IOSR Journal of Computer Engineering (IOSR-JCE)
e-ISSN: 2278-0661,p-ISSN: 2278-8727
PP 73-78
www.iosrjournals.org

An Efficient and secure time synchronization for mobile Underwater Sensor Network

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Abstract: *Time synchronization plays a critical role in distributed network systems. In this paper, we investigate the time synchronization problem in the context of underwater sensor networks (UWSNs). A synchronization algorithm for UWSNs must consider additional factors such as long propagation delays from the use of acoustic communication and sensor node mobility. These unique challenges make the accuracy of synchronization procedures for UWSNs even more. This paper modifies Mobi-Sync, a novel time synchronization scheme for mobile underwater sensor networks for developing secure time synchronization method. Mobi-Sync distinguishes itself from previous approaches for terrestrial WSN by considering spatial correlation among the mobility patterns of neighboring UWSNs nodes. Simulation results show that Mobi-Sync outperforms existing schemes in both accuracy and energy efficiency, but mobi-Sync doesnt consider the security aspetcs. Simulation results show that our method outperforms existing synchronization schemes in both accuracy and energy efficiency.*

Keywords:*Underwater Sensor Networks, Time Synchronization, Security, Mobi-sync,*

I. Introduction

Time synchronization is an important concern that we need to consider especially for sensor networks. There are many time synchronization techniques that have been proposed for terrestrial WSN which provides high accuracy and high degree of precision. But the time synchronization techniques which are used in these terrestrial WSN cannot be directly applied to UWSN. This is because UWSN exhibit different features, when we compare UWSN with the terrestrial WSN. These features include node mobility, long propagation delay, limited bandwidth, limited transmission rate, high bit error rate etc. UWSNs require long propagation delays due to the low transmission speed of sound in water. For mobile UWSNs, the delays in propagation between these sensor nodes are time-varying because of sensor node mobility. All these reasons in UWSNs bring new challenges for time synchronization algorithms.

UWSNs have a number of applications such as Seismic monitoring to detect earthquakes and tsunami. Another application is the coordinating and sensing of chemical leaks or biological phenomena such as oil leakage, phytoplankton concentrations, oceanographic data collection, disaster prevention, pollution monitoring, offshore exploration, and military surveillance. Therefore time synchronization is an important requirement for many services provided by distributed networks. Secure time synchronization is one of the key concerns UWSn. These sensor nodes are likely to undergo many critical security attacks. Therefore, time synchronization must prevent the modification attempts made by these attackers. Attackers are there especially in applications such as military surveillance and oceanographic data collection. These attackers manipulate time stamp information of the neighboring nodes and provide the nodes with incorrect information. So it is important to ensure the security of synchronization in UWSNs against these attacks.

There are many time synchronization algorithms that have been proposed in UWSNs .These algorithms include Mobi-Sync, DA-Sync, MU-Sync, D-Sync, TSHL, CLUSS etc. Each algorithm has their own strength and short comings.

II. Related Works

Reference Broadcast Time synchronization (RBS) [1] is a method in which the receiver uses the physical layer broadcasts for comparing the clocks. This is slightly different from traditional methods which synchronize the sender's with the receiver's clock. RBS allows the nodes receiving the synchronization packets to use the packet's time of arrival as a reference point for clock synchronization.Timing-sync Protocol for Sensor Networks (TPSN) [2] works in two steps. In the first step, a hierarchical structure is established in the network and then a pair wise synchronization is performed along the edges of this structure to establish a global timescale throughout the network. Eventually all nodes in the network synchronize their clocks to a reference node. TPSN gives a 2 times better performance as compared to Reference Broadcast Synchronization (RBS).

Flooding Time Synchronization Protocol (FTSP)[3], uses low communication bandwidth and it is robust against node and link failures. The FTSP achieves its robustness by utilizing periodic flooding of synchronization messages, and implicit dynamic topology update. It differs from previous time-stamping algorithms in that it utilizes a single broadcasted message to establish synchronization points between the sender and receivers of the message.

TSHL ie Time synchronization for high latency [4] is the first time synchronization technique introduced for high latency networks. In the first phase, of TSHL the nodes estimate clock skew. In the second phase inorder to determine the offset, they swap skew compensated synchronization messages within the network. In phase one, without receiving any knowledge about the propagation delay we are estimating the clock skew, which means the accuracy of the estimation is dependent on consistency, not the duration, of propagation delay. This method assumes that the propagation is constant over the message exchange and clocks are short term stable.

D-Sync [5] method is a powerful approach that incorporates physical layer information, namely an estimate of the Doppler shift. Large Doppler shift has been identified as a major challenge to underwater communication. Doppler shift contains highly useful information that can be leveraged to greatly improve time synchronization. Specially, it provides an indication of the relative motion between nodes. Therefore the protocol, called D-sync, strategically exploits this feature to address the timing uncertainty due to node mobility.

MU-Sync[6] technique, which is a cluster-based synchronization algorithm Mobile UWSN. The MU SYNC mainly consists of 2 phases, In the first phase, the clock skew and offset is estimated. MU-sync performs the linear regression twice. The first regression enables the cluster head to gather the amount of propagation delay second linear regression is applied to this new set of points. MU-Sync can be directly applied to mobile multi-hop UWSN.

WATERSync[7] method is a correlation-based time synchronization protocol specifically for shallow underwater sensor networks. WATERSync integrates the time synchronization procedure with the tree-like network routing topology in vertical direction (the surface station is the tree root), which consists of Gradual Depth Timing (GDT) phase and Level 1 (i.e., between the surface station and first depth nodes) Skew Compensation (LSC) phase.

JSL [8] that is joint time synchronization and localization method is a joint solution for localization and time synchronization, in which the stratification effect of underwater medium is considered, By combining time synchronization and localization, the accuracy of both are improved jointly and the number of required exchanged messages is significantly reduced, which saves on energy consumption.

Mc-Sync [9] approach has two reference nodes along with time and will be located at opposite sides. To implement Mc-Sync algorithm, we need to consider two requirements that is to assume that the two reference nodes that are formed along the direction of ocean current and the node is placed in the connection link of the two reference nodes. The static reference node is connected to the mobile reference node through a light cable. After forming it we assume that the mobile reference node is in a still stage and the static reference node moves with the ocean current. The main factors affecting the movement of the static reference node is ocean current. The MU-sync is not energy efficient when compared to mc-sync as it does not allow the reference nodes to broadcast the synchronization messages. Thus the packet number of Mc-Sync is smaller when compared to MU-Sync.

Fikret Sivrikaya. [10] proposed a survey paper which reviews the time synchronization problem and the need for synchronization in sensor networks. All network time synchronization methods rely on some sort of message exchange between nodes. Non determinism in the network dynamics such as propagation time or physical channel access time makes the synchronization task challenging in many systems. Basic source of errors in network time synchronization methods are the send time which is the time spent to construct a message at the sender. It includes the overhead of operating system (such as context switches), and the time to transfer the message to the network interface for transmission. Another source of error is Access Time ie each packet faces some delay at the MAC layer before actual transmission. Then another source of error is the propagation time which is the time spent in propagation of the message between the network interfaces of the sender and the receiver.

Moreover, none of these protocols take security as one of their goals. Consequently, an adversary can easily attack any of these time synchronization protocols by capturing a fraction of the nodes and have them distribute faulty time synchronization messages. In effect, the nodes in the entire network will be out-of-sync with each other.

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III. Proposed Methodology

Here a Secure Synchronization protocol has been provided. In UWSN, the whole network is composed of three types of nodes: beacons, cluster heads, and ordinary nodes. Beacons have unlimited energy resources and perfect timing information. They can synchronize to UTC (Universal Time Coordinated) time constantly using GPS services without recalibrating their atomic clocks or performing any synchronization algorithms. In this regard, they provide the time reference for the sensors positioned underwater. Beacons communicate with cluster heads and each cluster has and only has one cluster head. The beacon is placed on the water surface and is equipped with GPS to obtain UTC time. Each sensor node is assigned a unique identifier (ID). .

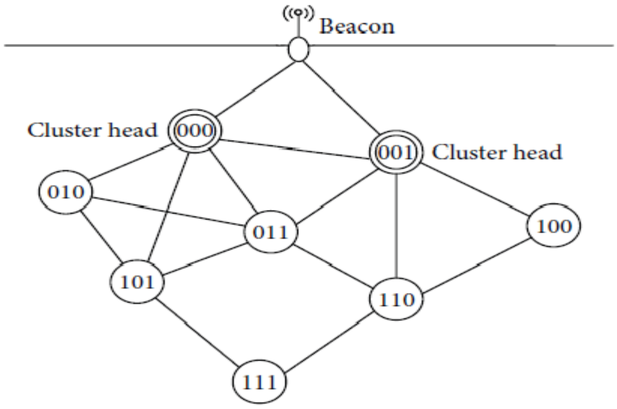

Figure 1. Network Topology

The proposed system consists of the following procedure:

A. Topology creation

Initially all the 3 nodes required in the system have been deployed that is the ordinary nodes, super nodes and the surfacebuoys. As these nodes are considered to be in UWSN, it has to be in motion. Therefore mobility is being provided for each of these nodes. In order for communication between these nodes create application agents and have been attached to the appropriate nodes.

B. Cluster Formation

During cluster formation each node belongs to one and only one cluster. Different clusters cannot share any common nodes. It is important for nodes to perform cluster consistency checking during the process of cluster formation. The ordinary nodes have been classified into different clusters. From each of the cluster a cluster head is being selected and that has been considered as the nearest super node for all the ordinary nodes in that cluster.

C. Cluster Head Selection

Each nodes in the cluster have been assigned an energy value. The node in each cluster with the highest energy has been chosen as the cluster head.

D. Authentication

After, all the nodes are assigned identities of either cluster heads or ordinary nodes. An attacker may participate in the process of cluster formation using malicious nodes. These malicious nodes can launch different attacks in order to introduce cluster inconsistency .So in order to ensure that there are no malicious nodes all the nodes in the system are authenticated by the beacon by sending a hash value. If the node id and the hash values do not match it is considered as a malicious node. The malicious nodes are found and they are removed from the cluster.

E. Message Exchange

The message exchange happens initially between the cluster head of the 1st cluster and the beacon. The cluster head sends a request message to get synchronized. The beacons get the time information from the satellite and send back a response to the cluster head with the time information.

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F. Delay Calculation

As the nodes in the Underwater are considered to be in motion there are chances for delay during the propagation. The delay during propagation is being calculated and added along with the time information

G. Synchronization

The cluster head on obtaining the real information provides the synchronized time to the other ordinary nodes in the cluster and all the nodes in first cluster get synchronized. Then consider any another node named destination in any other cluster need to get synchronized. Then the ordinary nodes in the synchronized cluster find a path to the destination node and provide it with the time information.

Advantages:

- Security is provided against attacks.
- More energy efficient and accurate when compared to other methods.
- Sensor node mobility and long propagation delays that occur during the communication are considered.

Disadvantages:

- Message overhead
- Suitable only for dense networks

IV. Implementation

The proposed method has been implemented using NS2 and the following results are obtained.

The different nodes required for the system have been created. The node at the surface of the water is named as Beacon and a node representing the satellite has also been created. Mobility is provided for each of these nodes. An energy value is being provided to each of the nodes. The ordinary nodes have been grouped into different clusters. In each cluster the node with the highest energy value has been chosen as the cluster head. In order to ensure there are no malicious nodes authentication is being done and the malicious nodes are removed from the network.

The cluster head of the first cluster send request message for time synchronization to Beacon. The request message consists of the time stamp information. The beacon is placed on the water surface and is equipped with GPS to obtain UTC time. So they obtain the time information and send back a response to the cluster head with the time information. Cluster head obtains the time information and since the nodes are in motion there are chances for delay. So delay during propagation is calculated and added along with the time. This information is provided to the ordinary nodes of the 1st cluster. Then consider any node of another cluster wants to get synchronized then the already synchronized ordinary node find a path to the unsynchronized node and provides them the information. The node creation and communication have been showed in the network animator.

V. Results And Analysis

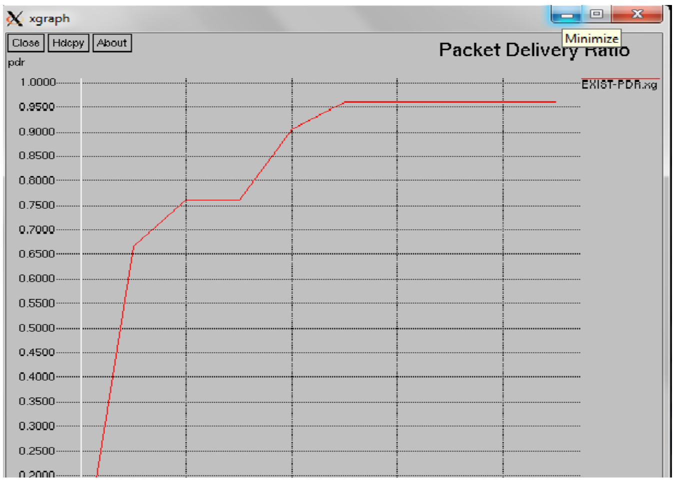

Figure 2.The Graph explains the ratio between the no of packets send and received during the network life.

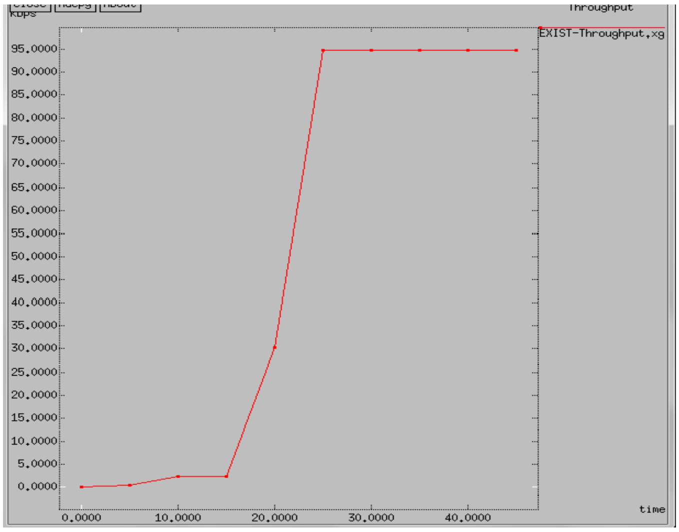

Figure 3. The Graph plots the throughput that is the no of packets passing in the network

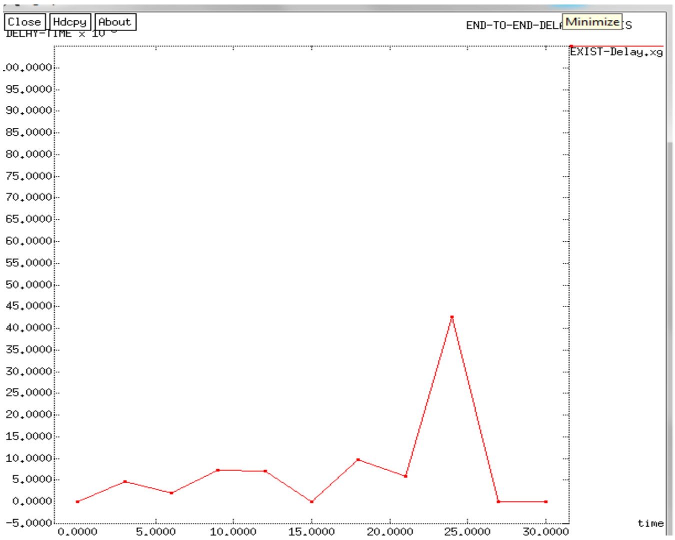

Figure 4. The graph plots the delay occurring during the packet delivery the difference in time received and the time sent.

VI. Conclusion

Mobi-Sync, a time synchronization scheme for mobile UWSNs. Mobi-Sync is the first time synchronization algorithm to utilize the spatial correlation characteristics of underwater objects, improving the synchronization accuracy as well as the energy efficiency. In this paper we modified Mobi-Sync to get secure synchronization. Secure time synchronization is one of the key concerns for UWSNs. UWSNs are often deployed in an environment, with many unattended sensor nodes. These sensor nodes are likely to undergo many critical security attacks, such as replay attack, message manipulation attack, and delay attack. Therefore, time synchronization must prevent the modification attempts made by these attackers. So here we propose an authentication method that ensures the security of synchronization under harsh underwater environments against these attacks.

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