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Adaptive Balanced Clustering For Wireless Sensor Network Energy Optimization

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Abstract

Many researches in wireless sensors network clustering aim to optimize the power and to balance the cluster with respect to cluster head and cluster nodes. The optimization of cluster and node in balanced way, will balance the processing overhead - and thus power consumption - over the clusters and nodes, so, the network nodes death will be balanced. In order to balance the clustering of the network in terms of equi-sizes clusters or equi-potential clusters, in some networks, far nodes will be very far from any clusters, and those nodes couldn't be included in any balanced clusters. This paper finds a solution for the far nodes. The solution that is contributed in this paper is based on balanced clustering of the network ignoring all far nodes temporary or initially, then, building virtual clustering technique. The fart nodes will be clustered independently in virtual clusters. Those clusters don't have heads of clusters that communicates directly with the base station, but instead it implies virtual cluster head that communicates directly with non-cluster head node in the nearest real cluster. The contributed algorithm of this paper where implemented and simulation results were recorded indicating that, it's efficient power consumption algorithm, and the balance of clusters will not be so affected. The comparison with LEACH, LEACH-M, and LEACH-L is demonstrated, in addition to the EECA algorithm.

Keywords: Wireless sensors network, clustering, energy optimization

Introduction

Many topologies were suggested to manage the large number of sensors that are installed in the wireless sensors network. The most common topology is the clustering based techniques. The clustering is simply divides the large group of sensors into smaller groups that is named clusters. Each cluster consists of a number of sensors (that is commonly known logically as nodes), where one of those nodes should be selected to be the head of cluster. The nodes only communicate with their cluster head, and each cluster head can communicate with any node inside its cluster [1] [2] [3] [4].

Clustering is a very common method because it simplifies data aggregation and make inside network processing (i.e. cluster head processing) which results in reducing the amount of data to be transmitted to the base station [8].

In hierarchal architecture of clustering, the nodes didn't see any element of the network, but the head of cluster. The head of cluster can see the base station, and the nodes inside its cluster. It is not able to see in planar way any node outside its cluster, whereas, the base station communicates directly with the head of clusters. The head of cluster represents a middle unit that passes the transfer between the base station and nodes [12].

Many topologies that are being used for clustering, such as Hybrid Energy Efficient Distributed (HEED), Mobility Resistant Efficient Clustering Approach (MRECA), Dynamic Clustering and Energy Efficient routing technique (EEDC),Low Energy Adaptive Clustering Hierarchy (LEACH), and Energy Efficient Clustering Algorithm (EECA) [1]. The different clustering algorithms are based according to different variables, such as distance between nodes, and nodes weight of energy [5].

The most important constraint that should be considered in the wireless sensor network design process is the sensor nodes operation with limited energy (batteries), and it is important to take in consideration the interval between the first nodes death and the last one. Energy optimization in wireless sensors network could be done in different scales. When talking about clustering, the clustering topology that is needed should conserve the energy and deal with balance nodes without putting overhead over a part of the network rather than other part.

The Low Energy Adaptive Clustering Hierarchy (LEACH) protocol combines the Time Division Multiplexing (TDMA) style contention free communication with a clustering algorithm for wireless sensor networks [7] [8].

LEACH operates in rounds that consist of two main phases: setup phase and steady-state phase. The clusters heads and the hierarchal structure are determined during the setup phase, and then the communication schedule within the cluster is established. The cluster head is responsible for the coordination of the cluster activity and data transmission to the base station, so; its energy requirements are significantly large compared to the other nodes in a cluster. Thus, what LEACH does is a rotation of the responsibility of cluster head among the sensor nodes in a cluster to evenly distribute energy load [7].

A sensor node only communicates with its cluster head, and it is only allowed to transmit data during its allocated slots indicated by the schedule received from the cluster head. It is then the cluster heads responsibility to transmit data collected by one of its nodes to the base station. Each sensor node uses the minimum required transmit power to communicate with its cluster head then it turns off wireless radio between its designated slots, but the cluster head must stay awake at all time to receive data from all sensing nodes at all-time [11].

The work in [1] is modification on LEACH algorithm. It introduced new concept named "potential". The potential is a unified contributed measurement of distance, energy, and digital overhead (i.e. processing and transfer) on the sensor's node. The modified clustering was done to balance the network clusters in terms of equi-potential clusters. The simulation results were more balancing of nodes death interval over the LEACH, but far nodes that were not taken place in the EECA algorithm. This research paper presents a solution of the far nodes without affecting down the energy optimization of overall network

Related Works

It is well known, a main point of consideration in the design of a wireless sensors network is the optimization of power dissipation between sensor nodes.

I presented in [1] a novel algorithm to cluster and balance the network; and name it Energy Efficient Clustering Algorithm (EECA). That research introduced new measurement for cluster balancing (i.e. it named it "potential"). The potential is a contributed measurement for energy balancing to handle the distance, the energy, and the overhead over the node. But the far nodes problem where completely ignored in [1].

In [1], the authors considered at this issue, especially researching the time between the death of the first node and the last one in a network. So, it presented a fuzzy logic base adaptive clustering algorithm to solve this problem, and did a comparison with the results of LEACH, LEACH-M and LEACH-L algorithms. This research didn't focus on the un-clustered far nodes at old.

It is of great importance to create equal clusters size wise or potential wise, where the author of [3] presented a modification on the Fuzzy C-Mean Clustering (FCM) algorithm itself, to enable generating equal sizes clusters.

The research in [4] considered energy efficient routing protocols, and they have presented a new protocol “Equalized Cluster Head Election Routing Protocol” - ECHERP, this protocol works on energy conversation through balanced clustering, it simply models the network as a linear system and calculates the nodes combinations that are nominated to be a cluster head using Gaussian elimination algorithm.

Continuing from the previous related works, and standing from my previous work in [1], this paper is looking into the node that is left out of all the clusters so we can get to them and propose a solution to this issue.

Problem Description

The work in [1] presents a novel clustering of wireless sensors network based on potential value that makes the clustering balanced. The balanced clustering causes all nodes to be died within very small interval. This will minimizes the loose of recording of the dead sensors in the same time that extends the network life time at most.

In addition, the research [3] presents clustering algorithm to make all clusters in the network to be balanced in terms of sizes. A research of [3], presented a modification to the Fuzzy Mean-Clustering algorithm in which that results dividing the nodes into equal clusters to achieve several goals, especially energy optimization.

When balanced clustering is done, some nodes are left out because they are very far from all the other clusters. It couldn't be included in any cluster, because attaching them to any cluster will damage the balance process.

Figure (1) shows the balanced clustering and far nodes problem. The main issue that rises to attention here is that these nodes are lost and not seen by any of the cluster heads, thus the information collected by these nodes is lost and not considered by the base station.

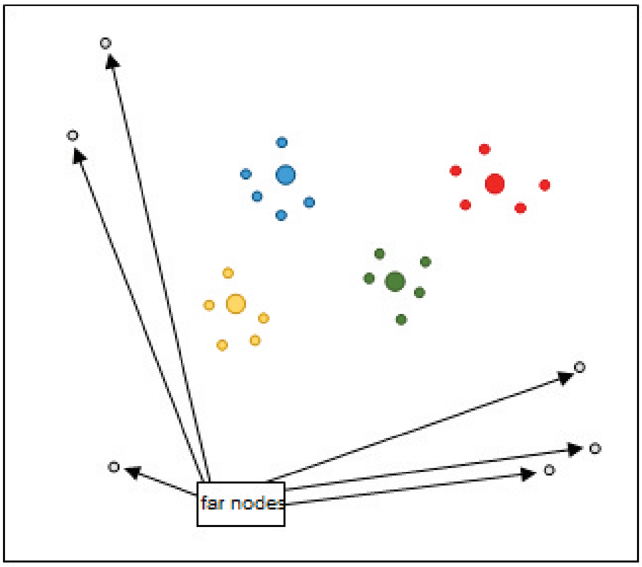

Figure 1. Illustration of far nodes

The approach introduced in this paper is to create virtual clusters that contain all the far nodes, then connect these virtual clusters to a virtual cluster head (represented by a specific node in the closest cluster to this virtual cluster), thus making use of all the nodes in our network while maintaining energy optimization.

Methodology

When creating equal clusters [1], a number of far nodes may be resulted, that means, node didn't undergo any cluster. The reason that this type of nodes is generated is that, the clustering algorithm couldn't be balanced if those nodes attached to some head of clusters directly, in addition to that the far distance between nodes, make the clustering not well established.

According to that clustering in [1], the aggregated data is not transmitted to the base station directly (Since only cluster heads are allowed to communicate with the base station. This problem should be solved. But the solution shouldn't affect the performance of the network.

Figure (1) shows a number of sensing nodes grouped in four equal clusters, each with its own cluster head. A number of nodes those are considered to be far nodes regards to EECA Algorithm [1] are left without clustering to any cluster.

This paper proposed a solution to deal with the far nodes so that they are taken in consideration by the base station. The contributed topology of clustering is that, making virtual clusters to classify the far nodes. The principle of virtual cluster is that, those clusters are not intended to have cluster head that communicates directly to the base station. In fact, the clustering will - in most cases - allow a limited number of clusters, so that, when finishing the clustering and far nodes is left, there is no way to add more clusters with respect to the base station.

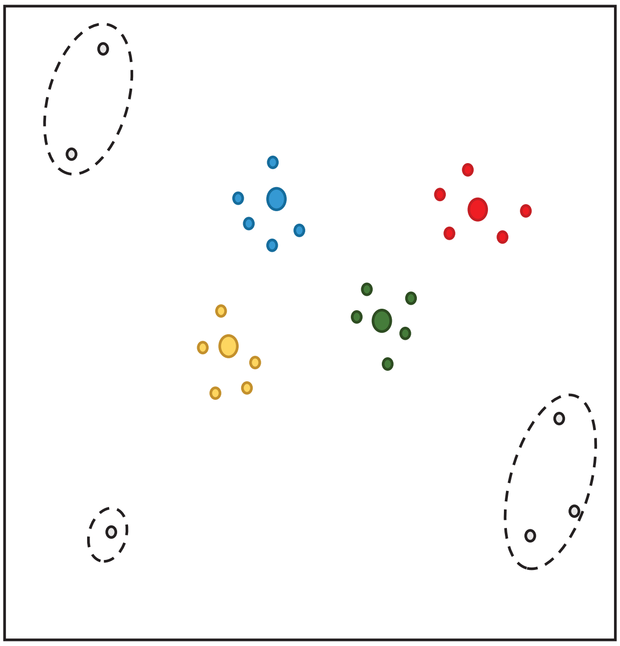

Figure 2. Virtual clusters

Thus, including them in virtual clusters will involve creating special clusters for those far nodes, then, selecting head of cluster to be virtual head of cluster. So that, the virtual cluster head will manage the virtual cluster nodes. Once, the virtual clusters are created and the virtual cluster heads are selected, each virtual cluster head will be attached to one of the real clusters, and thus, communicating with the base station through that real cluster head. The far nodes may be classified to more than one cluster as shown in figure (2).

First of all, the far nodes are clustered separately by the use of fuzzy C-mean clustering algorithm. The use of fuzzy C-mean algorithm enables to quickly cluster the nodes in separated clusters depending on the Euclidean distance. The virtual head of each cluster is determined to be the maximum power node in the virtual cluster. Figure (2) illustrates the virtual clustering.

To link the virtual cluster to the real cluster, the Euclidean distance between each the virtual head of cluster and all the real cluster heads is being calculated. The virtual cluster head is then linked to the minimal Euclidean distance real cluster. The Euclidean distance is being calculated using equation (1).

$$d(p,q) = d(q,p) = \sqrt{\sum_{i=1}^{n}((qi - pi))^2} \qquad (1)$$

Once, the closest cluster is determined with respect to the virtual cluster, the virtual cluster will be connected to the real cluster but not with the cluster head directly. Whereas, the virtual cluster head will be linked to a node in the real cluster but it is not the cluster head, this node will be named "the transparent node" which is higher in hierarchy with respect to the virtual cluster, but it is lower in hierarchy with respect to the real cluster head.

The Euclidean distance between the head of the virtual cluster and each node in the closest cluster is calculated. The closest 30% of the real cluster nodes to the virtual cluster head are selected, and then candidate to be transparent nodes as shown in figure (3).

Regarding to the 30% of candidate nodes, the maximum energy one will be selected as transparent node. The fact that, the transparent node has a relatively high transfer overhead, then, it should be with relatively higher energy.

The transparent nodes energy is determined in terms of potential; the potential is first introduced in [1]. The highest potential nodes ensures that, high energy with low Euclidean distance in addition to minimal power consumption scheme via its sensing recording and data collection, processing, and transfer bits, also, the battery leakage factor is taking into account. The potential is calculated using equation (2) as defined in [1].

P = 1/Eq + 1/Er - d *tq – k (2)

Where:
P: the potential.
Eq: the Euclidean distance, given in equation (1)
Er: the total remaining energy in the sensor's battery.
d: the transmission data cost function
tq: the energy slop of transmission data
k: the battery self-leakage factor

Once, the transparent node is selected (as in figure (4)) the complete operation will be started. The overall network nodes will start to collect data, the far nodes will send their data to the virtual head of its virtual cluster, the virtual head of cluster communicates directly to the transparent nodes, the transparent node and all real cluster nodes will communicate directly to the real cluster heads.

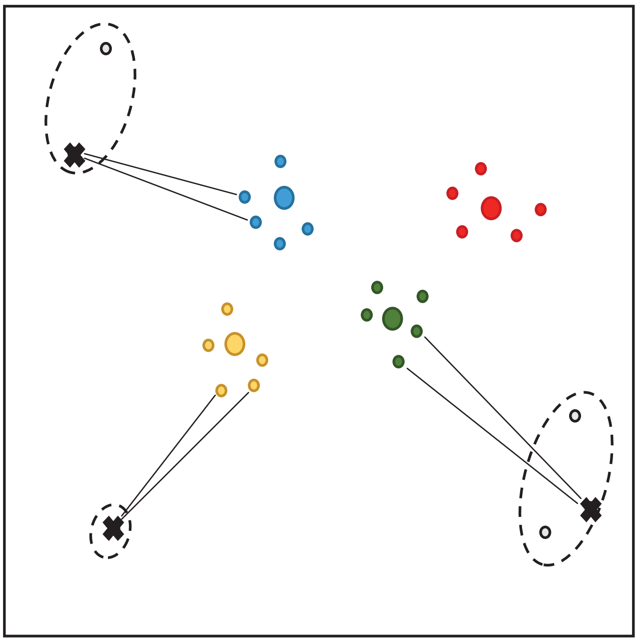

Figure 3. Closest one third of nodes to virtual cluster head

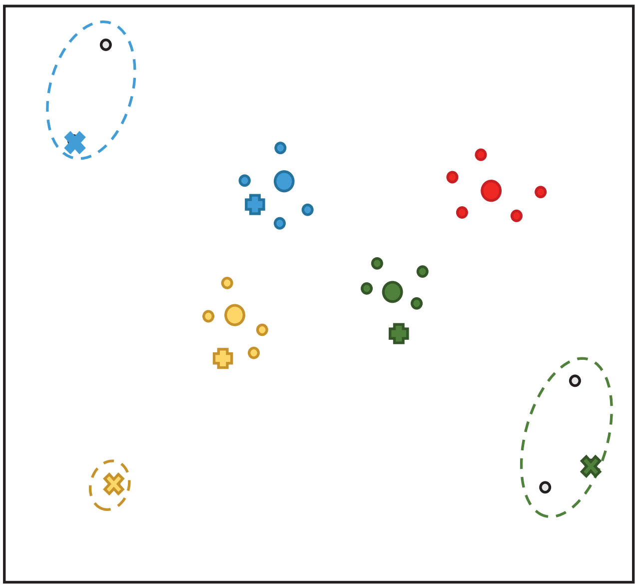

Figure 4. Virtual cluster topology results

The algorithm flow chart is illustrated in figure (5). This novel approach presents a realistic clustering algorithm, where the results will be discussed in the next section.

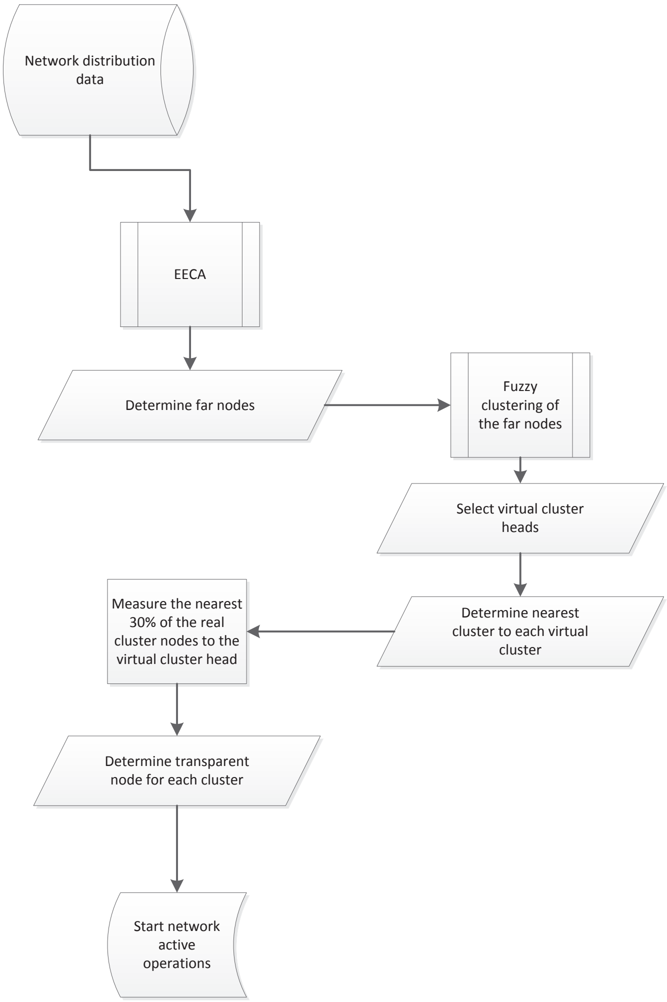

Figure 5. Flow chart of the presented algorithm

Results

The goal of this paper is to complete the clustering algorithm that is not completed in [1], so, a simulation program was designed in MATLAB. The results should be compared with LEACH, LEACH-M, LEACH-L, and the EECA that was presented in [1]. So, the parameters of the network that are used are appropriate to the presented results in [1].

Figure (6) shows the testing data set sample that is the same data set used in [1]. Initially, the far nodes locations are clear in the data set.

Figure (7) shows the clustering results based on EECA balanced clustering technique. The far nodes have disappeared, and have not been taken into account when the sample has been clustered into equi-potential clusters at old.

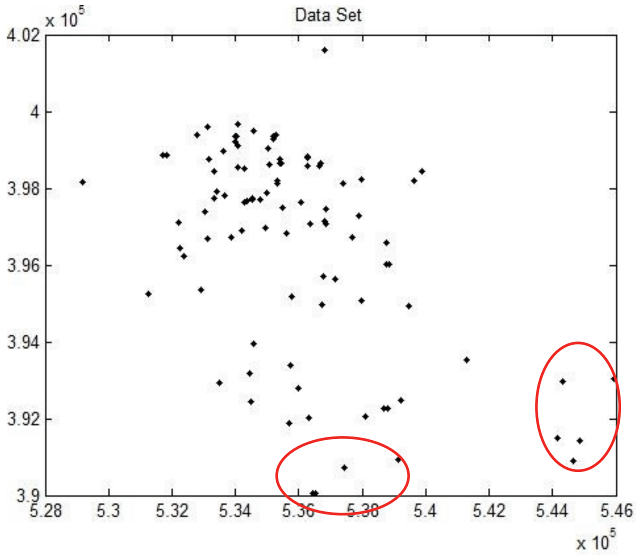

Figure 6- Data Set

Whereas figure (8) shows the contributed clustering results, it shows all clusters without any ignored node. The far nodes have been added into virtual clusters and then added to the nearest cluster, which helps making use of all the nodes.

The balance comparison results, is presented by comparing the contributed algorithm with each of them; LEACH, LEACH-L, LEACH-M, and EECA algorithm. The comparison is shown in figure (9). The life time cycle of the wireless sensors network is extended in the contributed algorithm with respect to LEACH algorithm. Also, the node death interval becomes more efficient than all LEACH algorithms, but the balance become worth than the pure EECA algorithm.

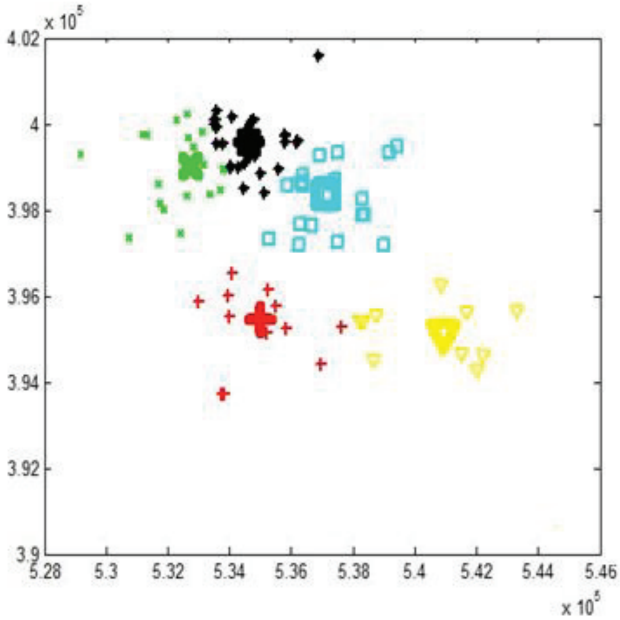

Figure 7. Clusters without far nodes

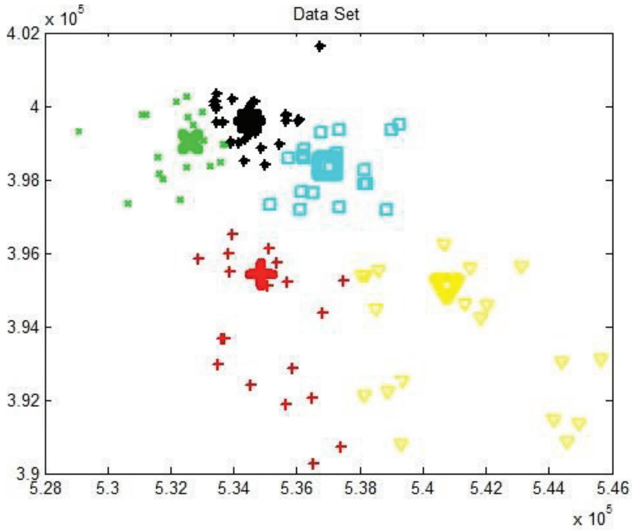

Figure 8. Clusters after adding the far nodes

The presented optimized energy clustering scheme presents extending of the network lifetime cycle, even though it worth than the EECA, but the EECA that is presented in [1] is not complete solution algorithm, because it cancels the far nodes at old.
Over the testing network, the far nodes transmit 18% of data. So, in the conventional EECA that was presented in [1], the energy scheme is more typical, but 18% of the data collections were lost.

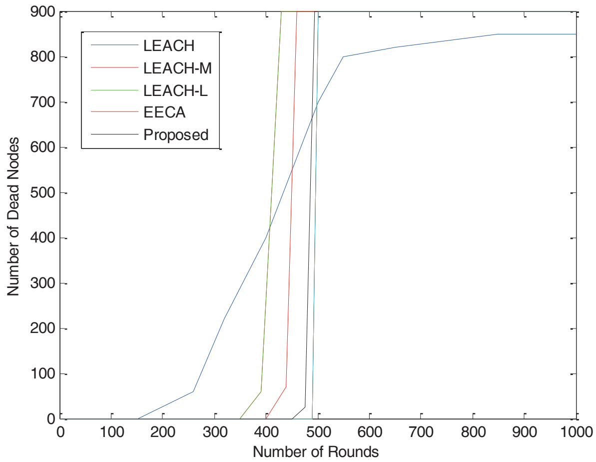

Figure 9. Death of nodes intervals among different algorithms

Conclusion
The wireless sensors network balancing could be done in a methodology that optimizes the network energy scheme. The energy optimization extends the network life time cycle; thus, reduce the cost and effort that could be applied to the network. The previous work that is demonstrating energy efficient clustering algorithm (EECA) aimed to balance the network clusters with either equi-sizes or equi-potential energy clusters. That achieved an important energy optimization step, but it was resulting in far nodes those couldn't be added to any cluster. Neglecting the far nodes makes the network more smooth and easiest the power scheme and mode, but it didn’t involve all the network nodes either in optimization, or in information gathering.

This paper contributes a modification algorithm on over the EECA algorithm to solve the far nodes problem, and thus, the related problems. The contributed algorithm builds a complex scheme to virtually cluster the needed nodes. The basic of this algorithm is EECA, and then, the problem will be solved in the suggested contributed model. This algorithm can cluster the complete network without ignoring any node. In addition, the performance of the contributed algorithm was much better than the LEACH in energy and node death scheme, also better then LEACH-L and LEACH-M. Even though it is not better than the EECA, but it's near it, in addition to that, the EECA doesn't consider all the network nodes while the contributed algorithm does.

This paper is an improvement on the EECA in that; it involves all network nodes that the EECA didn't. Also, the interval of node death is very close to EECA. Thus, the results in this paper are more realistic than the original EECA, and could be trusted over the all network life time cycle.

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