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Fixed Cluster Formations with Nearest Cluster Heads in Wsns

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Abstract

The limited battery usage of a sensor node is one of the significant issues in WSNs. Therefore, extending the lifetime of WSNs through energy efficient mechanisms has become a challenging research area. Previous studies have shown that clustering can decrease the transmission distance of the sensor nodes thus, prolongs the lifetime of the network. In literature, most of the LEACH variants aim to set-up clusters in each round by changing CHs randomly. These formations cause to spend high amount of energy and induce additional network costs. In this paper, an energy-efficient nearest constant clustering approach is proposed to solve the problems of LEACH based protocols. The proposed approach uses constant clusters which are formed only once when algorithm starts. The cluster formation remains fixed until the energies of the all sensors are finished. Proposed approach aims to select nearest CHs in each cluster randomly without changing the cluster formations.

Index Terms: Routing, fixed clustering, WSNs.

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1. Introduction

Wireless Sensor Networks (WSN) are able to perform data collection, aggregation and communication from an environment through many distributed individual sensor nodes through radio communications. By sensing the environmental events within their respective ranges, the sensor nodes collect data of interest and communicate the data through the nodes until the data finally reaches to the base-stations (BSs) for final processing. WSNs have become increasingly useful in a variety of critical applications, such as environmental monitoring, smart offices, battlefield surveillance, and transportation traffic monitoring by Sohraby et al., 2007 and Dargie et al., 2010.

According to the participating way of the nodes, routing protocols can be classified into three categories, namely, direct communication, multi-hop routing and clustering protocols. With direct communication, each sensor directly transmits the sensed data to a remote receiver. Thus, the sensor nodes do not require any type of communication amongst themselves. With multi-hop routing, each sensor node transmits its data to the remote

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receiver through other sensor nodes in the network by Akyildiz and Vural, 2010.

With clustering, a cluster head (CH) is responsible for conveying any information obtained by the nodes in its cluster. The CHs may aggregate and compress the data before sending it to the BS. It has been shown that clustering is an efficient and scalable way to organize WSNs although the energy dissipation of cluster heads is more than the regular sensor nodes by Akyildiz et al., 2002.

2. Related Work

LEACH by Heinzelman et al., 2004 is the fundamental clustering protocol for WSNs. In LEACH, each data transmission round consists of a set-up and steady-state phases. At set-up phase, some of the nodes in the network elect themselves to be local CHs with a certain probability. As a node is elected to be a CH, it broadcasts an advertisement message which contains the information qualifying for the CH. After the advertisement of the CHs, the remaining nodes join to a cluster by finding the closest CH. In the steady-state phase, cluster members gather data continuously and transmit these data to certain CHs in certain slots. The CHs fuse these data and forward the collected data to the BS. LEACH protocol can provide a significant amount of energy saving when compared to direct transmission or multi-hop routing.

On the other hand, in LEACH, a cluster topology changes at every transmission round due to the randomized cluster formation structure. Selection of new CHs and forming new clusters for every round induce more energy consumption and bring extra network costs. The same problem is also observed in other LEACH based protocols.

The performance of LEACH is improved in the literature by some new algorithms. Authors propose some protocols which provide significant enhancements to LEACH. Many of them propose to change the CH selection process of LEACH to obtain energy-efficiency. CHs and cluster formations are changed in every round of LEACH. This structure of LEACH causes to dissipate significant amount of energy. Because of this restriction, CH selection is controlled adaptively according to the energy reserve of local active nodes in by Zhao and Liang, 2004. Unlike LEACH, this approach is a distributed self-organizing scheme without any centric control and it has higher tolerance than LEACH to on-off topology changes. The adaptiveness of this approach makes significant reduction in communication based energy consumption.

Time-based CH selection for LEACH (TB-LEACH) is presented in by Junping et al., 2008. TB-LEACH only modifies the CH determination method of the LEACH to form uniform cluster pieces. The competition for CHs depends on a random time interval in TB-LEACH. To become a new CH, a node has to have shortest time interval value. The number of CHs is controlled with a counter. After the election of CHs, the remaining phases are same as LEACH. TB-LEACH has longer system lifetime values and better energy-efficiency than LEACH.

Stable Cluster Head Election (SCHE) by Muhamad et al., 2008 improves the CH selection of LEACH to obtain the optimal probability of becoming a CH. Authors of Muhamad et al., 2008 find an optimal probability value for becoming CH. Simulations illustrate that, this algorithm decreases significant amount of communication energy when compared with LEACH.

Leader Election with Load Balancing Energy (LELE) is introduced in by Shirmohammadi et al., 2009. LELE compares the remaining energy and distance of a node with its neighbors to determine it as a CH. The homogeneous distribution of CHs is proposed in this protocol. The probability of being CH varies correlative with the difference of the energy level of one node with its neighbors. It achieves better performance than LEACH in terms of network lifetime while balancing the energy consumption of the nodes.

To solve the issue in variability of the number of CHs in LEACH, authors design Two Step Cluster Head Selection (TSCHS) in by Sun et al., 2009. It uses two stages: temporary CH election stage and optimal CH election stage which is performed by using the current energy and distances to the BS of the temporary CHs to elect CHs. As a result, unlike LEACH, the number of CHs is changed and the network operates with the optimum number of clusters. TSCHS enhances the network life span and balances the energy wastage of the entire network. Optimal election of a CH is efficient in decreasing energy wastage of the nodes and thus extends network lifetime.

Optimal CH selection algorithm which does not need to use the position information of the nodes is described in by Ayughi et al., 2010. The algorithm works based on two parameters: the energy levels of the nodes and number of neighbors of the nodes. The algorithm also takes mobility of the nodes into consideration. The nodes may enter a new cluster when they move and the new CH is should be selected by moving nodes to reduce energy dissipation of the network. After the simulations, it is demonstrated that, the remaining energy of the sensors is more than in LEACH.

Modified-LEACH (ModLEACH) by Mahmood et al., 2013 contains an effective CH changing method and double transmission power levels. The amplifier energy is adjusted as same for all types of communications in LEACH. On the other hand, in ModLEACH, few energy level is arranged for communications inside of the cluster. Multi power level usage of ModLEACH provides to minimize the amount of packet drops, collisions and interference from different signals. When a node is chosen as a CH, the routing protocol in ModLEACH forces it to adjust high power amplification and when a node is not CH, that node switches its mode to low level power amplification mode. Threshold based CH determination scheme is also designed in ModLEACH to obtain more effective CH replacement. If the energy of the current CH is bigger than the threshold it becomes a CH if not a new CH is determined and new cluster formation occurs again. Simulations of ModLEACH demonstrate that, ModLEACH is more successful than LEACH in terms of throughput, network lifetime and energy-efficiency.

In this paper, to overcome this problem, constant clustering with nearest cluster heads (CHs) is proposed for WSNs. Proposed algorithm not only reduces the overall energy dissipation but also increases the network lifetime significantly. Proposed algorithm uses threshold based CH selection and selection of the nearest node approaches together. Instead of changing CHs for every round, proposed method uses constant clustering approach. Section III, describes the details and operation of proposed method and its phases.

3. Proposed Algorithm

The sensors are randomly scattered in a region as illustrated in Fig. 1. The proposed algorithm begins with the determination of the CHs. The CHs are elected randomly at first. The clusters are formed for once in cluster formation phase. The constant clustering scheme of the proposed algorithm provides to reduce the network and cluster formation cost of LEACH based approaches. Sensors in the network do not move, thus sending location information is performed for once.

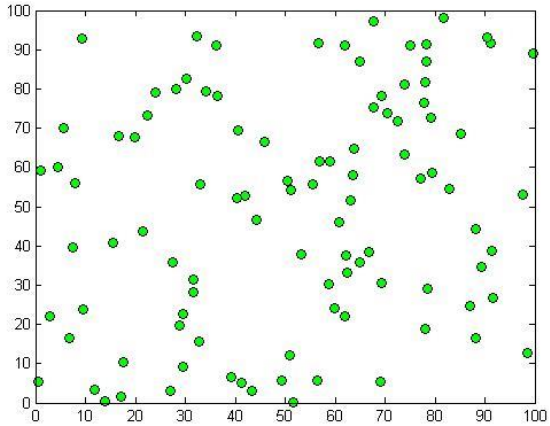

Fig.1. The randomly distributed sensors in WSN.

When cluster heads are determined, they send CH notification message to all sensor nodes in the network. Every member node attends to the closest cluster. After this participation, the cluster formation is complete. In every cluster, CH is liable for gathering data from its associated cluster elements. When data gathering is accomplished by the CHs in each cluster, each CH delivers gathered data to the base station which is located outside of the WSN. In the proposed algorithm, each CH node chooses nearest member as a CH node from alive members in the cluster at the beginning of new round. After this election, new picked CH begins to collect data from cluster members. Then this new elected CH which is shown in Fig. 2 transmits the gathered data to the BS.

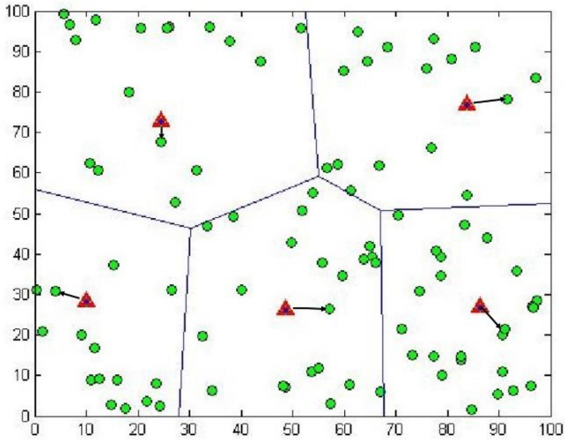

Fig.2. Nearest CH election process in the proposed algorithm.

Note that, in the proposed algorithm, the cluster formation is carried out only once, the CH selection is repeated in each round for each cluster. The Fig. 3 shows the general working mechanism of the proposed algorithm which contains set-up phase where the clusters are formed for only once and steady-state phase which has repeating rounds. Rounds consist of CH selection and data transmission.

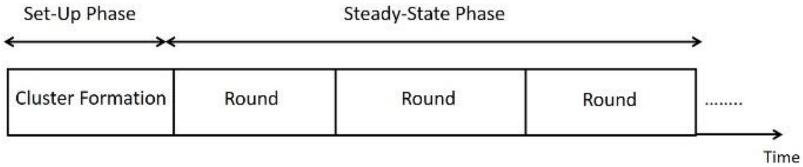

Fig.3. The overview of the proposed algorithm.

4. Experiment and Analysis

The simulations are performed in MATLAB. 100 sensors are randomly distributed in a 100 m x 100 m area as illustrated in Fig. 1 and BS is put outside of the area which is at coordinates of (150,50). Same simulation values of LEACH by Heinzelman et al., 2004 are taken to simulate the proposed algorithm and ModLEACH. Simulations are repeated for 100 iterations to get more consistent results. Table I shows the simulation parameters.

Table 1. Simulation Environment Parameters

Parameter	Value
Network Size	100 m x 100 m
Number of Sensors	100
BS Position	(150,50)
Initial Energy of Each Sensor	2 J
Data Packet Length	6400 bits
Control Packet Length	200 bits
Transceiver Energy (Eelec)	50 nJ/bit
Aggregation Energy for Each Bit (EDA)	5 nJ/bit/signal
Free Space Amplification Energy (εfs)	10 pJ/bit/m2
Multipath Amplification Energy (εmp)	0.0013 pJ/bit/m4

To determine optimal number of clusters value of the proposed algorithm, the algorithm is simulated for varied number of clusters. Fig. 4 illustrates the results of this determination. Note that, for LEACH this value is 5% of the number of sensors in the network. For the proposed algorithm, the optimum number of clusters is 10% of the number of sensors in the network.

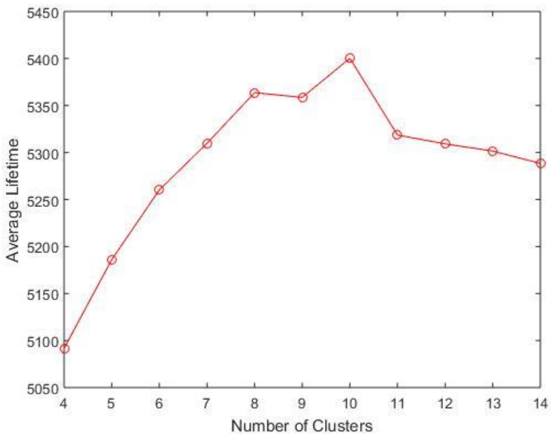

Fig.4. Average Lifetime of the proposed algorithm in terms of varied number of clusters.

5. Comparison Results of the Proposed Algorithm

In this section, the performance comparisons of LEACH, ModLEACH and the proposed algorithm are evaluated in terms of residual energy, number of alive nodes, lifetime and total data transmitted to the BS. To obtain more scalable results, 100 iterations are realized. For each iteration, the average values of the results are recorded.

5.1. Remaining Energy

Total remaining energy of the sensors according to the rounds is showed in the following figure. By using constant clustering, it is seen that proposed algorithm is more energy efficient than LEACH and ModLEACH. For round 2000, while LEACH conserves 15-16% of its initial energy, proposed algorithm keeps approximately 40% of its initial energy. When all nodes are dead in LEACH network, proposed algorithm still holds 10% of its total initial energy.

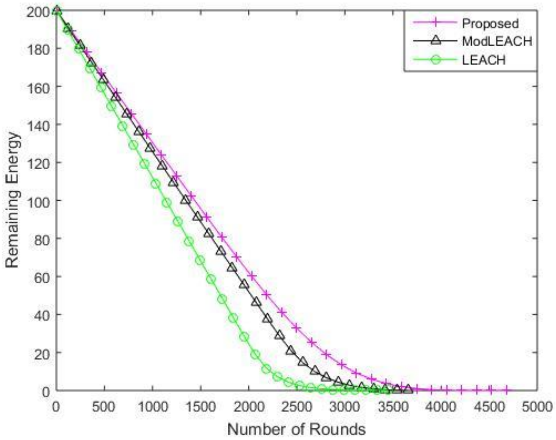

Fig.5. Comparison of Remaining Energy

5.2. Number of Alive Nodes

Fig. 6 shows the number of alive sensors thus the network life span for proposed algorithm and other algorithms. With proposed algorithm, the network lifetime is extended from 3000 rounds to 4500 rounds, about 50% enhancement is obtained when compared to other protocols.

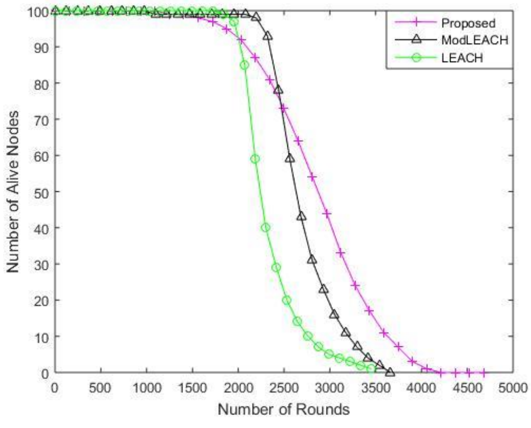

Fig.6. Comparison of Number of Alive Nodes

5.3. Throughput

The cumulative number of packets delivered to base station per round is plotted in Fig. 7. With fixed clustering, proposed algorithm can continuously gather data for each round to send to the BS. On the other hand, due to the probabilistic CH selection mechanism, LEACH based algorithms cannot form clusters for some rounds. As a result, the throughput of proposed algorithm is significantly better than the compared protocols.

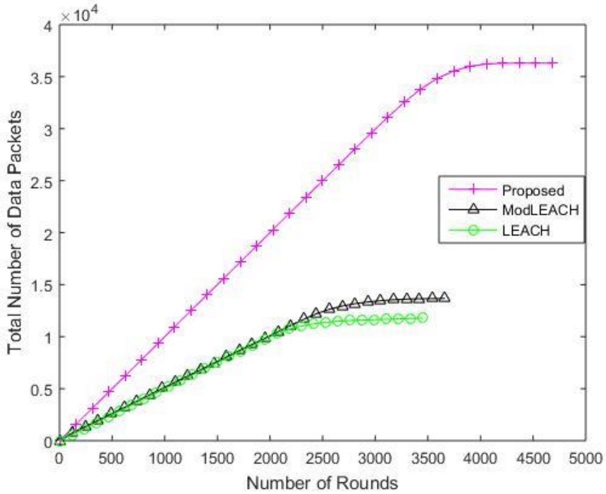

Fig.7. Comparison of Throughput

6. Conclusions

Saving energy, extending lifetime by Bianzino et al., 2012 and green networking solutions by Khan et al., 2014 for WSNs by Albagory et al., 2014 have become challenging research topics nowadays by Abuhaiba and Al-Sallut, 2015. By designing constant clustering topology and reducing number of CH changes, proposed algorithm decreases clustering overhead significantly. Simulation results prove that, proposed algorithm decreases energy consumption of traditional LEACH based protocols, prolongs lifetime of the WSN and provides significant throughput improvement when compared with LEACH and ModLEACH.

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