Study of Energy Efficient Time Synchronization Algorithm for the development of Smart Wireless Sensor Network

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***Abstract*— Time Synchronization algorithm guarantees the connectivity, coverage, reliability and security of networking operations for a maximized period of time. We propose energy efficient time synchronization algorithm for deployment of Underwater Wireless Sensor Network (UWSN) for the purpose of monitoring phenomenon of our interest in the coverage region. This paper describes a prototype of a synchronization protocol which is suitable for UWSN considering the effects of both propagation delay and movement. In the algorithm, no time synchronization is necessary if the time stamps of the received data packets are within the tolerance. In this context, the network underwater neither performs global time synchronizations frequently nor periodically and it reduces the time used to synchronize clocks among sensor nodes.**

***Index Terms*— Algorithm, Protocols, Time Synchronization, Underwater Wireless sensor Network (UWSN).**

I. INTRODUCTION

Wireless sensor network consists of a large number of tiny sensor nodes that are deployed in environmental fields to serve various applications. Facilitated with the ability of wireless communication and intelligent computations, these nodes become smart sensors which do not only process information but recognize various physical parameters and are able to cooperate with each other and self-organize into the network. With the presence of such new features sensor nodes operates more efficiently in terms of both data acquisition and energy consumption [1]. The limitations of sensor node resources such as memory, computational ability, bandwidth and energy source are the challenges in network design. A smart wireless sensor network must be able to deal with these constraints as well as to guarantee the connectivity, coverage, reliability and security of networking operations for a maximized lifetime. In the paper existing time synchronization protocols for wireless sensor networks are described in section II. In section III we have specified an example of Energy Efficient Algorithm. Effect of Undercurrent to synchronization is discussed in section IV and conclusion is described in section V.

II. EXISTING TIME SYNCHRONIZATION PROTOCOLS FOR WIRELESS SENSOR NETWORK

In the subsection we describe a brief overview of various widely used protocols for time synchronization in Wireless Sensor Networks.

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A. Time Synchronization in Adhoc Network.

This synchronization protocol was devised by Romer [2] to facilitate synchronization in ad-hoc wireless network. In the scheme the mobile computing devices communicate with each other's when they enter in its vicinity. This is obtained by bidirectional communication link. Author suggested that two nodes which do not enter each other's communication range can communicate by Store and Forward technique. Here an intermediate node receives the sender's message, stores it for a while and transmits it to intended receiver when they enters each other's vicinity. This protocol is very effective in environments with strict resource constraints. In the protocol each node use local clock and the time transformation method updates the timestamps. The final timestamp is expressed as an interval with a lower bound and an upper bound. These protocols are suitable for the applications which required the transmission outside the range. Here energy is saved by avoiding the Computer clock correction in local nodes. The drawback of this protocol is that estimation synchronization error is increased.

B. Reference Broadcast Synchronization Protocol.

In Reference Broadcast Synchronization Protocol (RBS) an intermediate node is used to synchronize the local time of two nodes The intermediate node transmits a "reference packet" to the two nodes. The two nodes record their time and exchange this recorded time to find the difference. The same message received approximately at the same time if two receivers are within the range of the same sender. Receivers synchronize themselves by recording the local time as soon as the message arrives. In the protocol, non-synthesized Reference Broadcasting method is used to compute the difference between nodes' offset [3]. The merit of this protocol is that by using it wastage of the energy on the clock updates is prevented. The major drawback of the protocol is that the energy is wasted to synchronize the reference sender [4].

C. Probabilistic Clock Synchronization Protocol.

Most synchronization protocols rely on deterministic algorithms as they usually guarantee an upper bound on the error in clock offset estimation. When there is a scarcity of system resources, the synchronization accuracy is assured by large number of messages exchange. In such situations, probabilistic algorithms can provide reasonable synchronization accuracy with lower computational and network overhead than deterministic protocols. The advantage of probabilistic synchronization is that the number of messages exchanged among nodes and the computational load on each node is reduced [4].

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It allows tradeoff between synchronization accuracy and resource cost. It also provides the support for multihop networks which extend across several domains. The drawback is that they are not fit for safety critical applications as it will not provide guarantee on accuracy.

D. Time Diffusion Synchronization Protocol.

Time Diffusion Synchronization Protocol [5] enables all the sensors in the network to have a local time that is within a small bounded time deviation from the network wide "equilibrium" time. In the protocol there are multiple cycles in the active phase and each cycle has multiple rounds. Due to clock skews, the algorithm must be applied periodically. The advantage of this technique is that it provides synchronization even without external servers. The drawback of this protocol is that it leads to higher complexity and its convergence time is also very high.

E. Lightweight and Energy Efficient Time Synchronization Protocol.

In Lightweight and Energy Efficient Time Synchronization Protocol each node in the network uses a slot timer to count slots and maintain node time. Sensor nodes are equipped with Hardware oscillators that can be used for the slot timer counting. There is irregular change in the oscillator frequency because of various physical effects. Two slot timers once have the same instant value may change after some time. Therefore to maintain the long time synchronization, tracking is needed periodically. This protocol [6] has two phases: initial time synchronization and time synchronization maintaining, i.e., acquiring and tracking. In Initial time synchronization phase, all the nodes in the network which are switched on will synchronize to the root node. Here the root node is equipped with the GPS. When a node is switched on, first it checks whether it is the root node. If it is the root node then it send the SYNC packet immediately and start a slot timer to count slots. If it is not a root node then it will remain in the listening state and wait for the SYNC packet to come.

II. AN EXAMPLE OF ENERGY EFFICIENT ALGORITHM

It is based on the Interactive Convergence Time Synchronization (ICTS) algorithm which is similar to the one discussed by [7]. In ICTS, the network-wide synchronization is achieved by having each node first derive the time offsets between itself and all of its neighbors by exchanging messages. Each node then computes the average of the measured clock offset and uses it to adjust its own clock, so that all the sensor nodes in the neighborhood will establish a common equilibrium time. Various terms used in this context are: Time offset, Data Packets, Profiling synchronization. They are described as follows:-

B. Time Offset.

The protocol applies the single message broadcast method which is used in FTSP [8] to compute the offset between two nodes. FTSP successfully eliminates major sources of uncertainties in the packet recommission (i.e., transmission time, access time, reception time, interrupt-handling time) by performing MAC-layer timestamping multiple times for every message at each byte boundary and embeds a final error-corrected and averaged timestamp into the message. The only uncertainty is the propagation time (for packets to traverse the wireless link) which is often very small and can be safely ignored. According to Mar´oti's findings [8], which uses only 6 timestamps per message, FTSP achieves the time stamping accuracy of 1.4 μs on the Mica2 platform. Thus, one radio broadcast is sufficient for all the neighbors to accurately calculate the time offsets between their clocks and sender's clocks, each of which is simply the difference between transmission and reception timestamps.

C. Data Packets.

The neighbor sensors oscillate in the range and at the border of a node if the node is considered as a "sink point" in its territory. Limited by single acoustic channel and lower bandwidth the sink node cannot request a resynchronization with all the nodes once a neighbor sensor shifts over the acoustic range no matter a neighbor node is carried away from or brought in the sink node's territory by undercurrent or ocean wave. Here we can design a protocol which timestamps each of the data message. The timestamp will help the profile manager (see in subsection C) to determine if the data is confidential to be used or not.

D. Profiling Synchronization

As mentioned in the introduction section, a sensor which is brought into another sensor territory by the undercurrent should be examined the clock first to guarantee that data provided by this sensor has a confidential clock. The protocol creates a Profile Manager (PM) whose function is to maintain a history profile recording relative clock drift between all its neighbor nodes and the nodes who have been its neighbors before. PM establishes one history profile copy for each neighbor node.

PM also calculates a mean value μ for each profile copy with discrete or continuous probability distributions depending on the number of messages which the neighbor nodes provided.

For discrete probability distributions, the protocol uses variance to compute μ, for continuous probability distributions, and we could use normal distribution to generate μ which is the location in Gaussian distribution.

For continuous probability distributions, the profile manager treats the message as a confidential data message and buffers the data, if not, the data will be dropped because of untrusting.

III. THE EFFECT OF UNDERCURRENT TO SYNCHRONIZATION

The mobility of each node brings neighbor problem to a data profiling cluster. Sensors are deployed in different layers in an open space underwater. The shape is changed when pressure comes outside. The pressure to the data profiling space in real world is undercurrent. Water moves along with many factors e.g., wind on the ocean surface, earth's rotation, etc., and of course from unpredicted orientations. That is to say, if we research the synchronization of UWSN, we could not dismiss the high mobility even the sensors are anchored relative stable.

The second characteristic of the network underwater is that we cannot treat sensors underwater as 2-D plane layout. Research on wireless sensor network above the ground usually assumes that the network is deployed onto the controlled environment without thinking too much about the latitude. That is to say, the horizontal distance between two nodes above the ground plays more important role in research work on attributions of wireless sensor network above the ground. However, the network underwater exists in a realm of 3-D world. The vertical movement is as important as the horizontal movement when nodes are in a fluid environment. We need to use cube or sphere to describe the behavior of a node underwater instead of rectangle or circle in plane. The respective parameters to be followed are shown as:-

Table 1: Parameters and their corresponding simulation values.

Parameter Name	Value Simulation
Radius	100 m
Acoustic Range	35m
Acoustic Speed	1500m
Sensor clock drift	± 0.3 ms/sec
Initial clock offset	±1.0 ms
Threshold of accuracy	350 µs

The other challenges of acoustics signals includes Bandwidth, Propagation delay, Shadow zones, energy, failures, attenuation etc.

IV. CONCLUSION

In the paper we have discussed in brief a list of various time synchronization protocols for WSNs based on different factors including precision, accuracy, cost, and complexity. This study will help the researchers/designers in building a successful time synchronization protocols as well as also help them to integrate various features to create a successful time synchronization protocols for their applications. We have focused on those factors that are essential for the design of a new time synchronization protocol for an Underwater Wireless Sensor Netwrok (UWSN). The effect of large propagation delay of acoustic media in communication is addressed in simulating the prototype protocol.

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