IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 04, Issue 01 (January. 2014), ||V4|| PP 06-11

An Alternative Approach for Energy Efficient Time Synchronization in Wireless Sensor Networks

Rajni Kaushal[1], Avtar Singh Buttar[2]
[1]*Punjab Institute of Technology, PTU Main Campus Kapurthala, India*
[2]*Associate Professor, Punjab Institute of Technology, PTU Main Campus Kapurthala, India*

Abstract: - Time synchronization is an important aspect in Wireless Sensor Networks (WSN). They make wide use of synchronized time in many contexts like data fusion etc. Without synchronizing, the sensed data will lose valuable context. Existing time synchronization methods cannot be used with such wireless networks as at the time of their designing such networks were not foreseen. So either present synchronization techniques need to be extended to WSN or are to be approached in different way. While designing synchronizing algorithm, requirements of energy, cost, scope, scalability, lifetime of WSN should be kept in mind. In this paper different approach for time synchronization in sensor networks is presented. This paper proposes an improved algorithm used for WSN in fixed deployment scenario of nodes. The Proposed algorithm is compared with Reference-Broadcast Synchronization (RBS) synchronization technique. Simulation results and Performance analysis shows that compared with RBS synchronization algorithms, the proposed time synchronization algorithm takes shorter time for synchronizing whole network and is more energy efficient.

Keywords: - *wireless sensor networks, time synchronization, synchronization algorithm, energy efficiency*

I. INTRODUCTION

Sensing is a technique used to gather information about a physical object or process, including the occurrence of events (i.e., changes in state such as a drop in temperature or pressure). An object which performs such sensing task is known as sensor. Sensors link the physical with the digital world by capturing and revealing real-world phenomena and converting these into a form that can be processed, stored, and actuated upon [11]. The field of WSN is an active area of research and development. A wireless network consists of spatially distributed devices or nodes which monitor physical or environmental conditions such as temperature, vibration, sound, pressure, motion and pollutants, at different locations cooperatively [8, 10]. Each device is equipped with sensing components, a transceiver for wireless communication, computing circuitry for processing and networking of the data, and an energy source, which is usually a battery [7]. The small devices called nodes communicate by radio in WSN. Limited memory and computation resources are inherently present in it. Nodes can send data, receive data, or act as routers in the network [9].

From past few years, applications such as environment monitoring (e.g., temperature, humidity), analyzing motion of animals or vehicles, intruder detection, tracking troops or targets etc. have been developed. Because of the availability of small, inexpensive sensors nowadays, the deployment of WSN has allowed us to monitor and, finally, control various aspects of the physical world. These WSN are made from many wireless sensors in a high configuration suitable to an application to monitor a specific area.

Time synchronization and energy efficiency are challenges for the WSN. Time synchronization is required to ensure that sensing time can be compared in a meaningful way. The main reason for clock or time synchronization in WSN is that the sensed data will be of limited value if it is not associated with coordinates of the sensor i.e., time stamp and position. The other basic but vital function which depends upon clock synchronization is data fusion, i.e., data is combined from multiple sensors into high level data [6]. Time synchronization algorithm should be designed in such a way that it also helps in reducing the energy consumption of network.

This paper is organized as follows: Section II gives a brief description of related work while Section III describes Proposed Algorithm and its steps. Section IV describes study and experiments undertaken and the effectiveness of the proposed algorithm is evaluated. The plots of the result are also given. Section V gives the conclusion and future directions are outlined as well.

II. RELATED WORK

Various time synchronization algorithms have been proposed and can be divided into three categories. First, one is the sender-based time synchronization, second is sender- receiver, and third is receiver-receiver time synchronization [1]. Reference Broadcast Synchronization algorithm is of the receiver-receiver based time synchronization algorithm. RBS algorithm is easily realized with less storage space. It can satisfy the majority low-precision time synchronization requests rather than high-precision time synchronization applications such as target tracking [1]. In WSN energy-efficiency and synchronization are the most serious issues. Many researchers have tried to utilize the battery power by designing the energy efficient time synchronization algorithm to reduce energy consumption levels and shorten the time required for synchronization. Firstly in (2001), [4] proposed the idea of time synchronization algorithm by taking time and energy challenge into account and proposed the post facto synchronization technique in which all the nodes are in sleep mode. When event occurs nodes reconcile their clocks and synchronization is achieved quickly, thereby preventing them from wasting energy on unnecessary synchronization messages. In (2002), [3] presented RBS, in which nodes send reference beacons to their neighbors using physical-layer broadcasts. It relies on broadcasting messages among a set of receivers to synchronize them with each other. In the wireless medium, broadcasted messages will arrive at multiple receivers at approximately the same time.

In (2003), [5] presented Timing-sync Protocol for Sensor Networks (TPSN) that aims at providing network-wide time synchronization in a sensor network. In this algorithm, 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. Finally, all nodes in the network synchronize their clocks to a reference node. They argue that TPSN roughly gives a 2x better performance as compared to RBS and verify this by implementing RBS on motes. They show with the increase in number of nodes being deployed, making TPSN completely scalable. In (2007), [2] proposed energy aware hybrid approach. In this TPSN and RBS techniques are used and one new hybrid approach is proposed which is energy efficient. The hybrid synchronization algorithm was designed to switch between TPSN and the RBS. These two algorithms allow all the sensors in a network to synchronize themselves within a few microseconds of each other, while at the same time using the least amount of energy possible. The savings in energy varies upon the density of the sensors as well as the reception-to-transmission ratio of energy usage. In (2010), [1] proposed Self-adaptive hierarchical time synchronization algorithm is a one-way time synchronization algorithm based on cluster-layer topology, which is different from those algorithms that achieve time synchronization through the round-trip message exchange mechanism. And its significant advantage is to avoid the imprecision caused by round-trip message exchange in WSN. Theoretical analysis and simulation results show that the proposed algorithm is able to save the network energy consumption, reduce synchronization time cost and improve its accuracy. All the techniques have some merits and demerits.

III. PROPOSED ALGORITHM

Enhanced Time Synchronization Algorithm (ETSA) has been proposed in this paper in which we calculate synchronization time and energy dissipation and compare with RBS algorithm.
Proposed algorithm divided into two parts

1. Synchronization time is calculated using cpu cycles.
2. Energy is calculated by using dist*dist with specific packet size.

3.1 Proposed Algorithm Steps:

Step1: Node with the smallest Id elected as the reference node.

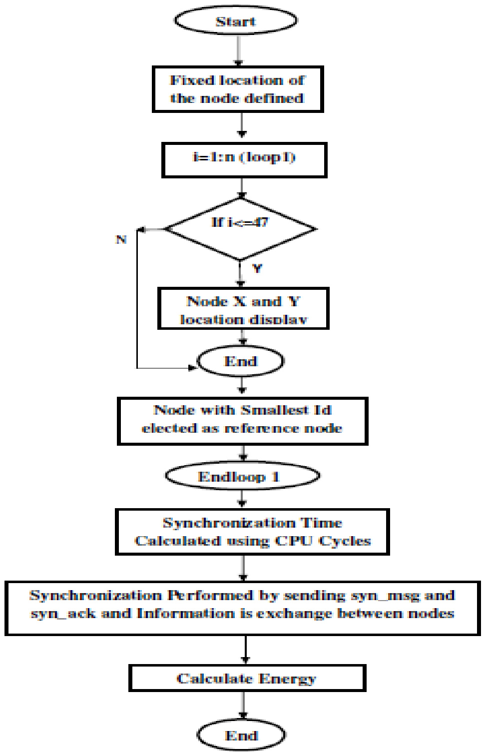
Step2: Reference Node acts as transmitter and sends Syn_msg to node 2 acting as receiver.

Step3: Receiver sends syn_ack to transmitter confirming synchronization.

Step4: Information is exchanged between the nodes.

Step5: Sync time is calculated between the nodes.

Step6: After the two nodes are synchronized. Receiver node in turn becomes transmitter for the node with next id number acting as receiver.



The flow chart given above shows various steps of algorithm ETSA

The process will continue until all the nodes in entire network are synchronized. Thus synchronizing time is calculated using CPU cycles. In propose algorithm, if n nodes are there then each node gets synchronized 2 times. Whereas in case of RBS technique one node synchronizes (n-1) number of times and thus synchronization time in the case of RBS technique is more than the proposed algorithm as the steps included in RBS are more as compared to proposed algorithm.

IV. SIMULATION RESULTS

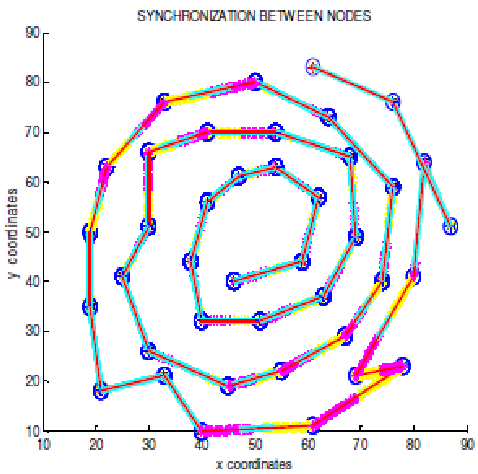


Fig 1: Proposed algorithm

Energy is also calculated using the energy formula. Thus it is seen from simulation results that proposed algorithm considerably reduces synchronization time and energy consumption. Thus ETSA algorithm is energy efficient. The computational study is carried on a PC with an Intel® Core™ i3-2350M Processor 2.30 GHz with MATLAB 2007b software.

Table 1: Used parameter details

PARAMETERS	VALUES
Network area	100*100m^2
No of nodes	10, 20, 30, 40
Initial energy	0.5J
Etx	5nJ/bit
Efs	10pJ/bits/m^2
Packet size	4000 bits

The simulation parameters used in the experiment is shown in Table I. Fixed deployment of nodes has been taken in coordinates x=100, y=100. This section compares the proposed algorithm ETSA with RBS synchronization algorithm. The performance evaluation is calculated in terms of Synchronizing time. .

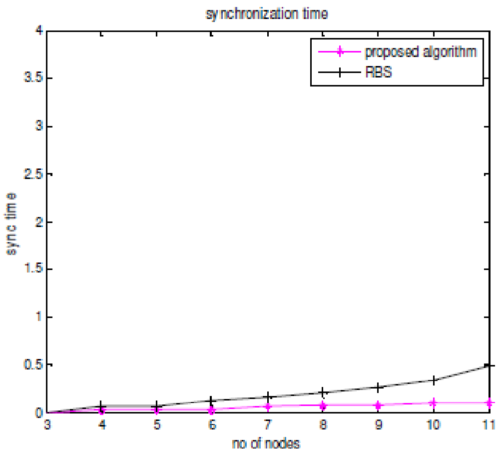


Fig 2: Comparison between RBS and proposed algorithm with 10 no of nodes

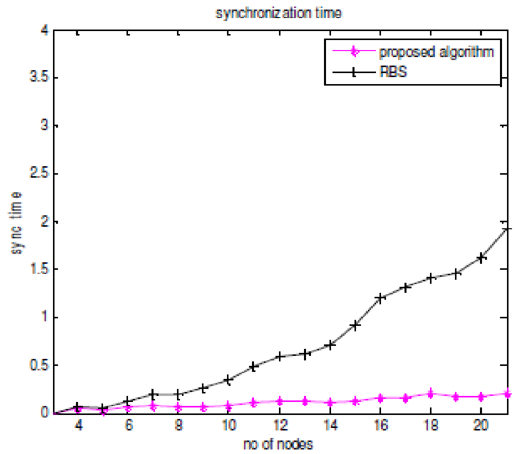


Fig 3: Comparison between RBS and proposed algorithm with 20 no of nodes

Simulation results show that RBS technique takes more time over the proposed algorithm for synchronizing the entire network. Fig 2 to Fig 5 shows the sync delay in proposed and RBS technique. Fig 2 and Fig 3 above show Synchronization Time Comparison between RBS and proposed algorithm ETSA. Synchronizing time can be seen from Table 2 as 143.2ms & 44ms for 10 nodes and 639.6ms & 96.8ms for 20 nodes for RBS and ETSA respectively. Results clearly show ETSA to be a better approach than RBS.

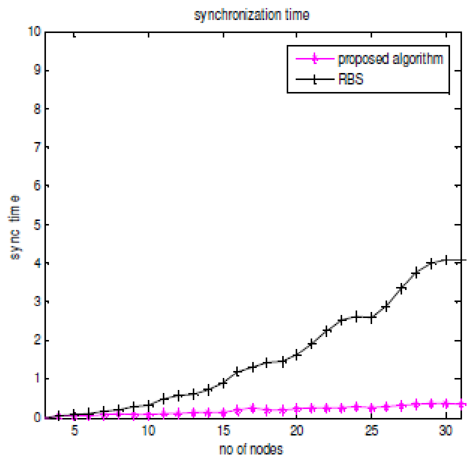


Fig 4: Comparison between RBS and proposed algorithm with 30 no of nodes

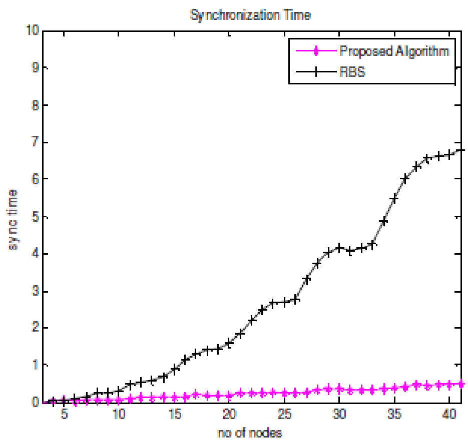


Fig 5: Comparison between RBS and proposed algorithm with 40 no of nodes

Fig 4 and Fig 5 above show Synchronization Time Comparison between RBS and proposed algorithm ETSA. Synchronizing time can be seen from Table 2 as 1508.2 ms & 170.6 ms for 30 nodes and 2472ms & 231ms for 40 nodes for RBS and ETSA respectively. Results clearly show ETSA to be a better approach than

RBS. Table 2 shows the comparison between the RBS and ETSA in terms of synchronization time in fixed deployment scenario in tabular form. From simulation results it is shown that RBS technique takes more time over the proposed algorithm for synchronizing the entire network.

Table 2: Synchronization time comparison between RBS and Proposed Algorithm

Number of Nodes	Synchronization time in RBS Algorithm (ms)	Synchronization time in Proposed Algorithm (ms)
Nodes 10	143.2	44.0
Nodes 20	639.6	98.8
Nodes 30	1508.2	170.6
Nodes 40	2472.0	231.0

Table 3: Comparison of Energy remaining in network between RBS and Proposed Algorithm. The simulations have been carried out in MATLAB

No of Nodes	RBS Algorithm	Proposed Algorithm
	Remaining energy in Network (mJ)	Remaining energy in Network (mJ)
10	491.9	498.2
20	463.9	496.2
30	415.9	494.2
40	347.9	492.2

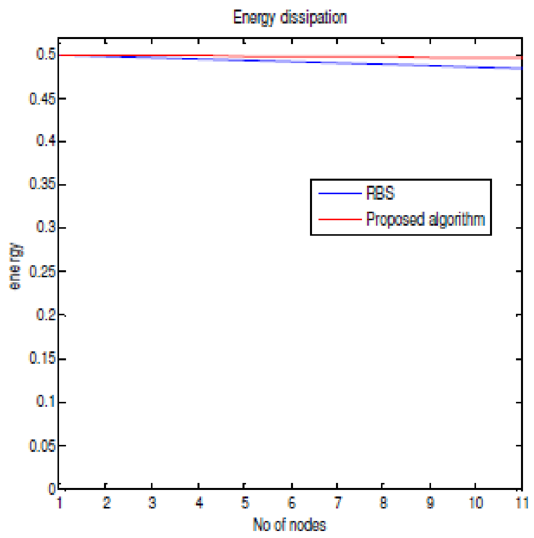


Fig 6: Energy Consumption comparison with 10 numbers of nodes

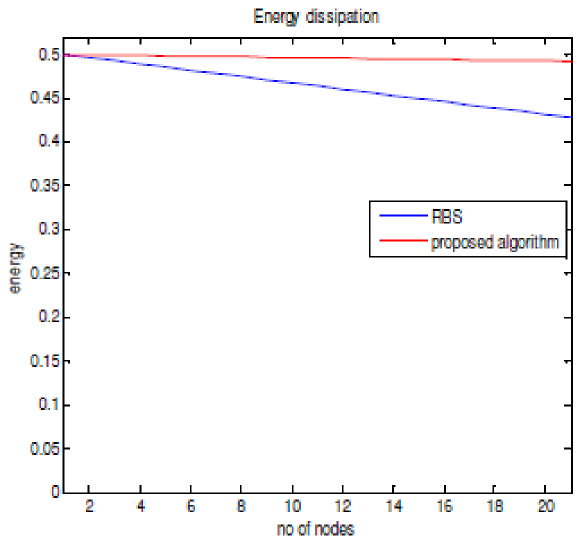


Fig 7: Energy Consumption comparison with 20 numbers of nodes

Fig 6 and Fig 7 above show comparison of Energy Consumption between RBS and ETSA with 10 & 20 no of nodes. Energy consumption can be seen from Table 3. Energy remaining in the network for RBS algorithm & proposed algorithm is 491.9mJ & 498.2 mJ respectively for 10 nodes, 463.9mJ & 496.2 mJ respectively for 20 nodes. Results clearly show ETSA to be a energy efficient approach.

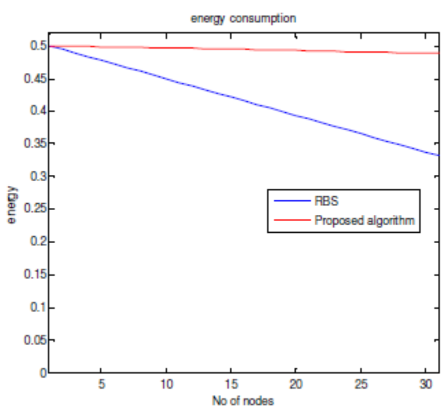


Fig 8: Energy Consumption comparison with 30 numbers of nodes

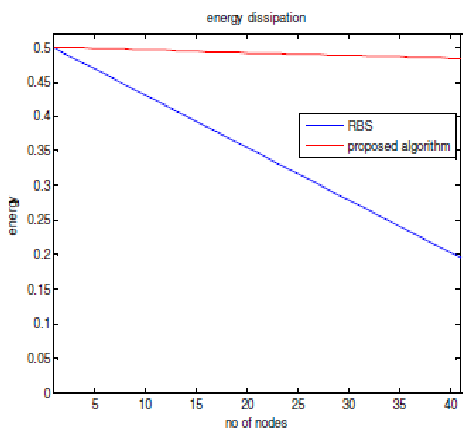


Fig 9: Energy Consumption comparison with 40 numbers of nodes

Fig 8 and Fig 9 above show comparison of Energy Consumption between RBS and ETSA with 30 & 40 no of nodes. Energy consumption can be seen from Table 3. Energy remaining in the network for RBS algorithm & proposed algorithm is 415.9mJ & 494.2 mJ respectively for 30 nodes, 347.9mJ & 492.2 mJ respectively for 40 nodes. Results clearly show ETSA to be a energy efficient approach.

V. CONCLUSION

An improved Time synchronization algorithm which is energy efficient and takes less time to synchronize the entire network has been proposed for fixed deployment of nodes in wireless sensor network. The simulations have been carried out for 10, 20, 30, and 40 numbers of nodes. From simulation results it is seen that our approach takes less time to synchronize the entire network than the RBS Technique. With the increase in number of nodes synchronization time increase slightly in proposed algorithm whereas increase in sync time in the RBS algorithm is very rapid. Similarly simulation analysis shows that energy consumption with proposed algorithm is much less as compared to RBS scheme. In future we plan to enhance the proposed technique by implementing it on variety of networks especially large scale networks to explore that whether other requirements like scalability etc are met.

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