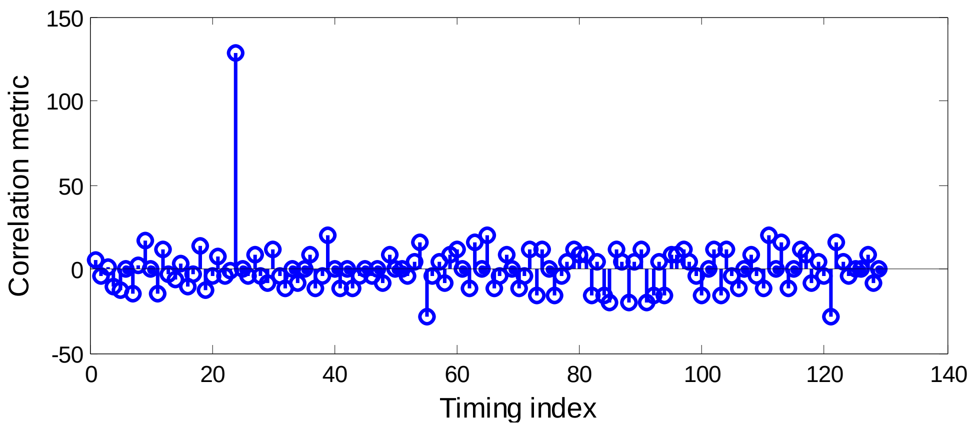

Fig. 3: Delay Estimation.

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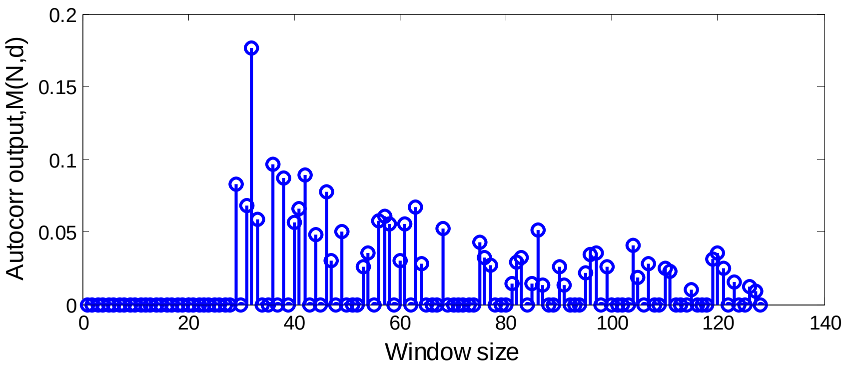

Fig. 4: Autocorrelation Output.

Fig.5 shows the comparisons graph of frequencies estimated using various methods [9],[10],[11] by linear interpolation. The estimates from each method are compared against the known frequency and the effects of DFT maximizer selection errors are included in the performance results to show system effectiveness. In general it appears that Macleod's and Quinn's second estimators are good in performance with respect to RMSE and significantly better than the other two techniques. An important consideration in estimator selection is computational complexity. The MQE is generally simplest and requires only simple arithmetic and a single divide to compute. Macleod's offers excellent performance overall but requires divisions and a square root for the correction calculation. Quinn's second, also an excellent performer, requires several divides and natural logarithms. Quinn's first (square) is much simpler but still requires several divides.

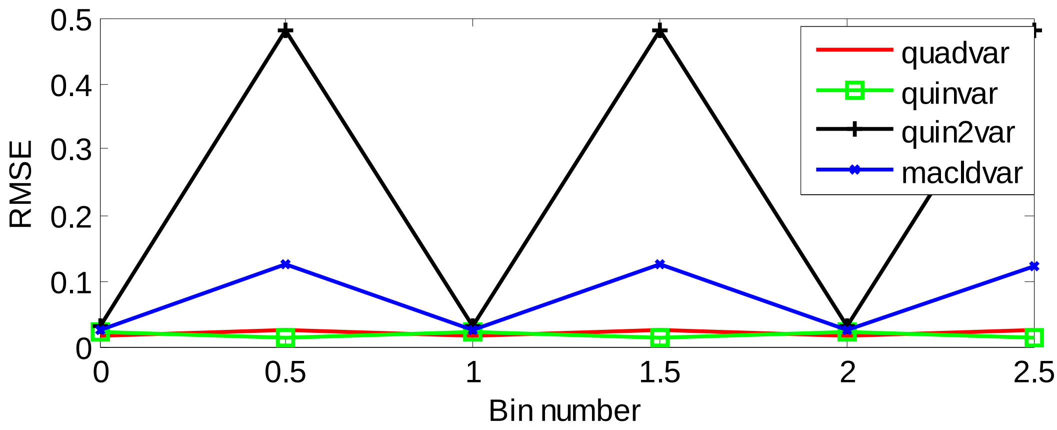

Fig. 5: Frequency Estimation Comparison Graph.

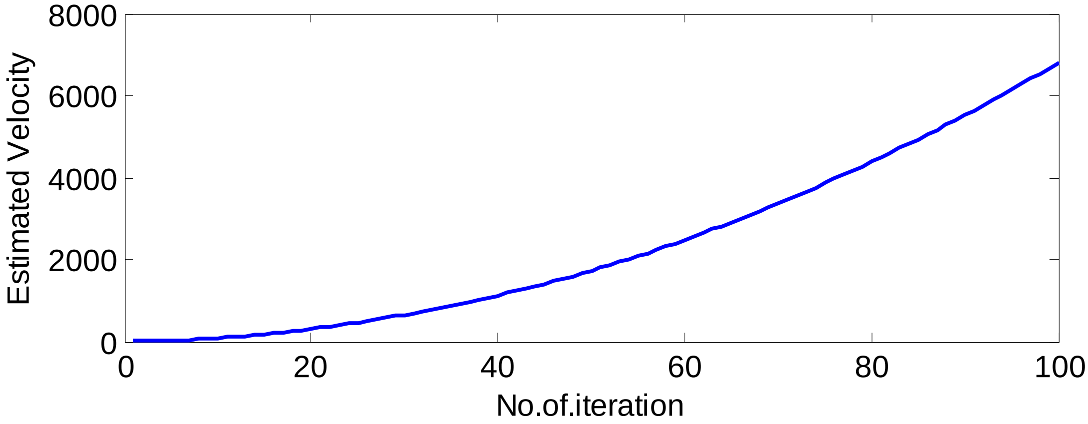

Fig. 6: Estimated velocity.

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By using the kalman filter, the velocity has been estimated and it is shown in Fig.6. And also the error between the prior and posterior velocity can be found.

Conclusion:

In this paper, the Doppler scaling factor has been introduced and the delay estimation is shown in simulation results. And the sensor node mobility is found by the message exchange between the two nodes, the ordinary node and the reference node. After this, a multiple message exchange is occurred between these nodes where the reference node is in movement. The delay between the message exchange is calculated by using Doppler scaling factor and with the linear interpolation, the frequency has been estimated by using various methods. Also the velocity has been estimated, thereby repeating this process with various skew and offset values, the propagation delay is reduced, which increases the efficiency and accuracy of the message exchange.

REFERENCES

Akyildiz, I.F., D. Pompili and T. Melodia, 2004. “Challenges for Efficient Communication in underwater Acoustic Sensor Networks,” *ACM SIGBED* Rev., 1(1): 3-8.

Akyildiz, I.F., D. Pompili and T. Melodia, 2005. “Underwater Acoustic Sensor Networks: Research Challenges,” *Ad Hoc Networks,* 3(3): 257-279.

Chirdchoo, N., W.S. Soh and K.C. Chua, 2008. “MU-Sync: A Time Synchronization Protocol for Underwater Mobile Networks,” Proc.Third ACM Int’l Workshop Underwater Networks (WuWNet ’08).

Liu, J., Z. Zhou, Z. Peng, J.H. Cui, M. Zuba and L. Fiondella, 2012. “Mobi-Sync: Efficient Time Synchronization for Mobile Underwater Sensor Networks,” *IEEE Trans. Parallel and Distributed Systems (TPDS).*

Lu, F., D. Mirza and C. Schurgers, 2010. “D-Sync: Doppler-Based Time Synchronization for Mobile Underwater Sensor Networks,” *Proc. Fifth ACM Int’l Workshop UnderWater Networks (WUWNet ’10)*.

Macleod, M.D., 1998. "Fast Nearly ML Estimation of the Parameters of Real or Complex Single Tones or Resolved Multiple Tones," *IEEE Trans. Sig. Proc*., 46(1): 141-148.

Quinn, BG., 1994. "Estimating frequency by interpolation using Fourier coefficients," *IEEE Trans. Sig. Proc.,* 42(5): 1264-1268.

Quinn, BG., 1997. "Estimation of frequency, amplitude and phase from the DFT of a time series," *IEEE Trans. Sig. Proc.,* 45(3): 814-817.

Syed, A. and J. Heidemann, 2006, “Time Synchronization for High Latency Acoustic Networks,” *Proc. IEEE INFOCOM*.