http://ansinet.com/itj

ITJ

ISSN 1812-5638

# INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (23): 7844-7848, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.7844.7848


# A Kind of Low Energy Consumption Time Synchronization Algorithm for Wireless Sensor Network

[1]Shaoxing Wu and [2]Fangchong Su
[1]Computer Network Center, Nanyang Institute of Technology
[2]Recruitment and Employment Office, Nanyang Institute of Technology, 473004, Nanyang, China

**Abstract:** Low energy consumption is one of the important technical requirements of the time synchronization algorithm of wireless sensor network. In order to reduce energy consumption, a kind of low energy consumption time synchronization algorithm for wireless sensor network is proposed as LECTS. This algorithm is based on the mechanism of TPSN algorithm, improves in two phases at the same time to reduce energy consumption. In the level discovery phase, it uses the distance between nodes to limit the broadcast of some nodes to reduce the packets sending; in the synchronization phase, combining unidirectional broadcast and two-way message exchange mechanism, can also reduce the packet's delivery. The simulation results show that this algorithm greatly reduces the energy consumption of time synchronization of wireless sensor networks and node density is greater, the energy saving is more remarkable.

**Key words:** Wireless sensor networks, time synchronization, energy consumption, two-way message exchange, broadcast synchronization

## INTRODUCTION

Time synchronization is a key technology of sensor network system to work together (Sivrikaya and Yener, 2004), precise time synchronization is the base to realize the sensor network protocol itself, data fusion, TDMA scheduling, sleep coordination, positioning, etc.
Through the tireless efforts of the researchers at home and abroad to undertake in-depth research, they put forward a lot of kinds of time synchronization algorithm (Elson *et al*., 2002). These algorithms widely used two basic methods such as broadcast method and pairwise synchronization method. RBS (Elson *et al*., 2002), DMTS (Ping, 2003), FTSP (Maroti *et al*., 2004) are the typical representatives of the broadcast methods; TPSN (Ganeriwal *et al*., 2003), Tiny-sync/Mini-sync (Yoon *et al*., 2007) are the typical representatives of the pairwise synchronization method. The researchers introduce the clustering mechanism of ad hoc network to improve the synchronization accuracy (Kim *et al*., 2006). In recent years, the firefly's technology and coordination technology are put forward (Xu *et al*., 2008), these solve the problems of synchronization error accumulation with jump distance and poor scalability existing, existing in wireless sensor network time synchronization protocol which cannot overcome. Firefly technology and coordination technology are still in the phase of theoretical research, with the development and further research of wireless sensor network, which could become the mainstream technology of future wireless sensor network time synchronization.

Due to the application characteristics of wireless sensor network and simplicity of nodes, the synchronization algorithm not only requires high synchronization accuracy, but also needs the low network overhead. For wireless sensor network energy problems, the researchers at home and abroad will consider how to reduce energy consumption in the aspects of routing protocol design, positioning algorithm, time synchronization algorithm and so on. Classic time synchronization algorithm TPSN is composed of two phases: layer discovery and synchronization phase. TPSN adopts two-way message exchange synchronization mechanism, it can obtain higher precision (the synchronization accuracy of TPSN algorithm is twice to the RBS algorithm). But as a result each slave node is group interaction with the master node, the energy cost is considerable.

Aiming to TPSN topology, many researchers brought forward various improvement methods to reduce energy consumption, but most of the methods are improved in the protocol's synchronous phase. In recent years researchers have proposed combining broadcast method and pairwise synchronization method in time synchronization algorithm of wireless sensor network, these algorithms combine the advantages of broadcast

**Corresponding Author:** Shaoxing Wu, Computer Network Center, Nanyang Institute of Technology, Henan, China

method and pairwise synchronization method, that is, which can obtain the high accuracy of time synchronization and effectively reduce the synchronization packet overhead. Xiao, L. from Northwestern Polytechnical University network technology institute proposed STSP algorithm (Xiao *et al*., 2008) which combines broadcast method and pairwise synchronization method, this algorithm accuracy is obviously lower than TPSN algorithm, but a lot of packet switching is saved to reduce the energy consumption.

The algorithm is not improved in layer discovery stage, which needs to constantly broadcast actually in layer discovery stages and consumes a lot of energy, the energy consumed in this stage is not less than that in synchronous phase, even more energy, so this cannot be ignored (Kang *et al*., 2005). This study proposes a LECTS (Low Energy Consumption Time Synchronization) algorithm, in layer discovery phase node distance is used to limit the broadcast of part of nodes and reduce the sending of broadcast packets; at the same time in the synchronous phase, the distance $d_{i,\ i+1}$ between the nodes is introduced based on the STSP algorithm. The root node selects the nearest lower nodes as response nodes, which can reduce the transmission delay between the root node and response nodes, so it can reduce the energy consumption for information exchange between the root node and response nodes and improve the synchronization accuracy.

## LECTS ALGORITHM

Assumes that the wireless sensor network coverage is a region with side length a, a large number of nodes is uniformly distributed in the area, the total number of nodes is N, the distances between adjacent nodes are known. The broadcast distance of each sensor node is R. The sink node is located in the network center position.

**Layer discovery phase:** First of all, a grade broadcasting limited distance is set as d. $d_{0,1}$ represents the distance between hierarchical level 0 and hierarchical level 1, $d_{1,2}$ represents the distance between hierarchical level 1 and hierarchical level 2, $d_{i,i+1}$ represents the distance between hierarchical level i and hierarchical level i+1. If the grade of sink node is 0, sink node sends a preparation time synchronization packet; the message packet contains the node id and the grade number 0 of this node. The node that received this information packet sets its own grade at 1 and according to the distance to the sink node to determine whether to do grade broadcast. If $d_{0,1}$>d, node will do grade broadcast; otherwise will not broadcast. The

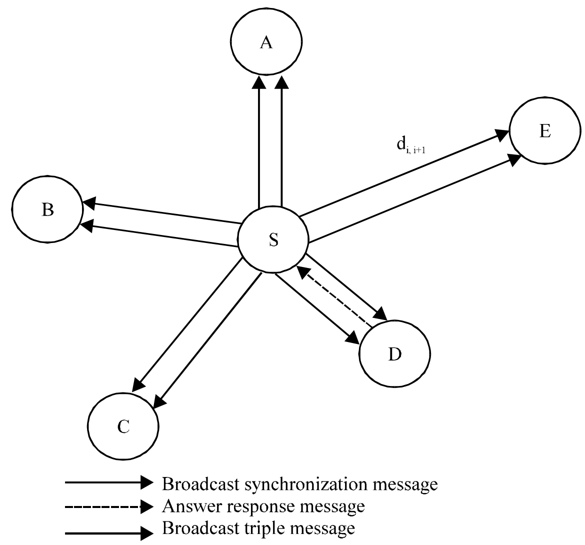


Fig.1: Information exchange diagram

node without grade receives level 1 broadcast information and sets itself as a level 2, similarly the node can do grade broadcast if it fulfills $d_{1,2}$>d. In the entire network, only the nodes if that fulfill $d_{i,\ i+1}$>d can do broadcast, which repeat the process until the network completes the grade's establishment.

**Synchronous phase:** After grade establishment completes, the sink node sends synchronization messages, can synchronize all the nodes in a sensor network layer by layer, so as to achieve the entire network synchronization. In this phase, the sink node broadcasts synchronization packets and chooses the node with nearest distance to $d_{0,1}$ as a response node. As shown in Fig. 1, node S chooses the node D with nearest distance to $d_{i,\ i+1}$ as a response node. All of the nodes record the local time after they receive the synchronization information from S, but only node D answers a reply message to node S after it delays a random time. After node S receives a reply packet, it will broadcast the synchronization packets. The synchronization mechanism through two-way message exchange is illustrated in expression (1), which can calculate the time migration δ and propagation delay α (Yu *et al*., 2009) between S and node D.

$$\begin{cases} \delta = \dfrac{(T_2 - T_1) - (T_4 - T_5)}{2} \\ \alpha = \dfrac{(T_2 - T_1) - (T_4 - T_3)}{2} \end{cases} \tag{1}$$

Time offset d, propagation delay a and time $T_2$ that node D receives synchronized message packet form a

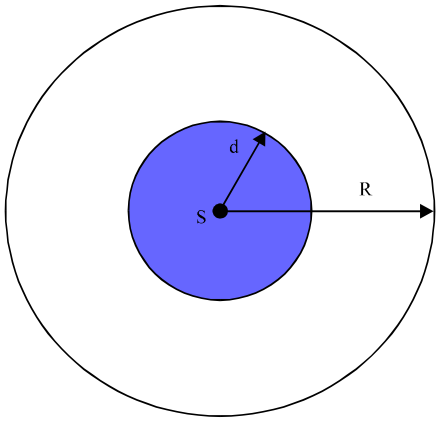


Fig. 2: Limited broadcast area

triple packet together, then node S broadcasts a triple packet to the lower nodes. Response node D receives the triple packet, according to the time offset d and propagation delay n to adjust its time, other nodes compare the accepted $T_2$ and its accepted synchronization packet time $T'_2$ to achieve the time difference $\Delta T = T_2 - T'_2$ and adjust its time difference as $T = t+\Delta T+\delta$, (in the expression t is the current local time of this node). Thus a sink node achieves the synchronization with layer grade 1 nodes, repeating the upper synchronization process can realize the entire network synchronization.

**Analysis of information packets:** The entire network synchronization needs to experience layer discovery and synchronization two stages. In layer discovery phase the broadcasting from part of nodes are limited, a broadcast area is shown in Fig. 2, S is the center node, R is the broadcast distance, d is the limited distance for grades, S is used to do grade broadcast. The nodes in the shaded area are restricted to do grade broadcast, that is, the node is limited to broadcast if its distance with center node is less than d, the circular area is regarded as the broadcast nodes in the next layer. If the shaded part area is $\pi d^2$, then the ring area is $\pi R^2-\pi d^2$, the whole area of a sensor network is $a^2$, the total node number is N.

If the nodes distribute uniformly, the density of nodes is defined as the node number at unit area, if it is remarked as ρ, then :

$$\rho = \frac{N}{a^2} \tag{2}$$

The node number at shadow area is $n_d$:

$$n_d = \frac{\pi d^2 N}{a^2} = \pi d^2 \rho \tag{3}$$

Then the node number of ring area is remarked as n, then:

$$n = \frac{\pi (R^2 - d^2)}{a^2} = \pi (R^2 - d^2)\rho \tag{4}$$

In this phase, the number n (d, ρ) of message packets needed to be broadcast equals the node number. That is:

$$n\ (d, \rho) = n = \pi\ (R^2 - d^2)\ \rho \tag{5}$$

In synchronous phase traditional TPSN each node will reply to a response information,if it receives a synchronization information, this improved algorithm selects the nearest node as a response node, other nodes do not send response node. If the node density is n ρ, this can save ρ-1 response messages. While in the traditional broadcast packets the packet number needed to be broadcast is 2N, the number of broadcast packets that the algorithm needs is twice than that in the discovery phase, that is 2N (d, ρ).

But there are some isolated nodes also need to broadcast packets, assuming that isolated node number is n, if the value of d is bigger, the isolated nodes become more and the density is greater. The number of isolated nodes is the increasing function about d and node density ρ, which is marked as $n_0$ (d, ρ), that is, the broadcast packets number of isolated nodes.

The number of broadcast packets of this algorithm is total = 3nd (d, ρ)+n (d, ρ).

**The determination of optimal broadcast limited distance d:** Optimal broadcast limited distance d refers to d value while the number of broadcast message packets is the minimum in the synchronization process. The following expression is solving partial derivative of total to d and the partial derivative is ordered to equal to zero. That is:

$$\frac{\partial(\text{total})}{\partial d} = -6\pi\rho . d + \frac{\partial [n_0 (d, \rho)]}{\partial d} = 0 \tag{6}$$

Because the expression $n_0$ (d, ρ) is difficult to derived, so this paper through a lot of experiments to determine the relationship between d and node density n ρ and selects the optimal broadcast limited distance d.

## SIMULATION EXPERIMENTS AND ANALYSIS

The simulation experiments are preceded in NS-2 platform, the sensor network is set in $60\times60m^2$ area, the total number of nodes is N which are uniformly distributed in this area, the broadcast distance R is 10m. According to

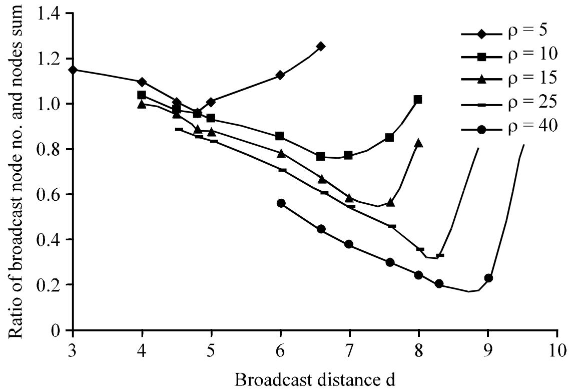


Fig. 3: Relationship between d and the ratio of broadcast node number to node sum under different density

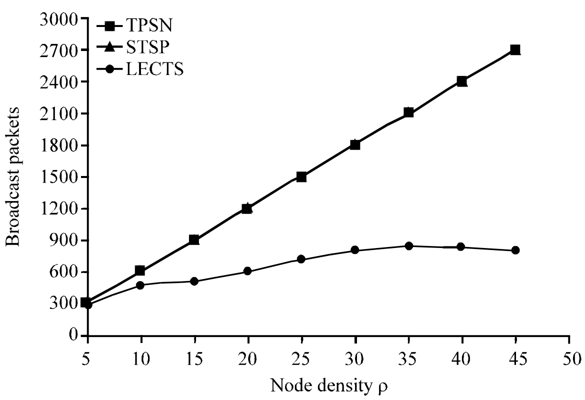


Fig.4: Relationship between broadcast packets and the node density ρ

the definition, node density ρ can be changed by the total number N of nodes. This study adopts the approaching method step by step to get the optimal value of d, under the condition of a certain network node density ρ, to seek for the d value with needed minimum broadcast packets to achieve all nodes synchronization; then changes network node density ρ by changing N value, so as to find the optimum broadcast limited distance d value under different network node density ρ. Figure 4 is the relationship diagram between broadcasting limited distance d and the ratio of node broadcast number to node sum under different density ρ, this can be seen from the diagram, when d is greater than the optimal value, isolated nodes increase rapidly, which verifies that the isolated node $n_0$ is the increasing function about d and node density ρ.

According to Fig. 3, the relationship between node density ρ and the optimal broadcast limited distance d can be obtained.

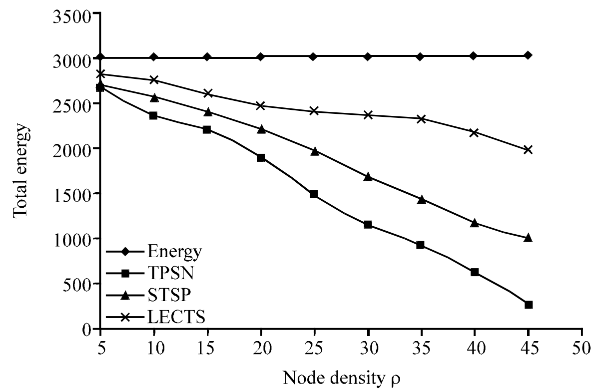


Fig.5: Relationship between total residual energy and the node density ρ

In this study, the simulation experiments of TPSN algorithm, STSP algorithm and LECTS algorithm are conducted and they are compared in three aspects of number of synchronous broadcasting packets, energy consumption and synchronization accuracy.

Figure 4 shows in the optimal broadcast limited distance, the relationship between number of broadcast packets and the node density ρ. It can be seen that the number of broadcast packets of TPSN algorithm and STSP algorithm is same and with the increase of the node density ρ, the number of broadcast packets is obviously smaller than the other two algorithms. This shows that in the high density network, the energy saving effect of LECTS algorithm is more obvious.

Figure 5 shows in the optimal broadcast limited distance d, the relationship between the total residual energy and the node density ρ after a synchronization completion. It is shown from the diagram, with the increase of density, the difference between residual energy and other two algorithms becomes big. The algorithm is better than STSP algorithm with greater energy saving, which greatly extends the life of the network.

Figure 6 shows in the optimal broadcast limited distance d, the relationship between synchronization accuracy and the number of network grade. The synchronization precision is higher than STSP algorithm, slightly lower than TPSN algorithm. This is due to the synchronous phase adopts a combination of one-way broadcast with a two-way exchange synchronization, the algorithm only selects a node to do response and the other nodes uses the time deviation between this node and base station and transmission delay for synchronization, thus the precision is reduced. While LECTS algorithm selects response nodes, it always

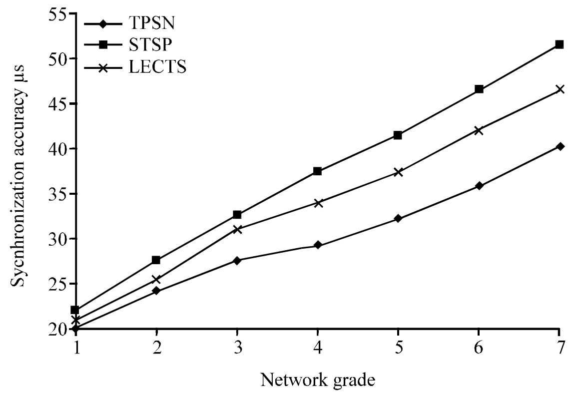


Fig. 6: Relationship between synchronization accuracy and the number of network grade

selects the nearest nodes to do response and STSP algorithm is a random selection, LECTS algorithm reduces the transmission delay between the root node and response nodes, so the accuracy is slightly higher than STSP algorithm.

## CONCLUSION

Time synchronization as a key technology of the sensor network, the requirement of its accuracy is not very high for most of the sensor network applications, so it is more important how to save energy. LECTS algorithm proposed in this paper, in the hierarchical discovery phase uses the distance between the nodes to limit part of nodes broadcast and reduce the packet delivery; in the synchronous phase, the combination with one-way broadcast and two-way message switching synchronization mechanism also reduces the delivery of packets. Compared with TPSN, this algorithm greatly saves the broadcast packets, information exchange cost and energy consumption under satisfying certain accuracy. The nodes in the simulation experiment of this paper are evenly distributed as the premise, which are not done the simulation in the environment of random distribution; therefore the later study work will be conducted in random environment and considering the influence of other factors.

## REFERENCES

Elson, J., L. Girod and D. Estrin, 2002. Fine-grained network time synchronization using reference broadcasts. ACM SIGOPS Operat. Syst. Rev., 36: 147-163.

Ganeriwal, S., R. Kumar and M.B. Srivastava, 2003. Timing-sync protocol for sensor networks. Proceedings of the 1st International Conference on Embedded Networked Sensor Systems, November 5-7, 2003, New York, USA., pp: 138-149.

Kang, G.L., F.B. Wang and W.J. Duan, 2005. Survey on time synchronization in wireless sensor networks. Comput. Autom. Meas. Control 13: 1021-1023.

Kim, H., D. Kim and S.E. Yoo, 2006. Cluster based hierarchical time synchronization for multi-hop wireless sensor networks. Proceedings of the 20th International Conference on Advanced Information Networking and Applications, Volume: 2, April 18-20, 2006, Vienna, Austria,.

Maroti, M., B. Kusy, G. Simon and A. Ledeczi, 2004. The flooding time synchronization protocol. Proceedings of the 2nd International Conference on Embedded Networked Sensor Systems, November 3-5, 2004, Baltimore, MD., USA., pp: 39-49.

Ping, S., 2003. Delay measurement time synchronization for wireless sensor networks. Intel Research Berkeley Lab, BerKeley, June, 2003. http://intel-research.net/Publications/Berkeley/081120031327_137.pdf.

Sivrikaya, F. and B. Yener, 2004. Time synchronization in sensor networks: A survey. IEEE Network, 18: 45-50.

Xiao, L., L. Cheng and F. Wang, 2008. A low cost time synchronization algorithm for wireless sensor networks. J. Comput. Res. Dev., 45: 126-130.

Xu, C.N., Y.J. Xu and X.W. Li, 2008. New time synchronization techniques for wireless sensor networks. J. Comput. Res. Dev., 45: 138-145.

Yoon, S., C. Veerarittiphan and M.L. Sichitiu, 2007. Tiny-sync: Tight time synchronization for wireless sensor networks. ACM Trans. Sens. Networks, Vol. 3. 10.1145/1240226.1240228

Yu, J.A., X.H. Chen and W.D. Wang, 2009. A low overhead time synchronization algorithm for wireless sensor networks. Comput. Simul., 26: 124-129.