

Energy Efficient Routing in Wireless Sensor Networks

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Abstract

Sensor nodes depend on batteries for energy source in Wireless Sensor Networks (WSNs). Low Energy Adaptive Clustering Hierarchy (LEACH) is a representative cluster-based routing protocol designed to ensure energy use efficiency whereas the virtual cluster exchange routing (VCR) information only with its closest node to build a network. In this paper, a protocol scheme was proposed wherein member nodes are designed to compare the currently sensed data with the previously sensed one and to switch to sleep mode when a match is achieved. The design is to help improve the transmission energy efficiency too.

Keywords: *Sensor node, LEACH, TEEN, Clustering Algorithm, VCR.*

1. Introduction

Sensor nodes in a Wireless Sensor Network (WSN) include a microcontroller, a radio transceiver, and a sensing module. The sensor nodes collect data and send to the sink node mostly through the multi-hop wireless mesh network. The network has expanded its application gradually, which now includes environmental monitoring, building hazard diagnosis, and patient monitoring as well as health care service applications [1]. In the sensor networks, MANET (Mobile Ad Hoc Network)-like environment wherein no AP (Access Point) or other fixed infrastructure exists is used. Also, autonomous and independent networks

are formed between the sensor nodes [2-4]. For sensor nodes, batteries are the main source of energy, but their operation characteristics do not allow the replacement or charge of batteries [5]. Low Energy Adaptive Clustering Hierarchy (LEACH) assumes that each lower-level node always has data to transmit [6]. Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN), on the other hand, uses threshold values which help prohibit data sensed previously from being sensed afresh or from being sent to upper-level nodes [7].

2. Related Studies

2.1. WSN Routing Protocols

A WSN is comprised of nodes that are connected to sensors detecting changes in the data under monitoring. Depending on network configuration, routing protocols for WSNs are divided into flat routing protocol and cluster-based hierarchical routing protocol [5]. In this protocol, lower-level nodes collect sensed changes in data and send them to upper-level nodes. The upper-level nodes then aggregate the data and forward them to BS. Some of the best-known cluster-based hierarchical routing protocols are LEACH, LEACH-C (LEACH-Centralized), and TEEN [8]. The routing protocols can also be divided into proactive network protocol and reactive network protocol depending on the network's mode of functioning and type of target application.

2.2. LEACH and TEEN

LEACH is built with several clusters, each of which has a cluster head (CH) and non-cluster heads (Non-CHs) and TEEN is a reactive network protocol where all nodes sense data continuously by reacting immediately to the changes occurring in the data. In LEACH, the CH controls all the sensor nodes within the cluster, fuses data sent by the sensor nodes, and forwards them to BS. Non-CHs, on the other hand, collect data and send them to the CH. Since it is in charge of aggregating data transmitted from Non-CHs and forwarding them to a remote BS, the CH consumes a lot of energy. Thus, the CH is selected from all the nodes at the beginning of a new round, according to the set probability. This taking turns allows each node to have an equal opportunity to become the CH [9-10].

However, in the reactive network protocol, it uses hard threshold (HT) and soft threshold as a sensing data (ST) [11]. When the value of the data collected by Non-CH nodes is either the same as or less than HT, the data get to be transmitted to the CHs. ST, on the other hand, is a small change in the value of the sensed data. When this value matches or exceeds data collected by Non-CH nodes, the data will get to be sent to the CHs. Once the network starts operating and when the sensed data reach their HT value, Non-CH nodes send the data to the CHs. Next, at the current cluster period, nodes will transmit data only when the current value of the sensed data exceeds HT and at the same time matches or exceeds ST. The purpose of using HT then is to have nodes transmit only the data of importance and to help reduce the number of transmissions conducted by them.

2.3. VCR

The virtual cluster exchange routing (VCR) information only with its closest node to build a network. At this point, the sensor node in the virtual cluster can send data to different cluster nodes or sink nodes without going through the virtual cluster head. The process of building the virtual cluster based on compactness between the nodes which are composed by selecting the heads of virtual cluster to build multiple virtual cluster, building path setting of partition nodes which are not included in the virtual cluster, and setting level for transmitting data between virtual clusters. In order to select the virtual cluster head, all sensor nodes send the ADV message to themselves and nearby nodes. At this point, the ACK message for the ADV message is not sent. Based on the sum of ADV messages from surrounding nodes, adjacent node information is determined. If a node receives messages whose sum is bigger than the standard value based on the node compactness, that node is selected as the cluster head. If two of neighboring nodes are selected as the cluster

head, the node with a bigger ADV message sum will be selected as the virtual cluster head.

3. Energy-Efficient Clustering Technique

The proposed scheme offers an alternative to help improve the energy efficiency of the entire network while taking into account the data collection occurring at Non-CH level in cluster-based routing protocols.

In this process, during which the cluster is created, ends and then triggers a new period, during which Non-CH nodes at once sense data in the environment and compare them with the ones stored in their internal memory during their time slot. In the initial period, no previously collected data exist, and hence no match between data sets. When the second period begins, Non-CH nodes come back from sleep mode and start sensing the environment and collecting data during the second time slot assigned to them, according to the TDMA (Time Division Multiple Access) schedule created by the CH of their respective cluster. If the previous and current data achieve a match, the nodes will switch to sleep mode to save energy. If the data do not match, the nodes will store the current data in their internal memory and then transmit them to the CHs. The drawback of the TEEN can be solved by the proposed scheme

4. Performance Evaluation

In this study, simulations based on the proposed scheme were conducted to compare the scheme with the two representative cluster-based routing algorithms, LEACH and TEEN, respectively. The performance evaluation parameter chosen for the comparison was the number of surviving nodes in the network over time.

4.1. Simulation Environment

For the simulations, it was made sure that the WSN had 100 nodes and a fixed BS. The nodes were randomly assigned to one of the three network algorithms, i.e., LEACH, TEEN, or the proposed scheme. For clustering and other issues, the parameters used in LEACH are listed in Table 1 [5].

Table 1. Simulation parameters for the proposed scheme

Parameter	Value
Network grid	From (0, 0) to (100, 100)
Base station coordinate	(50, 175)
Number of sensor nodes	100
E_{elec}	50 nJ/bit
E_{amp}	100 pJ/bitm ²
Initial energy/node	2J
K	5
E_{DA}	5 nJ/bit
E_{fs}	10 pJ/bit/m ²
E_{mp}	0.0013 pJ/bit/m ⁴

To help ease the simulation of the proposed scheme, an environmental scenario was created wherein the temperature was manipulated to fluctuate randomly between 0°C and 200°C at five-second intervals - as applied in TEEN. Regarding energy consumption, incorporating the proposed scheme into an existing routing algorithm for real-life simulation would result in energy consumption that is required for the data comparison process at Non-CH level. But the comparison concerned involves only simple comparison between the previously stored data and the currently sensed one. Another issue to consider was the variability in chances of having the same data in the provided simulation environment wherein temperature changed randomly.

4.2. Results and Analysis

Simulations were carried out to compare LEACH and the proposed scheme, and the number of surviving nodes in each protocol was compared over time. As shown in Fig.1 (a), the existing LEACH protocol had nodes that survived a maximum of 625 seconds, whereas the proposed scheme contributed to the survival of nodes for up to 840 seconds. Next, simulations were conducted to compare TEEN against the proposed scheme, i.e., to compare the number of surviving nodes over time while implementing TEEN's hard mode (HT) as opposed to implementing the proposed scheme. Under TEEN, the simulation set-up including cluster configuration was mostly similar to that of LEACH. However, the radio electronics model used in LEACH had to be altered so that the model in TEEN would represent both the idle time power dissipation and the sensing power consumption. Fig.1 (b) shows the results of the comparison between TEEN and the proposed scheme. The number of surviving nodes was greater over time in the proposed scheme compared to TEEN.

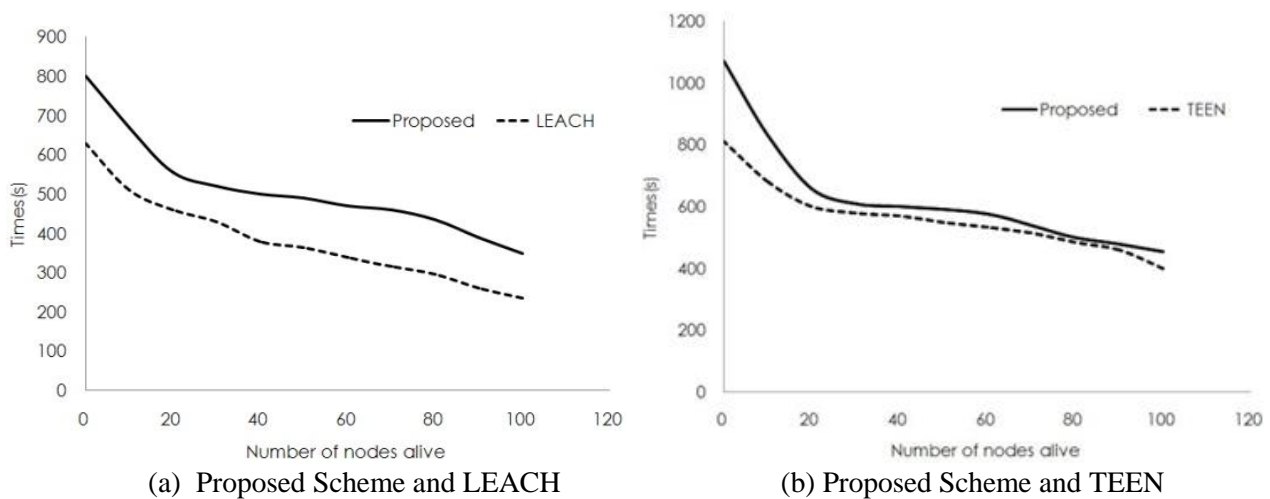


Fig. 1. Comparison between proposed scheme in terms of no. of surviving nodes over time. (a) proposed scheme and LEACH; (b) proposed scheme and TEEN.

5. Conclusion

In this paper, a protocol scheme was proposed to help save energy at lower-level nodes that compare the currently sensed data with the previously sensed one during their time slot and decide whether or not to send the data to upper-level nodes (CHs). The proposed scheme was compared with LEACH and TEEN through simulations. Compared with TEEN, the proposed scheme showed slightly better performance and helped solve the biggest problem of backfiring of TEEN's use of thresholds to prevent redundancy in data transmission which in some cases acts to prevent communication with entire upper-level nodes.

Acknowledgement

This research was supported by the RIC/PoDIT program in Mokwon Univerity.(Grant Number B0010564)

References

- [1] F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, A survey on sensor networks. *IEEE Comm. Mag.*, 40(2002), pp.102–114.
- [2] M. Rajiullah and S. Shimamoto, An Energy-Aware Periodical Data Gathering Protocol Using Deterministic Clustering in Wireless Sensor Networks (WSN). *WCNC IEEE*, (2007), pp. 3014-3018.
- [3] Paolo Santi, Topology control in wireless ad hoc and sensor networks, *ACM Computing Surveys (CSUR)*, 37(2005), pp. 164-194.
- [4] C. Schurgers, Energy efficient routing in wireless sensor networks, *Military Communications Conference, IEEE*, 1(2001), pp. 357 – 361.
- [5] W. R. Heinzelman, A. Chandrakasan and H. Balakrishnan, Energy-Efficient Communication Protocol for Wireless Microsensor Networks, *Proc.*, (2000) pp. 3005-3014.
- [6] W. B. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan, Application-Specific Protocol Architectures for Wireless Networks. *IEEE Trans. on Wireless Comm.*,1(2000), pp. 660-670.
- [7] N. Ahmad, N. Riaz, and M. Hussain, Ad hoc wireless Sensor Network Architecture for Disaster Survivor Detectio. *IJAST*, 34(2011), pp. 9-16.
- [8] W. Heinzelman, A. Chandrakasan and H. Balakrishnan, An Application-Specific Protocol Architecture for Wireless Microsensor Networks. *IEEE Trans. on Wireless Comm.*, Oct., 1(2002), pp. 660-670.
- [9] R. H. Wendi, S. Amit, W. Alice, and A. P. Chandrakasan, Energy-scalable algorithms and protocols for wireless microsensor networks. *International Conference on Acoustics, Speech, and Signal Processing - ICASSP*, 6(2000), pp. 3722–3725.
- [10] S. Cho, B. Shrestha, K. H. La, B. Hong, and J. Lee, An Energy-Efficient Cluster- Based Routing in Wireless Sensor Networks, *Communications in Computer and Information Science*, 265(2011), pp. 15-22.
- [11] M. Aratir and D. P. Agrawal, TEEN : A Protocol for Enhanced Efficiency in Wireless Sensor Networks, *Parallel and Distributed Processing Symposium, Proceedings 15th International*, April (2000), pp.2009-2015.