Time Synchronized Fair Data Transmission in Secure UWSNs

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Abstract: ***In Underwater Wireless Sensor Networks (UWSNs), energy consumption, throughput, security and delay reduction are the main area of concern. During transmission problems might occur such as congestion, collision, lack of time synchronization. Thus creates loss of energy and increased end – end delay degrading the lifetime and performance of the network. In our work, we mainly concentrate on time synchronization among all nodes and a fair data transmission in the network that reliably assigns channel to the nodes and allow packets transmission by using Time Distance Metrics (TDM). Time Distance Metrics is used to maintain packets in the queue of each node, fair channel allocation and competition waiting. Thus our work reduces energy consumption with increased throughput and reduced delay with an increased network performance.***

Keywords: Energy, Throughput, Delay, Time Synchronization, Time Distance Metrics

1. Introduction

Underwater Wireless Sensor Networks (UWSNs) are a collection of self – organized and distributed wireless communication networks that consist of a large number of underwater sensor node [1]. The use of such sensors has increased rapidly in many fields. These Underwater Sensor Networks are used for gas/oil spills monitoring, oceanographic data collection, offshore exploration, submarine detection, disaster prevention, pollution monitoring, water quality monitoring, military surveillance etc [2][3][4]. These underwater sensors resemble the terrestrial sensors. However, the UWSNs does not use radio signal or electromagnetic signals. Instead they make use of acoustic signals [5].

There are many restrictions to the sensor nodes in underwater environment. Some of them are salinity, humidity, temperature, mobility of nodes, changing underwater environment. Due to the high attenuation of electromagnetic signals in water environment, it is not at all suitable for underwater communication. From observation, nodes without any self-propelling capability can move with ocean current and wind at the rate of 0.83- 1.67m/s and existing Autonomous Underwater Vehicles (AUV) typically move at a rate of up to 2.9m/s[6].

1.1 Types of Underwater Sensor Networks

- Static - Each node is well attached to docks, anchored buoys or to the seafloor.
- Semi Mobile – Sensors are suspended from buoys that are deployed by a ship and used temporarily, then left in place for hours or days [7]. They are removed when the task is completed or when power goes down in order to recharge them.
- Mobile – These Sensors are attached to AUVs (Autonomous Underwater Vehicles), low-power gliders or unpowered drifters [8]. Mobility is very much useful to maximize sensor coverage with limited hardware. But it also raises challenges for localization and maintaining a connected network. Energy required in such sensor set up for communication is plentiful in AUVs.

1.2 Applications of Underwater Sensor Networks:

- Seismic Monitoring– A beneficial applications of underwater sensor networks are seismic monitoring for oil extraction from underwater fields [9]. “4 – D seismic” is useful for judging performance and motivating intervention.
- Underwater robots– This supports groups of underwater autonomous robots that can eventually sense, collect and transmit data such as chemical leaks or biological phenomena like phytoplankton concentrations and also equipment monitoring [10].

1.3 Factors Affecting the Underwater Wireless Communication

- Multipath–Due to the presence of multi path between source and sink, mechanisms to identify best route may be a tedious task for the sensor nodes.
- Noise–These may be due to the underwater environmental activities or may also be due to the interference of other propagating signals.
- High delay–The transmission speed in the underwater environment using acoustic signals is five orders of magnitude lower than in the radio channel.
- Doppler spread–This causes degradation in the performance of digital communication

1.4 Challenges of Underwater Sensor Networks:

There are several challenges [11] faced in the underwater environments which are as follows:

- Extraction of data reliably
- Clock synchronization

- Energy management
- Network security
- Available bandwidth is limited due to the lack of fair channel sharing mechanisms [12].

2. Problem Statement

Security and Network performance are the crucial area of interest in sensor network. The objective of the research is of implementation of cluster based fair data transmission strategy consists of queue management, transmission control and competition waiting. To achieve enhanced network performance by reducing the congestion. The proposed system also focuses on security by authenticating each node before it starts communication for time synchronization

3. Contribution

In this paper we propose a well organized solution to ensure that the communications between the underwater sensor nodes are fair and reduced congestion. Hence queue management, transmission channel allocation, time synchronization is implemented to achieve fair transmission with increased throughput and reduced error rate / packet loss. In Queue Management module, it maintains a metric known as Time – Distance Metrics (TDM) which assigns priority to the incoming packets. It also maintains two queues: in – queue and out – queue. In fair transmission, it allocates channel for nodes sending packets based on TDM which reduces the congestion. Time Synchronization modules enforces on the security by using regression model. Thus it achieves security with increased throughput, reduced delay, reduced packet loss.

4. Related Work

Time synchronization attacks have great impact on a set of sensor network applications and services which depend on accurate time synchronization to perform their respective functions. All attacks on time synchronization protocols of UWSNs tries to deceive some of the nodes that their neighbor's clocks are at a different time than they actually are [13,14,15].

Ming Xu, Guangzhong Liu, Daqi Zhu, and Huafeng Wu [16,17] apply a novel Cluster-based Secure Synchronization (CLUSS) protocol that concerns security as well as accuracy in synchronization. Before time synchronization, CLUSS performs cluster formation securely by means of cluster consistency checking. After the cluster formations, CLUSS performs the process of time synchronization.

Aravinda S. Rao, Jayavardhana Gubbi1, Tuan Ngo, James Nguyen, and Marimuthu Palaniswami1 [18], apply a time synchronization approach which divides the entire network into clusters by using LEACH approach and then by using multi – level pair wise synchronization, the time within the clusters are synchronized.

Pu Wang, Cheng Li, JunZheng [19] illustrate Minimum Cost Clustering Protocol (MCCP) – In this approach clusters are formed based on the cost metric [20].

5. Implementation

In order to overcome the disadvantages of the existing system we propose an enhanced approach to achieve security, fair allocation of bandwidth that enables efficient utilization of the energy and thus avoids congestion and guarantees improvement in overall network performance.

We construct a network consisting of nodes that are initially synchronized before they are set to transmit. Along with such synchronization we also enforce the fair channel/bandwidth allocation among the nodes. For this purpose, we utilize a metric named as Time Distance Metrics.

Time Distance Metrics can be defined as the ratio of entire end – to – end delay and the delivery distance of packet in the network. Consider the end – to end delay of a packet as T_d which is the time that has passed and the time T' which is the time still need to transmit.

$$T_d = t - t_0 \quad \ldots\ldots (1)$$

$$T' = (L' + L_{i+1})/V \quad \ldots\ldots (2)$$

where t is the generation time of the packet, t_0 is the current time, L' Euclidean Distance between node and the sink, L_{i+1} is the distance from current node i to the next hope j. Entire transmission of a packet can be given as $L_1+L_2+L_3+\ldots+L_i+L_{i+1}+L'$. Therefore Time Distance Metrics can be expressed as

$$M = (T' + T_d)/L \quad \ldots\ldots (3)$$

The concept of Time Distance Metrics is not only used for reducing delay but also to provide a fair share of the bandwidth among the cluster heads that intend to transmit at the same time.

The proposed system consists of:

i) Time synchronization: Initially the sink/beacon is provided with a standard time. This standard time is propagated to all the nodes that intend to participate in the packet transmission.

ii) Queue management: Each sensor node has a queue for storage that holds messages ready to be sent. Queue management has an enormous impact on network transmission efficiency and delay, effective queue management cannot only increase success rate of transmission, but also improves delivery fairness of packets. Queue management is to properly classify stored messages in the queue, and decide which to transfer based on priorities of each message and message discard principles, in order to achieve fair management of messages.

iii) Transmission control: There is a message queue in each node. When node compete channel to send messages, it needs to deliver messages according to certain mechanisms. Messages are sorted from big to small based on TDM the message whose TDM is greater than others can achieve priority to be sent. The node which have a larger value of TDM than other nodes have high priority to achieve channel.

iv) Competition waiting: Receiver only communicates with only one contender in each communication. Other failed contenders continue to contend the channel after this communication ends. We propose a dynamic competition waiting mechanism in order to satisfy fairness of channel competition and reduce collisions.

Algorithm 1 Packet Insert

Require: *New_packet*, **Queue*

```
Begin function
    td_new = time_distance(New_packet);
    if (td_new ≥ max_td) then
    free(New_packet);
    else
    node *s;
    s = (node*)malloc(sizeof(node));
    s -> packet = New_packet;
    s -> next = NULL;
    if (Queue -> rear == NULL) then
    Queue -> first = s;
    Queue -> rear = s;
    else
    Queue -> rear -> next = s;
    Queue -> rear =s;
    end if
    Update_Sort(Queue);
    end if
    return(Queue);
End function
```

Thus in case of network congestion, delaying a period time dynamically is helpful to compete for channel, avoid data collisions effectively and raise network performance and the success rate of data transmission.

When run nam out.nam, the animator will open. Here it is showing the nodes placed in respective positions. This is the initial phase where it shows the position of the nodes in the network that intends to participate in the transmission.

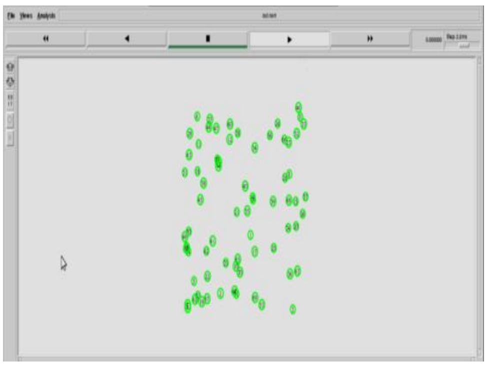

Figure 1 : NS2 interface showing intial position of the nodes

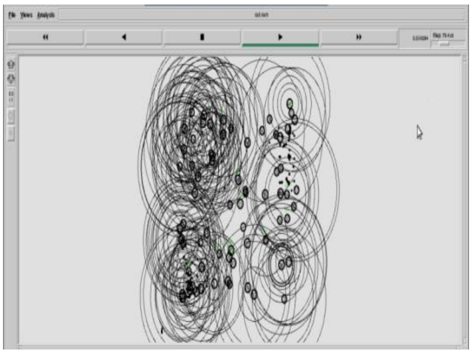

Figure 2 : NS2 simulation representing the transmission of the packets

In the above figure, it shows transmission of packets from source to the destination and also focuses on the queue management.

The below graph which are obtained by the simulation summarizes that the delay is eventually reduced though the traffic rate is increased. Thus attaining the goal of reduced propagation delay by using the Time Distance Metric for transmission of the packets from source to the sink. Due to the decrease of the delay we attain the increased or efficient utilization of the energy along with increased throughput. Thus our experiments have proven that we attain a better network performance in underwater sensor networks.

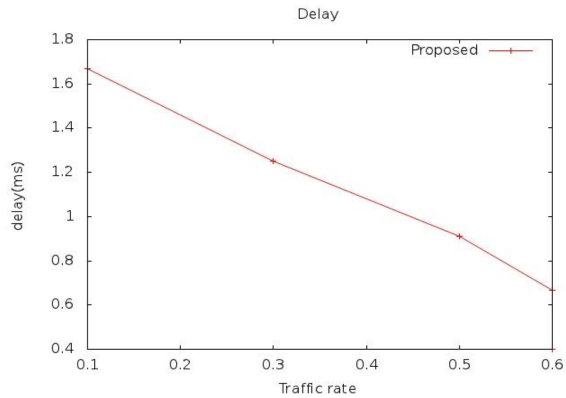

Figure : Representing graph of delay vs traffic rate

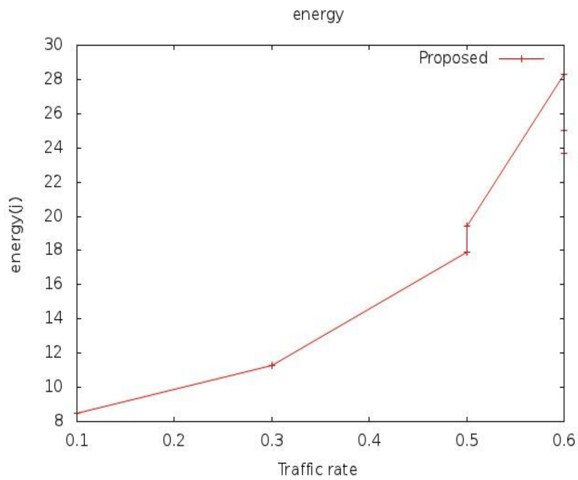

Figure: Representing graph of energy vs traffic rate

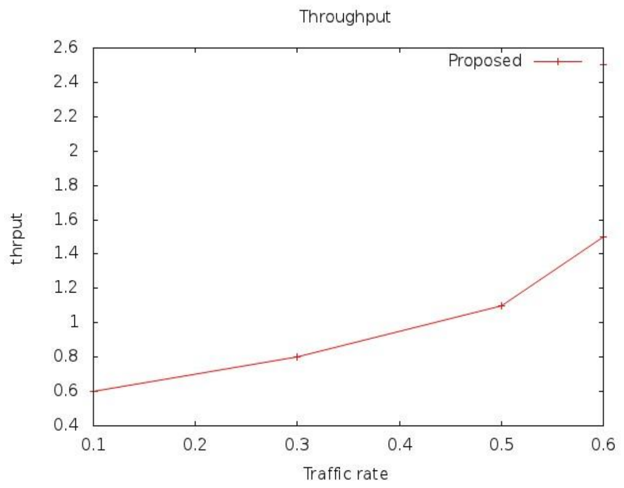

Figure : Representing graph of throughput vs traffic rate

6. Conclusion and Future Work

We have proposed time synchronized fair data transmission in secure UWSNs that ensures security of synchronization under harsh underwater environments against various attacks, including Sybil attack, replay attack, message manipulation attack, and delay attack. The time synchronization process ensures that all nodes are well synchronized thus delay can be minimized and the energy loss due to the delay can be reduced. We demonstrate through simulations that fair data transmission implemented along with time synchronization. Fair data transmission includes queue management, transmission control and competition waiting. This will mainly use Time Distance Metrics, which is a metrics used to allocate channel for the transmission, to place the packets in the queue. This assures reduce the number of sending control packets and its collision probability, decrease energy consumption and prolong the network lifetime. Simulation results show that when the network load is heavier, we can effectively improve the fairness of data transmission and the success rate of delivery, and reduce end-to-end delay, the average energy consumption and increased throughput. In future work, we will investigate the influence of MAC layer activities to the performance of time synchronization protocols, such as packet loss and retransmission. Moreover, we will perform the analysis of the adaptability of our strategy and evaluate its performance through real ocean experiments.

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