Energy Efficient Dynamic Cluster Based Clock Synchronization for Wireless Sensor Network*

Md. Mamun-Or-Rashid, Choong Seon Hong**, and Jinsung Cho

Dept. of Computer Engineering, Kyung Hee University,
Seocheon, Giheung, Yongin, Gyeonggi, 449-701 Korea
mamun@networking.khu.ac.kr, cshong@khu.ac.kr,
chojs@khu.ac.kr

Abstract. Core operations (e.g. TDMA scheduler, synchronized sleep period, data aggregation) of many proposed protocols for different layer of sensor network necessitate clock synchronization. Our paper mingles the scheme of dynamic clustering and diffusion based asynchronous averaging algorithm for clock synchronization in sensor network. Our proposed algorithm takes the advantage of dynamic clustering and then applies asynchronous averaging algorithm for synchronization to reduce number of rounds and operations required for converging time which in turn save energy significantly than energy required in diffusion based asynchronous averaging algorithm.

1 Introduction

Wireless sensor network is inherently distributed in nature. Time synchronization is a critical and well studied issue in distributed system, but sensor networks differ substantially in many ways from traditional distributed systems. Typical applications of sensor networks are environmental monitoring which detects several environmental parameters such as fire, oil slicks or animal herds. In order to determine the happening time and decision making in accordance with the happenings, synchronization of different devices has to be determined. Our work is motivated by [2], fully localized diffusion based technique for global clock synchronization. Keen observation about diffusion based method is it can achieve synchronization but it needs the participation of all the nodes in the network which in turn effectively reduce the lifetime of the nodes as the nodes consumes energy for the synchronization process. Also the time convergence requires large number of rounds and incurs huge amount of flooding overhead to exchange the clock collection and updates. Clustering can efficiently reduce flooding overhead and the node participation significantly which, in turn save energy and enlarge the lifetime of the network. In this paper we study how diffusion based technique can be benefited from a dynamic clustering to reduce its flooding overhead during clock exchange and thus make the synchronization process energy efficient. We have used passive clustering [3] which can avoid potential long setup time and reduce re-forwarding significantly.

* This work was supported by University ITRC project of MIC.
** Corresponding author.

L. Wang and Y. Jin (Eds.): FSKD 2005, LNAI 3614, pp. 1166 – 1169, 2005.

2 Related Work

A lot of research works [4] [5] [6] [7] [8] available in the field of clock synchronization in distributed systems. However, techniques described for synchronization in distributed system do not take into account the limited resource availability for sensor networks and other dynamic constraints such as mobility. Different works on clock synchronization in sensor network has been introduced in [1], and [8]. Our work is motivated by [2]. Three methods have been proposed for global clock synchronization in [2]. Those are (1) All-Node-Based, (2) Cluster Based and (3) Diffusion Based method. The idea of “All-Node-Based” method is impractical to implement due to its assumption of finding a single cycle which includes all the nodes at least once. To implement the idea of “All-Node-Based” method in a small manageable set they proposed “Cluster Based” method which create and maintain clusters and use “All-Node-Based” method to synchronize among the nodes of clusters. But still “Cluster Based” method is having a great amount of overhead for cluster maintenance which, ascertain its limitation to be implemented in energy constraint sensor network. Finally, the proposed fully localized “Diffusion Based” method for clock synchronization in which nodes can be synchronized at any time with its neighbor.

3 Dynamic Cluster Based Algorithm for Synchronization

Work In [2], Qun Li et al have proposed fully localized diffusion based technique for global clock synchronization in sensor networks with synchronous and asynchronous implementations. The technique is based on exchange and update clock information locally among the neighbor nodes. Synchronous rate based algorithm exchange clock reading values proportional to their clock difference in a set order. On the other hand, asynchronous method can synchronize with its neighbor at any time in any order. For detailed understanding of we refer [2].

Considering the reduced operation and less overhead of cluster head maintenance of passive clustering, we change the asynchronous algorithm in the following way:

Like other traditional synchronization algorithms our algorithm is having two major operations:

1. Collecting clock information and averaging
2. Sending the new clock value to be updated

In our algorithm cluster head and gateway nodes are responsible for initiating clock collection, averaging and updating. All gateway nodes and cluster heads are having equal probability to execute averaging operation, while asynchronous diffusion in based algorithm all nodes are responsible for clock averaging operation. Synchronization process is as follows

for each cluster head node hn_i and gateway node gn_i in the network {
if the node is a cluster head{
collect clock information from the member nodes of the cluster
compute the average of the clocks of the nodes in a cluster
send new clock to the members of the cluster }

if the node is a gateway node{
collect clock information from cluster head nodes within the gateways transmission range
compute the average clocks of the cluster head nodes
send new clock information to the cluster head nodes}}

4 Simulation

To justify our claim of reduction of operation and thus reduction of energy, we implement two different algorithms and compare the results. Implemented algorithm executed by varying number of nodes and transmission range. In case of asynchronous averaging algorithm for each time slot, each node executes the averaging operation and the order of the node is randomized. Similarly, our algorithm for each time slot cluster head and gateway nodes execute averaging operation once and the operation of those nodes are randomized. Real time deployment of our algorithm needs the time interval of synchronization operation for the sensor nodes which depends on the clock drift of the nodes in the sensor network.

Our first and second set of experiment has the following parameters

a. Roaming Space 200 X 200
b. Number of Nodes = 200

The experiment shows the number of rounds required for asynchronous averaging algorithm and passive clustering averaging algorithm. Both the algorithms require comparatively large number of rounds at lower transmission range and fewer numbers of rounds at high transmission range. At low transmission range the network nodes supposed to have fewer neighbors and the effect of diffusion operation effects slowly. Number of round requirement at higher transmission range can be explained with inverse logic.

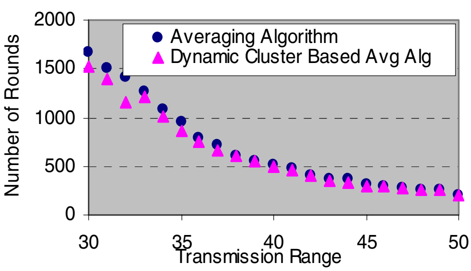

Fig. 1. Number of rounds---Fixed number of nodes---Varying transmission range

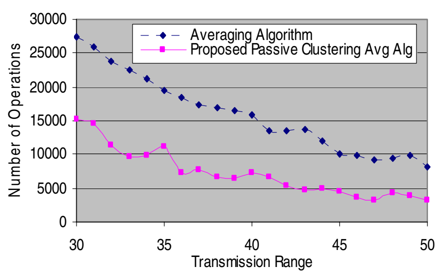

Fig. 2. Number of operations---Fixed number of nodes---Varying transmission range

Next set of experiments compares our proposed algorithm with asynchronous averaging algorithm under increasing number of nodes. Our proposed algorithm performs better both in terms of number of rounds and operations required for synchronization.

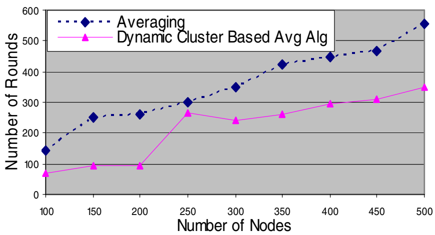

Fig. 3. Number of rounds --- varying number of nodes --- Fixed transmission range

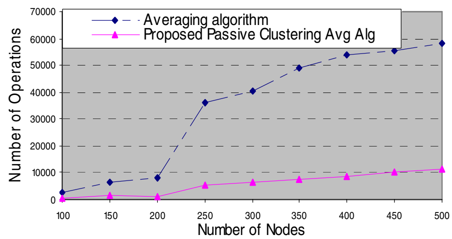

Fig. 4. Number of operations --- varying number of nodes --- Fixed transmission range

5 Conclusion

Diffusion based asynchronous averaging algorithm each node performs its operation locally and diffused to whole network to achieve the global synchronization. Albeit Cluster based method proposed in the same work have a better performance but suffered from the overhead of cluster creation and maintenance. One of the factors that affects the performance of diffusion based asynchronous algorithm is all node have the equal probability to execute averaging operation. Our proposed algorithm takes the advantage of passive clustering which reduces the chance of executing averaging operation in all nodes. Rather our proposed algorithm executes averaging operation only in cluster head and gateway nodes which makes it energy efficient.

References

1. J. Elson and D. Estrin, Time synchronization for wireless sensor networks, in Proc. of the 2001 International Parallel and Distributed Processing Symposium (IPDPS), Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing, San Francisco, CA, (2001)
2. Qun Li, Daniela Rus, Global Clock Synchronization in Sensor Networks, IEEE INFOCOM Vol. 1, Hong Kong, China, (2004) 564-574
3. Kwon, T.J., Gerla, M. Efficient flooding with passive clustering (PC) in ad hoc networks. ACM SIGCOMM Computer Communication Review 32 (2002) 44–56
4. Chalermek Intanagonwiwat, Ramesh Govindan, and Deborah Estrin. Directed diffusion: A scalable and robust communication paradigm for sensor networks. In MobiCOM, Boston, Massachusetts, (2000) 56-67
5. K. Arvind, Probabilistic Clock Synchronization in Distributed Systems, IEEE Transactions on Parallel and Distributed Systems , Volume 5 , Issue 5, (1994) 474 – 487
6. M.Lemmon, J. Ganguly, and L. Xia, Model-based clock synchronization in networks with drifting clocks, in Proc Of the 2000 Pacific Rim International Symposium on Dependable Computing, Los Angeles, CA, (2000) 177–185
7. B. Hofmann-Wellenhof, H. Lichtenegger, and J. Collins, Global Positioning System: Theory and Practice, 4th ed. Springer- Verlag, 1997
8. K. Romer, Time synchronization in ad hoc networks, in Proc. of ACM Mobihoc, Long Beach, CA, (2001) 173-182