International Journal of Internet, Broadcasting and Communication Vol.10 No.1 11-15 (2018)
http://dx.doi.org/10.7236/IJIBC.2018.10.1.2

IJIBC 18-1-2

Performance Evaluation of Distributed Clustering Protocol under Distance Estimation Error

Quoc Kien Nguyen[1], Taehyun Jeon[2*]

Department of Electrical and Information Engineering,
Seoul National University of Science and Technology, Seoul 01811, Korea
E-mail: {kiennq, thjeon}@seoultech.ac.kr

Abstract

The application of Wireless Sensor Networks requires a wise utilization of limited energy resources. Therefore, a wide range of routing protocols with a motivation to prolong the lifetime of a network has been proposed in recent years. Hierarchical clustering based protocols have become an object of a large number of studies that aim to efficiently utilize the limited energy of network components. In this paper, the effect of mismatch in parameter estimation is discussed to evaluate the robustness of a distanced based algorithm called distributed clustering protocol in homogeneous and heterogeneous environment. For quantitative analysis, performance simulations for this protocol are carried out in terms of the network lifetime which is the main criteria of efficiency for the energy limited system.

Keywords: *Sensor network, Estimation error, Clustering, Energy efficiency, Network lifetime.*

1. Introduction

Wireless sensor networks (WSNs) consist of a data sink and a group of low cost sensing devices connected via wireless data communication. It is broadly exploited in the wide area of applications requiring acquisition of physical parameters such as temperature, pressure, humidity and so on. WSNs consist of a huge number of energy limited sensor nodes that collect and deliver data to the gateway so called base station. As the energy resource is limited, it is vitally important to prolong the lifetime of the network operation by applying proper routing protocols that help to achieve stable functioning of the system. A simple, direct communication from the nodes to the data sink might force nodes to send collected data with considerably higher energy. Consequently, it is likely that the life time of each sensor node can be shortened. A huge number of researches and surveys have been carried out in recent years in the field of WSNs with the motivation to find out various data routing protocols that satisfy the following requirements: autonomy, scalability, energy efficiency and resilience [1, 2, 3].

The hierarchy based protocol is one of the most widely used protocols whose operation principles are based on generating clusters from all nodes and randomly assigned cluster heads [4]. Distribution of the cluster heads in the network area plays one of the main roles in low energy adaptive hierarchical clustering (LEACH) based protocol [5, 6, 7]. However, original LEACH protocol cannot control the allocation of cluster heads due to a random selection of them. Distributed clustering protocol (DCP) is a good reference of distance based algorithm to maintain the fair distribution of cluster head [8]. Furthermore, it can help to prolong the living time of each node in the network. In this paper, we focus on DCP in homogeneous and

Manuscript Received: Dec. 18, 2017 / Revised: Dec. 28, 2017 / Accepted: Jan. 5, 2018
Corresponding Author: thjeon@seoultech.ac.kr
Tel: +82-2-970-6409, Fax: +82-2-978-2754
Department of Electrical and Information Engineering, Seoul National University of Science and Technology, Korea

heterogeneous environment to analyze its performance and discuss the operating characteristics of DCP.

The distance or position based energy efficient algorithm including DCP might be affected by the error in distance estimation which is normally based on the strength of the receive signal. Simulations are carried out under the scenario when the estimated distance is different from the real distance in order to thoroughly understand the effect of the error in the main parameter of the protocol. This paper focuses on the effect of the mismatch in distance estimation in real field application where the received signal strength indicator of the signal is exploited to estimate the distance between nodes. The performance is measured in terms of the survival time of the nodes for various levels of distance mismatches. The crucial point of this simulation is to figure out whether DCP is robust to the distance estimation mismatch. In section 2, previous research works are discussed. Section 3 explains about the simulation condition and the result obtained from simulation. The conclusion is drawn in section 4.

2. Clustering protocol in WSN

2.1 LEACH Protocol

One of the most broadly recognized hierarchical clustering protocols is the LEACH protocol, which still has been gaining the attention of the researchers [9, 10, 11]. In this protocol, the main principle of operation is based on grouping all the nodes into clusters that are formed by generating cluster heads [5, 6]. Generally, all operation processes in this protocol can be divided into two phases: set-up phase and steady-state phase. In set-up phase, the main objective is to perform a cluster head selection process, which is done by implementing a probability of the node to become a cluster head. Additionally, only the nodes that have not been selected in the previous round can participate in the cluster head selection process for a current round. Furthermore, all nodes go with a randomly assigned number between 0 and 1 to be compared with a threshold. The nodes that have a number less than the threshold are chosen as cluster heads. By completing the cluster head selection, the protocol utilizes advertisement broadcasting to all nodes for building the cluster with its members in the current round. In this paper, LEACH is used as a reference for simulation in both heterogeneous and homogeneous network.

2.2 Distributed Clustering Protocol

In DCP, the cluster head is selected based on the comparison with the random indicator of each adjacent node [8]. DCP is a distance based algorithm which can be exploited to overcome the unbalanced work load distribution issue in LEACH. Furthermore, the number of cluster head depends on the structure of the network and the residual energy of each node. In this protocol, the distance between node and nearby node is the main factor to propose a node as a cluster head. The main idea of DCP is based on the information exchange among adjacent nodes and there is no general control from the data center. Therefore, this protocol can have the non-fixed number of cluster head in each round and it might highly depend on the position of nodes and the distance between nodes.

Since this algorithm depends on the distance as a major parameter, it is very important to evaluate the effect of the error in distance estimation on the performance of the system. In this paper, we compare the performance of DCP under various amount of distance estimation mismatch in heterogeneous as well as homogeneous network. In homogeneous network, the initial energy of each node is fixed while there are several nodes which have higher initial energy than the others in heterogeneous network. In the following section, we evaluate these effects on the distance based protocol.

3. Simulation Results

In this section, we analyze the sensitivity of the DCP which is one of the distance based protocols under different amount of distance mismatches. In the real field application, the distance estimation algorithm is commonly based on the received signal power. However, this type of estimation provides a relatively lower

accuracy since the received signal power may not always reflect the true distance between the transmitter and the receiver. This is because the geographical characteristics between the transmitter and the receiver may affect the propagation channel properties. In our simulation, the effect of measurement errors on the performance of the distance based protocol is analyzed in terms of the life time of the sensor nodes. For the quantitative analysis of the performance, the level of mismatch is defined as follows:

$$m = \frac{d - d_{est}}{d} \tag{1}$$

where d is the real distance and d_{est} is the estimated distance. In this simulation, the distance between the network and the data sink is assumed to be 100m and the initial energy is 0.5J for the homogeneous network. In a heterogeneous environment, the number of advanced nodes which have 50% higher initial energy is assumed to be 20% of the number of nodes. The distance estimation errors in terms of the mismatch level m defined in (1) are set to 0%, 50% and 100%, respectively for both cases. The network size is 100m×100m and the number of nodes is 100. Simulation results in terms of the first dead node index are summarized in Table 1. It can be shown that the first dead node index decreases when the mismatch rate increases in both homogeneous and heterogeneous network case. In the homogeneous case, the degradation with $m = 0.5$ which is equivalent to 50% mismatch level causes about 4.4% degradation in the first dead node index compared to the perfect estimation case. Also, with 100% mismatch, the degradation is about 5.1%. This result shows that the additional degradation is not so significant when the mismatch level grows from 50% to 100%. We can observe the similar trend in the heterogeneous case. In this case, the performance drops by 5.5% in case of 50% mismatch and by 6.9% with the 100% mismatch, respectively.

Table 1. First dead node index of DCP with various distance mismatches

Distance Mismatch	0	0.5	1.0
Homogeneous Case	718.2	686.4	681.8
Heterogeneous Case	732.7	692.7	682.5

In Figure 1, the performance of DCP in terms of the first dead node index is affected by distance mismatch in a relatively smaller level. It can be also shown that the performance of DCP remains the better over the conventional LEACH protocol even with a large amount of estimation error. The effect of the estimation error is limited by about 5.1% even with 100% mismatch environment in terms of the first dead node index.

The simulation result for the heterogeneous network is shown in Figure 2. In this result, the survival time is stretched out with more than 2000 rounds until the last node died. Simulation results also show that the performance of DCP remains the better even with a large amount of estimation error over the conventional protocol. Similarly, the effect of the estimation error is limited by about 6.8% even with 100% mismatch environment in terms of the first dead node index.

4. Conclusion

In this paper, the effect of distance estimation mismatch is discussed for one of the distance based energy efficient protocols for wireless sensor network. It is important to assess the robustness of the protocol which has to use the measured parameter in the field. Sensitivity of the distributed clustering protocol which is one of the distance based protocols targeting for energy efficiency is tested under various amounts of mismatch. Simulations are performed for both homogeneous and heterogeneous network. Simulation results indicate that the performance degradation is not so significant in terms of the first dead node with the increase of the estimation error while maintaining the considerable gaps over the conventional protocol.

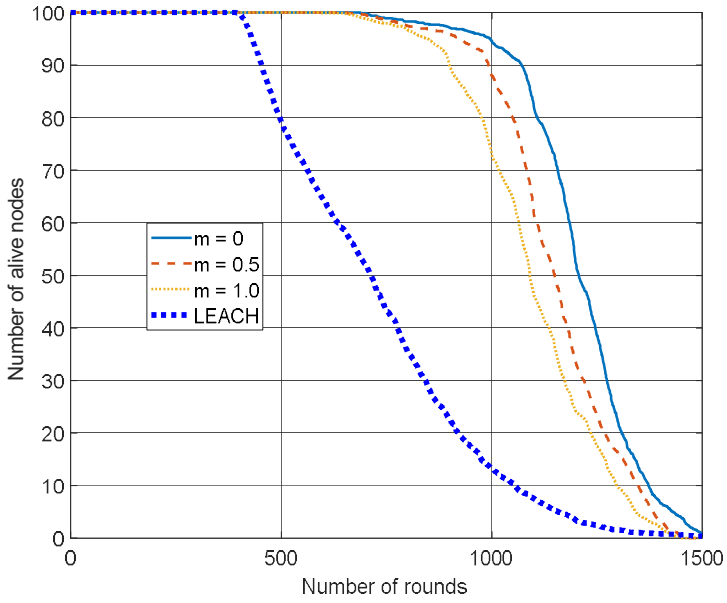

Figure 1. Performance of DCP in homogeneous environment with mismatch

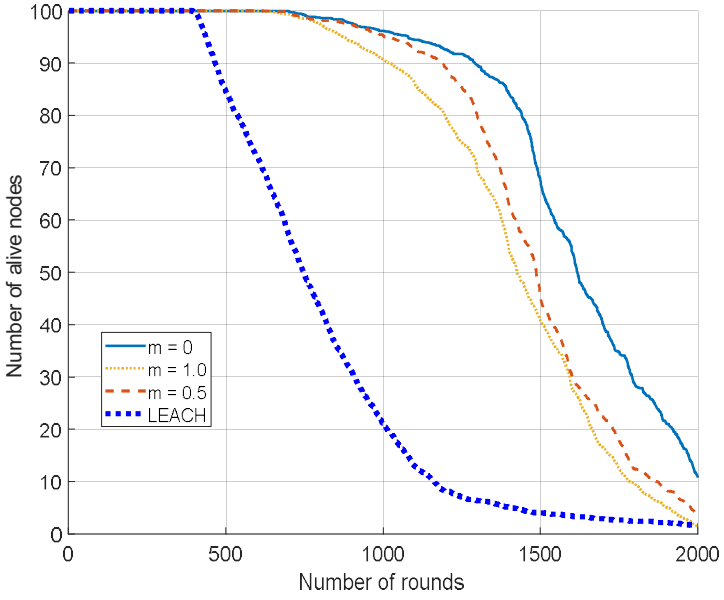

Figure 2. Performance of DCP in heterogeneous environment with mismatch

Acknowledgement

This study was supported by the Research Program funded by the SeoulTech(Seoul National University of Science and Technology).

References

[1] L. Xu, R. Collier, and G.M. O'Hare, "A survey of clustering techniques in WSNs and consideration of the challenges of applying such to 5G IoT scenarios," IEEE Internet of Things Journal, Vol. 4, No. 5, pp. 1229-1249, 2017.

[2] C.Y. Chong and S.P. Kumar, "Sensor networks: Evolution, opportunities, and challenges," Proceedings of IEEE, Vol. 91, No. 8, pp. 1247-1256, Aug 2003.

[3] Y. Gu, and A. Lo, "A Survey of Indoor Positioning Systems for Wireless Personal Networks," IEEE Communications Surveys & Tutorials, Vol. 11, No. 1, pp. 13-32, 2009.

[4] A.S. Toor and A.K. Jain, "A Survey of Routing Protocols in Wireless Sensor Networks: Hierarchical Routing," IEEE International Conference on Recent Advances and Innovations in Engineering, pp. 1-6, 2016.

[5] W. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-efficient communication protocol for wireless microsensor networks," The 33rd Hawaii International Conference on System Sciences, Vol. 8, p. 10, 2000.

[6] G. Dongfeng and X. Lijun, "LEACH Clustering Routing Protocol for WSN," Proceedings of the International Conference on Information Engineering and Applications, Vol. 4, Part II, pp. 153-160, 2013.

[7] V.G. Gungor, "Efficient available energy monitoring in wireless sensor networks," International Journal of Sensor Networks, Vol. 3, No. 1, pp. 25-32, 2008.

[8] Q.K. Nguyen and T. Jeon, "Distributed clustering protocol for wireless sensor network," International Journal of Sensor Networks, Vol. 19, No. 3/4, pp. 242-250, 2015.

[9] D. Yun, K. Jung and J. Lee, "The Routing Algorithm for Wireless Sensor Networks with Random Mobile Nodes," International Journal of Internet, Broadcasting and Communication, Vol. 9 No. 4, pp. 38-43, 2017.

[10] S. Jin, K. Jung and J. Lee, "Enhanced ML-LEACH with additional Relay Node," International Journal of Advanced Smart Convergence, Vol. 6, No. 3, pp. 9-16, 2017.

[11] S. Jang, K. Jung and J. Lee, "The Comparison of the 3D graph for the energy-equal of LEACH-Mobile," International Journal of Advanced Smart Convergence, Vol. 6, No. 1, pp. 57-67, 2017.