The Comparison of RBS and TDP for the Sensor Networks Synchronization

Hyojung Lee*, Byungchul Kim**, and Youngmi Kwon***

Abstract: Sensor networks have emerged as an interesting and important research area in the last few years. These networks require that time be synchronized more precisely than in traditional Internet applications. In this paper, we compared and analyzed the performance of the RBS and TDP mechanisms in the view of the number of generated messages and the synchronization accuracy. The reason that we chose the RBS ad the TDP mechanism to be compared is because the RBS is an innovative method to achieve the high accurate synchronization. And TDP is a new method taking over the NTP method which has been used widely in the Internet.

We simulated the performance of two methods assuming the IEEE 802.11 CSMA/CA MAC. As for the number of nodes in the sensor networks, two situations of 25 (for the small size network) and 100 (for the large size network) nodes are used. In the aspect of the number of messages generated for the synchronization, TDP is far better than RBS. But, the synchronization accuracy of RBS is far higher than that of TDP. We can conclude that in a small size sensor networks requiring very high accuracy, such as an application of very high speed objects tracking in a confined space, the RBS is more proper than TDP even though the RBS may generate more traffic than TDP. But, in a wide range sensor networks with a large number of nodes, TDP is more realistic though the accuracy is somewhat worse than RBS because RBS may make so many synchronization messages, and then consume more energies at each node. So, two mechanisms may be used selectively according to the required environments, without saying that the one method is always better than the other.

Keywords: sensor network, RBS, TDP, time synchronization

1. Introduction

Recent advances in miniaturization and low-cost, low-power design have led to active research in large-scale networks of small, wireless, low-power sensors and actuators [1]. These networks require that time be synchronized more precisely than in traditional Internet applications. For example, precise time synchronization among the sensor nodes is needed to estimate the movement of the fast fire event tracking or to suppress redundant messages by recognizing duplicate detections of the same event by different sensors [2].

Time synchronization problem has been investigated thoroughly in Internet and LANs. Several technologies such as GPS, radio ranging etc have been used to provide global synchronization in networks. Complex protocols such as NTP [3] have been developed so that it has kept the Internet's clocks ticking in phase. However, the time synchronization requirements differ drastically in the context of sensor networks. In general, sensor networks are dense group, consisting of a large number of sensor nodes. And it should consider the energy consumption. To operate in such a large network densities, we need the time synchronization algorithm to be scalable with the number of nodes being deployed [6-8]. Also, energy efficiency is a major concern in these networks due to the limited battery capacity of the sensor nodes. As the synchronization mechanisms for the sensor networks, the RBS and the TDP have been proposed [4-5]. The RBS is thoroughly different mechanism from NTP style. And the TDP is much similar with the major concept from the NTP method.

In this paper, we compared and analyzed the performance of the RBS and TDP mechanisms on the basis of variable factors in the wireless sensor network. Then we proposed the adaptability of the RBS and TDP mechanisms in different wireless sensor network environments.

Section 2 describes the RBS and TDP mechanisms. Section 3 details the simulation conditions and results. The conclusion of this paper is presented in Section 4.

2. Synchronization mechanisms

The time synchronization research which is very critical in sensor network can be categorized into 3 mechanisms. As three types of time synchronization mechanisms, there

Manuscript received September 30, 2005; accepted November 8, 2005.
* Department of Information and Communications Engineering, Chungnam National University,Daejeon, 305-764, Korea (hjlee@comnet.cnu.ac.kr)
** Department of Information and Communications Engineering, Chungnam National University, Daejeon, Korea (byckim@cnu.ac.kr)
*** **Corresponding Author;** Department of Information and Communications Engineering, Chungnam National University, Daejeon, Korea (ymkwon@cnu.ac.kr)

ISSN 1738-8899 ⓒ 2005 KIPS

are the NTP which relies on fixed time servers to synchronize the network [3], the RBS which translate time throughout the network [4] and the TDP which self-organizes to synchronize the network [5].

NTP (Network Time Protocol) which synchronizes the timeserver clocks distributed in the global network is a clock synchronization protocol based on TCP widely used in the Internet [3]. For years, protocols such as NTP have kept the clocks of networked systems in perfect synchronization. However because this new class of sensor networks has a large density of nodes and very limited energy resource at every node, we didn't consider the NTP itself as a candidate in sensor network synchronization. Instead of NTP itself, because the TDP is very similar with NTP in the major concept, we selected the RBS and the TDP as representative methods in sensor networks.

2.1 RBS

RBS mechanism is very innovatively accuracy-purpose synchronization method. Traditional synchronization methods contain many variable error factors in every steps of making synchronization message, being buffered to transmission queue, being scheduled to be transmitted to physical medium, transmission, being buffering in the receiving node, and process delays in the receiving node. So the measured and estimated time clock to correct may include many environment-dependent erroneous factors. The RBS mechanism eliminates many error factors by using single physical-layer broadcast channel.

Reference nodes periodically send messages to their neighbors using the network's physical-layer broadcast. A reference broadcast does not contain explicit timestamp information. Its purpose is just to trigger the recording of relative-time information for all the nodes within a transmission range. A transmitter broadcasts reference packets to n receivers ($n \geq 2$). Each receiver records the time that the reference message was received, according to its local clock. Then all the receivers exchange their observations each other. Each receiver makes its time-correction value by comparing and calculating all the other nodes' arrival time with its own recording time. Fig. 1 shows the point of the accuracy in RBS mechanism. In the traditional mechanism, the critical path including error factors was from making sending message (sender side) to finishing the received message (receiving side). But, in the RBS mechanism, the error-prone factor is included only from the time to receive the common-channel broadcast message to the time to recognize/process the received reference message (only at the receiving side).

In [4, 6], the RBS mechanism is further extended to multi-hop using "multi-hop clock conversion." Multi-hop clock conversion is designed to synchronize more than two transmission range wide networks. To provide multi-hop synchronization, *transmission nodes* are proposed to receive two or more reference broadcasts from different transmitters and to give translation information to each different transmission domain. This translation information is used to translate the time between different broadcast domains, thus synchronizes the wide-span sensor networks.

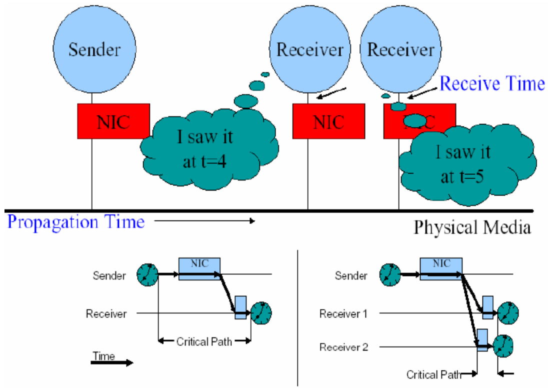

Fig. 1. RBS

2.2 TDP

TDP (Time-Diffusion Synchronization Protocol) does not depend on specialized time servers. It automatically organizes and determines the master nodes as the temporary time-servers in a transmission range. The merit of this TDP method is that it considers the energy consumption status of each node in the master-election process in sensor networks.

The TDP architecture consists of many algorithms and procedures as illustrated in Fig.. 2. The TDP automatically self-conFig.s by electing master nodes through the *election/reelection of master/diffused leader node procedure (ERP)* to synchronize the sensor network. After the procedure *ERP*, the elected master nodes start the *peer evaluation procedure (PEP)* while others do nothing. The procedure *PEP* helps to keep false nodes from becoming neither a master node nor a diffused leader node. After procedure *PEP*, the elected master nodes (denoted by W in Fig. 2) start the *time diffusion procedure (TP)*, where they diffuse the timing information messages at every δ seconds for a duration of τ seconds.

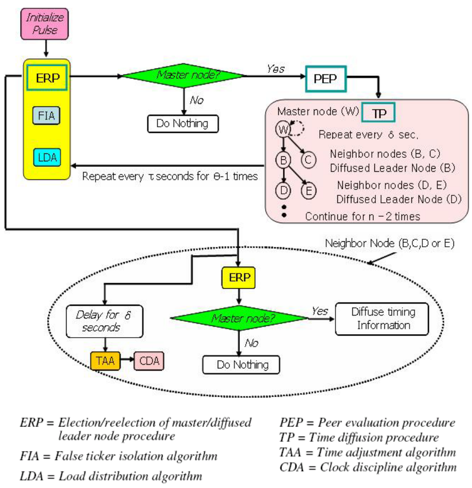

Fig. 2. TDP architecture

The inner process of synchronization after auto-selecting of master node is very similar to NTP. For the large-range global synchronization, the stratum is defined and used to span the synchronization range. In Fig. 2, the first stratum is formed with node W, B and C. And the second stratum is formed with node B, D and E.

3. Simulation and Results

3.1 Simulation environments

The Matlab 6.5 is used in simulation. For the MAC layer, the IEEE 802.11 CSMA/CA MAC is assumed. As for the number of sensor nodes, 25 (for the small size network) and 100 (for the large size network) nodes are used to get the synchronization error range. In TDP simulation, 25 sensor nodes are assumed to build two stratums, and 100 sensor nodes are assumed to build three stratums. Fig. 3 shows the 25 node configuration with 6 reference nodes. Reference nodes are used to trigger the synchronization process. In this Fig. the stratum is not shown explicitly, but the stratum level is increased as going into the center of the Fig.. In RBS simulation, up to the 25 nodes, the single hop RBS is assumed and up to the 100 nodes, the multi-hop RBS is assumed. The distance between each node is assumed to be a 10-dB reduction point. The delay in transmission time is assumed to include White Gaussian Noise and to follow a normal distribution with a confidence interval of 95 %.

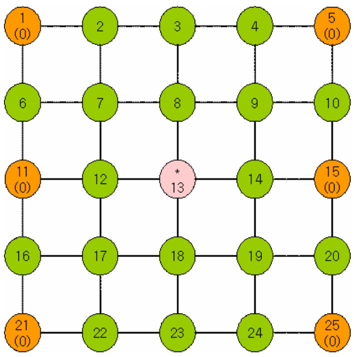

Fig. 3. 25 nodes grid

3.2 Results and Analysis

Fig. 4~Fig. 7 represent the results of the two synchronization mechanisms in terms of the error range and the table 1 shows the comparison results in terms of the number of messages generated.

As shown in table 1, the more the number of nodes which wish to synchronize, the more the number of messages generated in RBS, incredibly than TDP. The necessary time in synchronization of RBS would take longer than that of TDP and also the energy consumption would be higher. When the number of nodes exceeds 25, the number of generated messages in RBS is almost over 10 times of TDP, the RBS is not realistic synchronization method in large sensor networks with more than 25 sensor nodes.

But as we can see in Fig. 4 and Fig. 5, the accuracy of RBS mechanism is far better than TDP. As increasing the number of reference nodes, the overall accuracy of two schemes is enhanced. But at any case, the accuracy of RBS is better than that of TDP.

Fig. 6 and Fig. 7 show that accuracy of the worst case nodes in the environments of 25 sensor nodes and 100 sensor nodes in both schemes of RBS and TDP. In both environments, the worst case node in TDP method has worse accuracy results than RBS. TDP shows almost two times error values of RBS in some cases. In Fig. 7, the synchronization error range of RBS is about |2.9| micro sec, while that of TDP is about |4.8| micro sec except for the highest error. In conclusion, RBS has relatively better performance in terms of the synchronization error, generally than TDP.

In the view of the number of synchronization messages, the TDP is superior to the RBS. But, if any network requires the accurate error range and it consists of only the small number of nodes, the RBS mechanism is more acceptable than the TDP mechanism.

Table 1. A comparative table of the number of synchronization messages

	The number of synchronization messages			
The number of nodes	10	15	20	25
TDP	60	90	120	150
RBS	190	435	780	1225

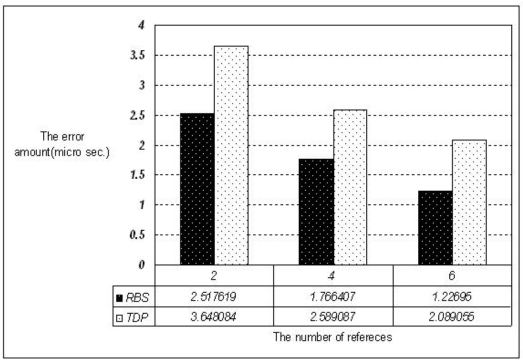

Fig. 4. The amount of errors in RBS and TDP (25 nodes)

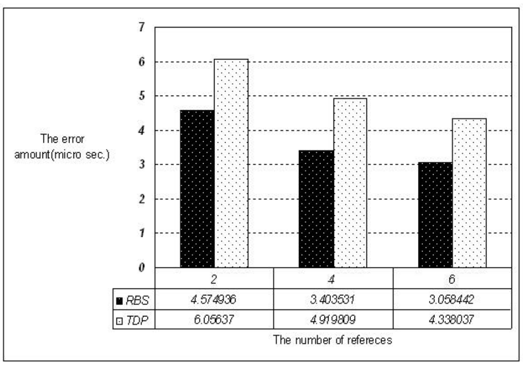

Fig. 5. The amount of errors in RBS and TDP (100 nodes)

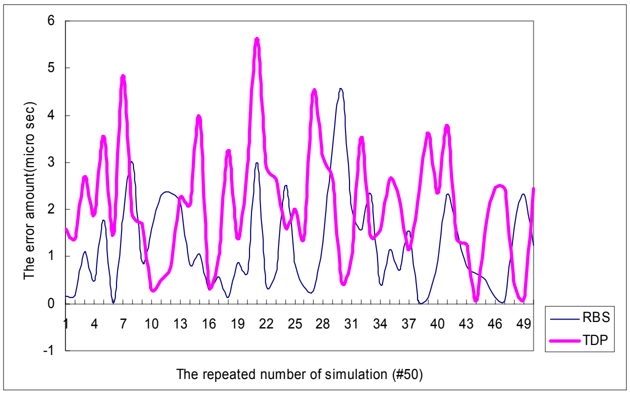

Fig. 6. A comparative graph of the synchronization error at the worst case node (node 13) in 25-grid with 6-Reference nodes

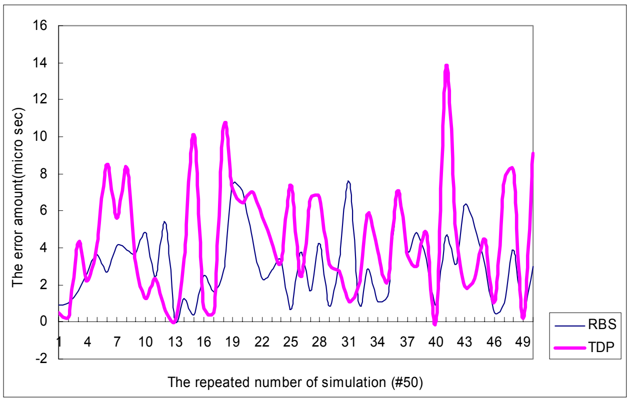

Fig. 7. A comparative graph of the synchronization error at worst case node (node 45) in 100-grid with 6-Reference nodes

4. Conclusions

In this paper, we compared and analyzed the performance of the RBS and TDP mechanisms in the factors of the generated messages and the accuracy range in the synchronization of wireless sensor networks. The different number of overall sensor nodes (25 and 100) and the different number of reference nodes are considered in the simulation.

In the simulation results based on the number of generated messages in overall synchronization, TDP is far better than RBS. But, in sensor network requiring a small number of nodes and more high synchronization accuracy, RBS mechanism is more adequate. So, two mechanisms may be used selectively according to the required environments, without saying that the one method is always better than the other.

There are several topics remained as a further study. The selection of an optimal transmission range should be researched to release the overhead of the primary-role-node of each synchronization algorithms. And it should be also considered to decrease the messages and total elapsed time for synchronization. The new synchronization algorithm can be developed to be operated adaptively according to the number of nodes to be synchronized, the requirements of the accuracy and the status of the average/min/max remaining battery life of nodes, etc.

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Hyojung Lee
She received the B.S. degree in mathematics from Dongguk University, Korea, in 2001. She is currently a graduate student at the Department of Information and Communications Engineering of Chungnam National University, Korea since 2003. Her research interests include sensor network, network management and traffic engineering.

Byung-Chul Kim
He received the B.S. degree in electronic engineering from Seoul National University and M.S. and Ph.D. degrees in electronic engineering from Korea Advanced Institute of Science and Technology (KAIST), Korea, in 1988, 1990, and 1996. He is currently a Professor at the Department of Information and Communications Engineering of Chungnam National University, Korea since 1999. Also, from 1993 to 1999, he worked as a Research Engineer at the Samsung Electronics. His research interests include computer networks, wireless internet, sensor networks and mobile communications.

Youngmi Kwon
She received the B.S. degree, M.S. and Ph.D. degrees in computer engineering from Seoul National University, Korea, in 1986, 1988, and 1996. She is currently a Professor at the Department of Information and Communications Engineering of Chungnam National University, Korea since 2002. Also, from 1993 to 1995, she worked as a Research Engineer at ETRI. And from 1996 to 2002, she worked as a Professor at the Department of computer Engineering of Mokwon University, Korea. Her research interests include network management, traffic engineering, QoS, routing and sensor network.