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Energy Efficient Cluster Head Selection Based on Distance for Hierarchical Wireless Sensor Networks

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Abstract: Wireless Sensor Network (WSN) has been an object of extensive research activities around the globe in recent decades. The WSN demands an efficient power management due to limited energy resources of the nodes and it can be achieved by implementing the energy efficient protocols. Hierarchy based protocols are recognized to be energy efficient. One of the most widely known hierarchical protocols is the Low-Energy Adaptive Clustering Hierarchy (LEACH). However, the cluster head distribution in LEACH is only based on the probability which is preset at the beginning of working procedure. Consequently, it can lead to the unbalance in selecting the cluster head in regard of the position. Numerous research focus on wisely distributing the cluster head position to achieve the prolonged lifetime of the network. In this study, we propose a modification of the LEACH protocol. It is expected that the proposed protocol can extend the lifetime of the system by incorporating the transmission distance between the network area and the data sink. Simulation results show that the proposed algorithm demonstrates the improved performance over the conventional protocol in terms of the network lifetime.

Key words: Wireless sensor network, mobile sink, routing protocols, clustering, LEACH, energy efficient protocols

INTRODUCTION

Wireless sensor networks are defined as the network with a big number of spatially distributed sensor elements. The sensors collect the data and transmit it to the gateway for the further processing. This type of the network has a broad range of applications that monitor the physical conditions of the environment such as sound, temperature, pressure and etc. In recent years, the WSN has become an integral part of the Internet of Things (IoT). The IoT represents the inter-networking of physical devices and other infrastructures embedded with electronics that collect the sensed data and enable all of those objects to exchange the data. This type of the internet creates virtually unlimited possibilities to integrate computer-based systems into real world which consequently bring the beneficial outcomes to the efficiency and the accuracy of existing internet infrastructure. The role of WSN in those processes can be defined as “bridge” that connects the digital world and the real world.

One of the main issues in WSNs is the limited amount of energy constrained by the battery capacity of the nodes (Jin *et al*., 2017; Jung and Lee, 2017). Therefore, the energy consumption management is a crucial part in the sensor network development. In recent years, a huge amount of researches on this issue have been conducted (Pantazis *et al*., 2013). Particularly, a broad variety of routing protocols such as the Low-Energy Adaptive Clustering Hierarchy (LEACH) and the Power-Efficient Gathering in Sensor Information Systems (PEGASIS) have been introduced to prolong the lifetime of the network (Lindsey and Raghaven-dra, 2002).

The data sink in WSN is used for collecting all sensed data for further transmission to the end users. The sink can be subdivided into the static sink and the dynamic sink. They determine the sink position which is fixed from the point of the deployed area of the nodes or moves along the certain path (Mottagi and Zahabi, 2015). The current research considers the assumption that the network is aware of the position of the data sink and the distance from it to the network. This study introduces the modification to hierarchical protocol LEACH which is based on the enhancement of the cluster generation incorporating the distance from the network area to the data sink. The number of clusters can be adjustable to the varying distance between the network area and the sink.

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MATERIALS AND METHODS

Proposed algorithm

Adaptive scanning radius: The proposed algorithm is based on the Distributed Clustering Protocol (DCP) (Nguyen and Jeon, 2015). In this approach, the formation of cluster heads in the system is determined by generating the scanning radius for selecting the cluster head. In other words, the radius is considered as a criterion of a cluster size, so that, the nodes in this radius are the candidates of the cluster head. Therefore, the size of the scanning area affects the number of cluster heads.

In the conventional algorithm, the transmission distance between the node and the data sink is closely related to the size of clustering area (Ren *et al*., 2010). For example, the further node tends to have a smaller cluster area. Under this background, we propose an equation to calculate the radius of the scanning area of each node in terms of the distance between the network area to data sink assuming the size of the network is fixed:

$$r_a = r_n \frac{d/d_{min}}{d_{min}/d_{max}} \quad (1)$$

Where:

- r_n = The radius of the network area
- d = A distance from one node to data sink
- d_{max} = A distance from data sink to the farthest position of the network
- d_{min} = A distance from data sink to closest point of network area

The idea of adaptive radius is based on the concept of DCP and the distance based algorithm. However, we implement an adaptive radius with different approach which considers the ratio r_a instead of the gap between d_{max} and d_{min}, so that, the network lifetime is improved in comparison with unequal clustering protocol while it requires lower computational complexity when proposing a cluster head.

Threshold for selecting a cluster head: Using the optimum r_a discussed in the previous section, the probability p_a that one node can be selected as a cluster head is proposed as follows:

$$P_a = 0.5\left|\frac{d_{min} - r_a}{d_{max} - r_a}\right| \quad (2)$$

Incorporating the probability mentioned above, we propose a modified equation for the threshold as shown in Eq. 3:

$$T(i) = \begin{cases} \dfrac{P_a}{1 - P_a\left[r_n \bmod \left(\dfrac{1}{P_a}\right)\right]}, & i \in \text{set of nodes} \\ 0 & \text{else} \end{cases} \quad (3)$$

In this Eq. 3, the threshold for being selected as a cluster head depends on the probability P_a which is only a function of the distance between the network and the data sink.

RESULTS AND DISCUSSION

This study discusses the results of simulations that are carried out to demonstrate the performance of the proposed protocol in comparison with the conventional ones. For the simulation scenarios, we consider that the data sink is placed in various distances from the network area. Although, the distance between network and data sink is changed, the other values of network parameters are always the same during the simulation. The network size is 100×100 m and the number of nodes is 100. The initial energy of the nodes is equal to 0.5 J. The probability of the nodes to become cluster head is equivalent to 0.1 for the conventional schemes. This implies that approximately 10% of nodes are chosen as a cluster head every round.

In Fig. 1, we assume that the data sink is located at 130 m away from the center of the network. We can see that the difference between the unequal clustering algorithm and the LEACH in terms of the first dead node index is not significant while the proposed one shows big improvement over the conventional schemes. In addition, the number of living nodes with the proposed algorithm is considerably higher than the conventional one as the number of rounds increase especially after the first dead

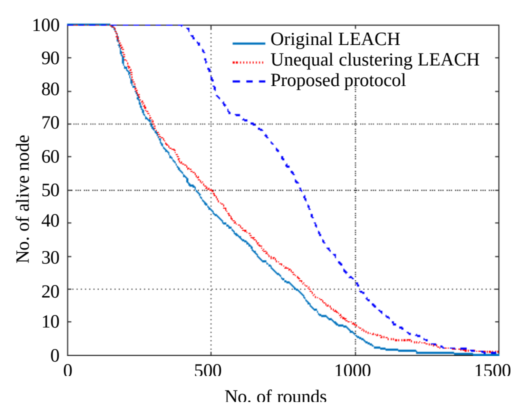

Fig. 1: Lifetime comparison with data sink located at 130 m from network center

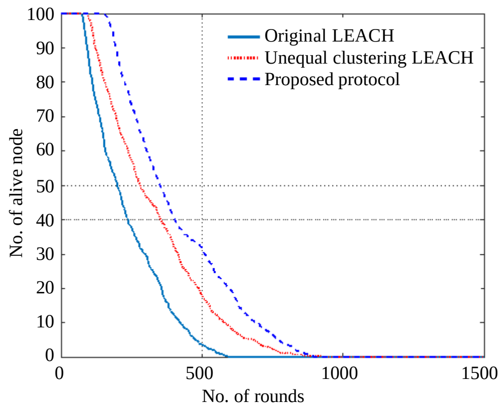

Fig. 2: Lifetime comparison with the data sink located at 170 m from network center

node occurs. Therefore, the overall lifetime of nodes increases significantly in this scenario. At the higher number of rounds our algorithm is always better than both LEACH and the unequal clustering LEACH.

In Fig. 2, the performance for data sink located at 170 m away from the network center is compared. It can be shown that, the proposed protocol performs better in terms of the lifetime as well as the first dead node index. LEACH performs worse than the other two algorithms. We can observe the similar trend in the performance curve where the number of living nodes of the conventional distance-based algorithm drops quickly while more living nodes are observed with the proposed algorithm at each round.

CONCLUSION

Among many issues in designing WSN with limited energy resources, the extension of the network lifetime is the major objective. However, it is difficult to guarantee the optimal energy consumption in distance based protocol when the distance between nodes and data sink is varied. The proposed modification of LEACH protocol provides the balanced power consumption regardless of the distance between the data sink and the deployed nodes. From the simulation results, the proposed method can regulate the number of clusters and reduce the unnecessary energy consumption due to the distance. It is expected that the proposed algorithm can bring the better performance in terms of energy efficiency compared to the conventional algorithms in the real field application.

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