Synchronization in Wireless Sensors Networks

Abstract—Over the recent years, the Synchronization challenges in wireless sensors networks has been a hot topic and continues to be as an active research area in the last few years. However its importance is shown in the way to better organizing the sensors into the network, to communicate with each other via radio links for sharing and Treatment of reliable information. The main topic in this paper, we propose an improvement over Timing-Sync for sensor Networks (TPSN) to synchronize nodes in a wireless sensors network more effectively, with a good precision and lower missed messages. The simulation result using ns-2.34 shows that this protocol has better synchronization accuracy and low missed messages as compare to TPSN.

Index Terms—Wireless sensors, Time synchronization, Clustering, offset.

I. INTRODUCTION

Wireless sensor networks (WSNs) have received an increased attention as a result of the plentiful benefits materialized in an extended range of application domains, i.e. traffic monitoring, surveillance, industrial automation, mobile vehicles tracking and location positioning to name few [1]. The ultimate objective of synchronization is to offer a solution that keeps stability between the sensors throughout the network operation. Synchronization is ranked among the major problems of research in distributed system including sensor networks, the majority of research has been focused on the study protocol and algorithms that addresses these issues to resolve.

Wireless sensor networks (WSNs) assume a collection of such tiny sensing devices connected wirelessly and which are used to observe and monitor a variety of phenomena in the real physical world. Many applications based on these WSNs, consider local clocks at each sensor node that need to be synchronized to a common and standard reference time [2].

Synchronization methods in Wireless sensor networks have to treat with a number of defies and design issues. Despite advancement in technology, sensor nodes in WSNs still have restrictions such as limited battery power, bandwidth constraint, limited computing power and limited memory. It creates the need for routing protocols to be highly adaptive and resource aware. Some of the challenges of synchronization algorithm are:

1. The nodes deploy randomly.
2. Each node executes their local clock independently.
3. Limited power source.

Even a network that consists of two nodes may have two clocks labeled with same frequencies, but they may not necessary be running at exactly the same speed due to several reasons. As times goes by the tiny difference aggregates till it reaches substantial level due to the lack of node’s synchronization. In addition to clock drift, some nodes might witness a sluggish start as opposed to the other nodes in the network, or simply some nodes may join the network at a later stage. In such cases, there would be a fixed clock difference offset. This is also another problem, which should be deciphered and resolved.

Sensor nodes are miniature instrument running with a limited energy, so it is a challenging task to synchronize nodes effectively due to energy consumption. Also, they usually lack processing power, and consequently preventing any complex algorithms to run on WSN [3]

In the reset of this paper, section 2 gives previous works, section 3 present Common sources of error/inaccuracy in synchronization systems. In section 4 we discuss the proposed synchronization protocol. In section 5, simulation results are presented to verify the superiority of our scheme. Finally, the conclusion is presented in section 6.

II. PREVIOUS WORK

In this section we will examine the particularities of the most interesting algorithms in wireless sensor networks.

A. Reference Broadcast Synchronization: RBS

Elson and al [4], [1], have proposed the RBS approach based on the concept of receiver-receiver synchronization. The RBS mechanism capitalizes on the diffusion nature of wireless medium. Every node maintains communication with the relative clock and every other clock in the network.

By comparing the timestamps of periodic broadcast messages, the nodes calculate the clock offsets between the receiving nodes, thus successfully eliminating any transmit latencies. Only processing delay at the receiver and the difference in propagation delay between the nodes are potential error sources.
B. Timing-Sync Protocol for sensor Network: TPSN

Garnewel and al introduced into [5], [2], new synchronization algorithm with the type Transmitter-receiver concept. TPSN works in two steps, hierarchical structures is established in the network and give a network node level and then a pair wise synchronization is performed along the edges of the hierarchical structure up to a total synchronization of the tree constructed with the message exchange mechanism.

C. Reference Based Tree Structured time synchronization: TSRT

Proposed by Surendra Rahmatakar and Ajay Agarwal [6], [2], the aim is to minimize the complexity of synchronization. TSRT Network synchronization consists of two steps: The first step, is building an ad-hoc tree structure, followed by the second step of the sensor nodes local clock’s synchronization trailed by the network evaluation phase. At the end of synchronization phase, the network realizes the wide synchronization of the local clock of all participating nodes.


Uses the method of collecting and linear regression for reducing the energy consumption of network [7], [2]. SLTP work in two phases, the first phase deals with the configuration of static and dynamic networks, which defines both, the node group leader and its determined members. Then the second phase initiates the timing synchronization.

E. Table of comparison

In this section, we propose carry out a comparison of the various synchronization algorithm described previously according to several metric (Table 1): the missed messages, precision, energy efficiency. According to these parameters, the result of our evaluated proposal (algorithm) will be presented at the end of the paper.

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Missed messages</th>
<th>Precision</th>
<th>Energy efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBS</td>
<td>Average</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>TPSN</td>
<td>High</td>
<td>Average</td>
<td>High</td>
</tr>
<tr>
<td>HRTS</td>
<td>Average</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>SLTP</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

III. SOURCES OF CLOCK SYNCHRONIZATION ERROR

The biggest source of error in synchronization algorithms stems from non-determinism in message delivery latency is the effort to reduce this non-determinism, which characterize the message delivery latency into four distinct components [8]:

- **Send Time**: The time spent at the sender to build the message.
- **Access Time**: This is the delay incurred when waiting in the network interface for access to the transmission channel.
- **Propagation Time**: The time it takes for the message to transmit from sender to receiver once it has left the sender. The propagation time is highly deterministic in WSN and it depends only on the distance between the two nodes. This time is less than one microsecond (for ranges under 300 meters).
- **Receive Time**: This is the time needed for processing at the receiver’s network interface.

The Send Time and Access Time are unknown and highly variable. However, for a set of receivers listening to a common sender, those times are identical for all of the receivers. The only variable time is the Propagation Time and Receive Time, which are much smaller in value. This approach entails synchronizing a set of receivers with each other, in contrast to synchronizing with the sender. We use this idea to significantly reduce the sources of error in our clock synchronization protocol [8].

IV. SYSTEM MODEL

We propose a new version for clustered based time synchronization algorithm for wireless sensors network to synchronize the whole of the network after the formation of the cluster-head (CH).

A. Assumptions

Some of the assumptions made in clustered time synchronization in wireless sensors network are as following.

- The network in composed by N sensor nodes deployed in square field and has formed cluster hierarchical topology.
- The base station (i.e. root node) is located outside the sensing field.
- The root node is predetermined at level-0.
- Nodes are location-unaware of its members and can communicate with them.
- The cluster head are a ware of their parent cluster heads.
- Every cluster head is synchronizing with its parent cluster head and finally every cluster head node is synchronized with the root node.
- Each node is synchronized with its CH.
- The communication channel is symmetric.

B. Proposed scheme

Our scheme is based on the ideas mentioned in [5], when the number of levels increases, local clock offset difference also increase. For this reasons our approach based on balanced clustering into network to minimize complexity and increase precision.

- The network composed by N sensors nodes deployed in square field and has formed and cluster hierarchical topology.
• Define the depth of cluster (Define the level depth for each cluster).
• Organizing nodes inside cluster
• Synchronization processes same as TPSN done that the mechanism of pair wise synchronization is performed along the edge of the hierarchical structure established in the earlier steps.

The advantage of using the clustering for time synchronization is that CH can prolong the battery life of the individual sensors and also the network lifetime. CH can reduce the rate of energy consumption by scheduling activities in the cluster. Clustering reduce the communication overhead for synchronization

We can resume our approach in the table below.

### Pseudo code for forming balanced clustering

1. TPSN hierarchy done
2. **For** $N_i$ sensors in network **do**
   - Level$_N_i$ = Level$_{Parent\_Node}$ + 1
3. **if** (Level$_N_i$ < max level in cluster) **then**
   - Level$_{Current\_Node}$ = Niveau$_N_i$
   - Level$_{cluster\_Current\_Node}$ = Level$_{Cluster\_Parent\_Node}$
4. **else if**
   - Initiate a new cluster (Level$_{current\_node}$=0; Level$_{cluster\_current\_node}$=Level$_{cluster\_Parent\_node}$+1).
5. **for** each group in the network **do**
   - Initiate the synchronization process from the root node.
   - Synchronize group members with their own cluster-head.
   - Synchronizing the cluster-head using the same phenomena as TPSN.
   - Synchronize the whole of the network

### Table 2: Simulation Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routing Protocol</td>
<td>DSDV</td>
</tr>
<tr>
<td>Speed of movement of nodes</td>
<td>1m/s</td>
</tr>
<tr>
<td>Temps de pause des nœuds</td>
<td>20 s</td>
</tr>
<tr>
<td>Type of antenna</td>
<td>Omni Antenna</td>
</tr>
<tr>
<td>Type of canal</td>
<td>Wireless Channel</td>
</tr>
<tr>
<td>Model of the radio propagation</td>
<td>TwoRayGround</td>
</tr>
<tr>
<td>Model of MAC layer</td>
<td>Mac/802_11</td>
</tr>
</tbody>
</table>

In this section also, some of the key concepts are evaluated. It should be noted that this is not a full evaluation of all the presented solutions, but to justify some of the arguments.

As shown in Fig.3, the performance of our improvement comparing to TPSN protocols in terms of offset. As it is clear from fig.3 that proposed scheme based on balanced cluster, the clock offset is decreased and the precision increased but in TPSN the clock difference is higher due the higher level.

![Offset comparison between our improvement and TPSN](image)

It is observed from the graph in Fig.4 the performance of our protocol comparing to TPSN in terms of the number of missed message. The goal is to improve the high precision of our improvement. The number of missed message of our approach is less than TPSN; these parameters increase the precision and the trust of our scheme.
is based on the sender-receiver time synchronization approach. Theoretical analysis and simulation show that proposed scheme is able to minimize the number of missed messages, save the energy consumption and improve its accuracy.

REFERENCES


VI. CONCLUSION

In this paper, we have defined an algorithm, based on the method of balanced clustering, for wide network time synchronization in wireless sensors network. Our improvement