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RESEARCH ARTICLE

Coverage Improvement by Using RNCHE Algorithm Based on LEACH Protocol for Wireless Sensor Network

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Abstract

Maximization of Wireless Sensor Network (WSN) lifetime cannot be achieved without carefully scheduling the energy utilization. Energy saving represents one of the important factors that should be taken into account during the design of any routing protocol. It also explained that some applications require getting a high degree of network coverage to get a full knowledge about the events occurs in the different parts of the network.

This work present proposed a new algorithm which develops Low Energy Adaptive Clustering Hierarchy (LEACH) algorithm to improve the network coverage. That called Reduced Number of Cluster Heads Enhancement (RNCHE) and it aims at reducing the energy consumption by avoiding communication with the sink node from two adjacent cluster heads in the network and providing them in the parts that left without any cluster head after the phase that LEACH algorithm selects some nodes to be responsible for data gathering and transferring.

Keywords: LEACH, RNCHE, WSN and Advanced nodes

1. Introduction

LEACH is a self-organizing and adaptive clustering protocol and also a simple routing protocol in WSNs [1]. It uses randomization to distribute the energy load evenly among the sensors in the network [2, 3].

Recent advances in wireless communications and electronics have enabled the development of low-cost, low-power and multifunctional sensor nodes that are small in size and have sensing, data processing and communicating components [4]. These devices leverage the idea of sensor networks [5]. WSN consists of a large number, may be hundreds or thousands, of small devices, which are called nodes or motes, with sensing, computation and wireless communication capabilities distributed to monitor physical or environmental conditions such as temperature, sound, motion, etc. [6]. Nodes in WSN communicate over short distances through wireless channels for information sharing and cooperative processing to accomplish common tasks and they have many advantages over other traditional ad hoc networks such as easy deployment and low cost [7].

In this paper provide improved schemes based on LEACH. It presents algorithm; to deals with the formation of adjacent clusters which may be very close to each other so the network will consume energy to transfer redundant data. Adjacent cluster merging algorithm is energy saving and in order to verify the performance of this algorithm, the energy consumed by the cluster heads that will be merged is computed for both LEACH and RNCHE.

2. The Coverage in WSNs Problem Description

The random selection of cluster heads depended by LEACH protocol may result in the choosing of two adjacent nodes to be cluster heads at the same round [8]. So the two formed cluster will be overlapped and the distances between their members may be very small.

This case leads to consume energy to gather and transmit a redundant data especially when the two selected cluster heads are very close to each other [9]. RNCHE aims at avoiding data redundancy and reducing the energy that is consumed by the two adjacent cluster heads because it minimizes the number of data transmissions towards the sink using clusters merging.

Reducing the number of transmission times towards the sink has a great effect on the energy saving in the network since energy needed to communicate with the sink node is larger than that needed to gather information within the cluster range because of the large distances between the network nodes and the sink node.

3. The RNCHE Algorithm Description

The algorithm suggests that any two adjacent cluster heads; the distance between them is less than or equal a predetermined threshold, should be merged to form one cluster.

Clusters heads can dedicate the existence of other cluster heads in their communication range depending on their receiving to the "advertisement message", each cluster head can estimate the distance between it and the "advertisement message" sender according to the strength of the signal received then they compare the estimated distance with the pre-determined threshold. If the distance between the two adjacent cluster heads is less than or equal to the threshold value, the following RNCHE is applied.

The algorithm Suppose that CH1 and CH2 are two adjacent cluster heads, the distance between CH1 and CH2 is d which is less than or equal to T, T is a distance threshold that its value is determined previously depending on the sensing and communication ranges of the sensors, A1 is the area of CH1 cluster, i.e. the area determined by of the Cluster Radius (CR) of CH1. A2 is the area of CH2 cluster and S is the overlapping area between CH1 and CH2 clusters. In Figure (1) these two overlapped clusters are shown.

Suppose that CH1 has a higher energy level than CH2, CH1 and CH2 will be merged and CH1 will be the head of the cluster formed from their merging. Because it is not preferred to make CH1 exhausted with the transmission from data gathered from the new cluster resulting from clusters merging, CH2 partitions A2 into a grid of MxN square cells and it selects the only members that can preserve the coverage for its cluster region. CH1 will do the same with (S) to achieve more energy saving.

In case of receiving more than one "advertisement message", the node selects the nearest CH whose energy level is more than the residual energy it has.

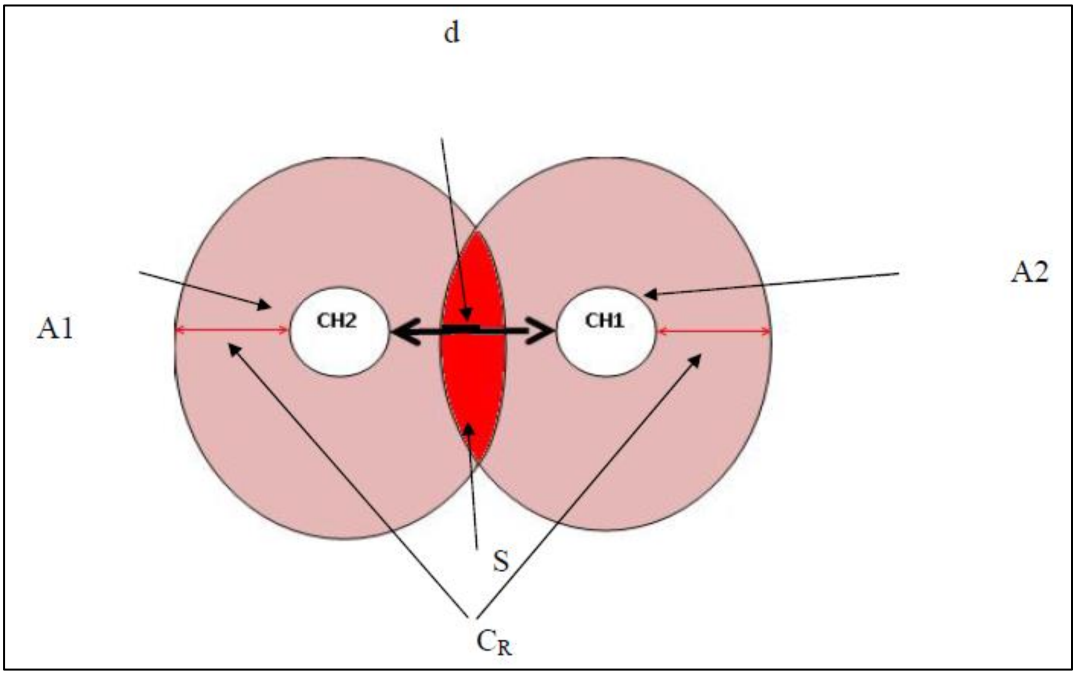

Figure 1: The overlapping between two clusters.

The area of the overlapping is mainly depended on the distance between the two clusters heads, the steps of RNCHE are as follows:

1. According to advertisement message, the energy values of both **CH1** and **CH2** are known by each other's.
2. Suppose **CH1** energy level > **CH2** energy level.
3. **CH2** divides **A2** into **MxN** square cells with **W** length, where **W** varied according to the sensing range of the sensors.
4. If there are more than one member of **CH2** in one cell, only one is selected.
5. **CH2** sends a message to **CH1** containing the ID's of the selected members in (4).
6. **CH1** partitions **S** into a grid into **KxL** square cells with the same**W** used by **CH2** in step (3).
7. For each cell in **S**, **CH1** do the following:

    If this cell contains **CH1** member together with **CH2** selected member, ***then*** **CH1** ignore it's member. ***Else*** it select this member (Figure 2.a. steps 3-7).
8. **CH1** sends a message to **CH2** which includes the time slot that **CH2** should start with in order to schedule it's selected members to avoid collision during data transmission.
9. **CH1** schedules all its members that have been chosen in (7).
10. **CH2** schedules all its selected members with a scheduling message which contain the ID of **CH1.** The selected members of **CH2** cluster terminate the connection with **CH2** and send their data to **CH1** (Figure 2.b).
11. Members of **CH1** send their data **CH1** as normal.
12. CH1 aggregates the whole received data and sends the aggregated data to the sink.

Algorithm 1: RNCHE algorithm.

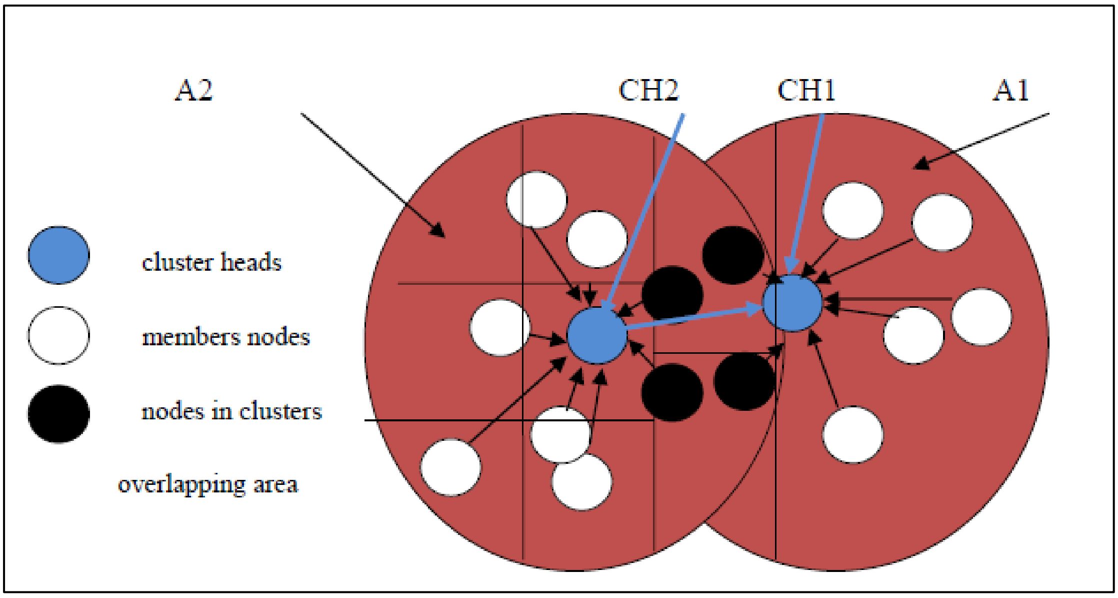

Figure 2.a: The partitioning of CH2 cluster region and the overlapping area.

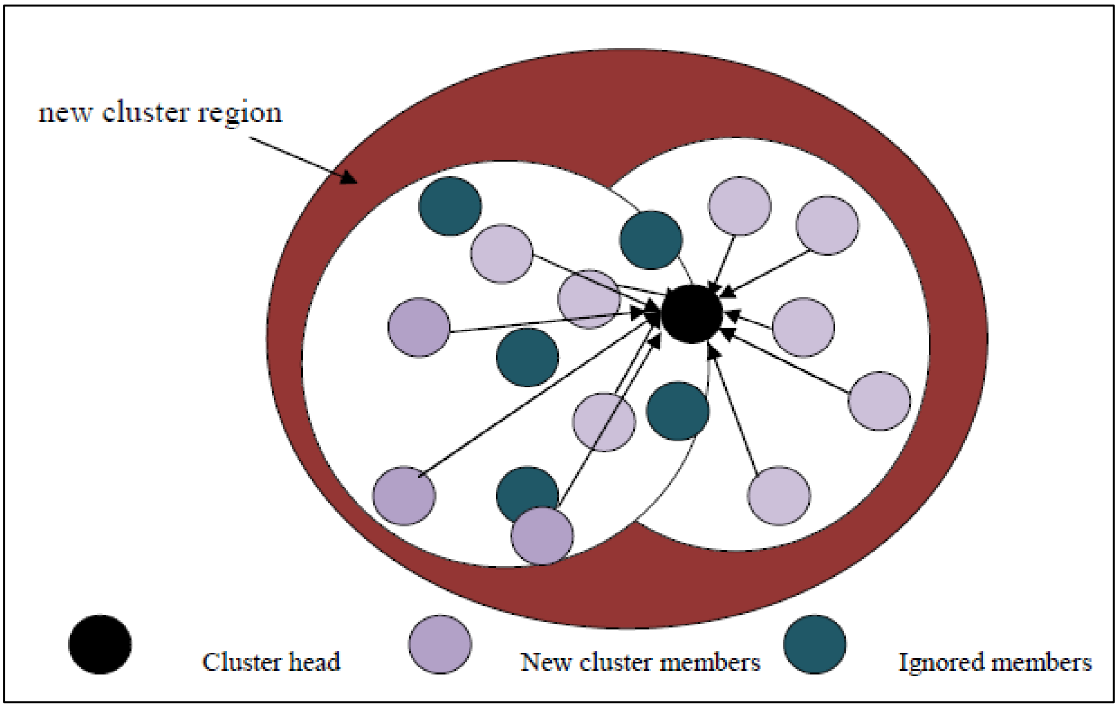

Figure 2.b: New cluster construction.

Figure 2: Adjacent clusters merging.

4. Performance Measurement

LEACH protocol and the proposed algorithm are simulated using the proper environments, then the results are recorded and compared depending on certain comparison factors.

Since the important goal of the adjacent cluster merging algorithm is energy saving and in order to verify the performance of this algorithm, the energy consumed by the cluster heads that will be merged is computed for both LEACH and RNCHE. The following procedure is applied to compare the results:

- The energy value of each cluster head is recorded before and after the round at which it acts as cluster head. The difference between these two levels is computed to find out the energy consumed when the nodes served as CH.
- The difference values -calculated in the previous step- of the CHs that will be merged when applying the cluster merging algorithm are accumulated together to computed the total energy consumed by the two adjacent cluster heads, the summation values of LEACH protocol will be compare with the corresponding values of cluster merging algorithm.

The second proposed algorithm is not only concerned with energy levels, this algorithm aims also to increase the number of nodes that sending their data to the sink in the parts where no coverage is provided by LEACH, so two factors are depended to show the algorithm efficiency; they are the number of active nodes (nodes that send data to their normal or advanced CHs) and the energy levels of the normal nodes.

After a certain number of execution rounds, the number of the active nodes are computed and compared for each round for both LEACH and the proposed algorithm, The energy levels of nodes after the last round is also compared in order to see that the normal nodes energies are kept without a great change by the additional data gathering tasks caused by the responses to the queries sent by the advanced nodes to provide the necessary coverage. The reason behind the energy keeping of the normal nodes is that the cluster heads responsibilities are taken by advanced nodes.

This work provides many of the conditions that should be taken into account to ensure a fair comparison. These conditions are:

- **The similarity between the simulation topologies:** The locations of the normal nodes deployed in the two environments used to simulate LEACH protocol and the new algorithm are exactly the same and the existence of the advanced nodes in the second algorithm environment would never affect the locations of the normal nodes, the sizes of the networks and the sink nodes locations were also the same. This accurate similarity is essential because the changing of nodes locations leads to changing the adjacency of the nodes and the distances between them, this will affect the energy consumed by the CHs because of the variation of the number of their neighbors and the distances between them which make the comparison operation untrusted.
- **The similarity between the cluster heads nodes at each round:** The nodes that will act cluster heads at each round of the execution of the algorithm that are wanted to be compared should be the same. To explain the meaning clearer consider the following example: If the nodes with IDs 7,15,38 and 40 are acting as CHs in

round (0) of LEACH protocol, the same nodes should be forced to be cluster heads at the same round during the execution of the proposed algorithms.

5. The Reduced Number of Cluster Heads Enhancement Algorithm Results:

Reduced Number of Cluster Heads Enhancement algorithm is tested three times for each one of the three environments (50, 75 and 100 nodes environments), LEACH is executed first, CHs are selected randomly depending on LEACH algorithm and the nodes that acted as CHs during each round of the simulation is recorded in order to use them as cluster heads at the same rounds during the simulation of the proposed RNCHE algorithm. Energy values are calculated according to the radio energy model, are used to calculate the energy consumed by the two adjacent cluster heads during the round they act as cluster heads in LEACH and after the clusters merging using RNCHE algorithm.

Some of the runs contain more than one merging case and this mainly depends on the locations of the cluster heads that selected randomly by LEACH, in these cases the results of only two merging cases are presented.

Tables (1, 2 and 3) show the summation of the energy consumed by the adjacent cluster heads before and after their merging using 50, 75 and 100-nodes networks respectively.

Figures (3, 4 and 5) contain two columns, the first one represents the summation of the energy consumed by the two CHs in LEACH while the second represents that summation after applying the merging algorithm.

Figure (3) shows the results of the first, second and third simulation runs using the 50-nodes network. In the same manner, Figure (4) explained the results of 75-nodes network while the results of first, second and the third simulation runs of the 100-nodes network are shown in Figure (5).

As it has mentioned earlier, some simulation runs have more than one merging case.

Table 1: The energy values of the adjacent cluster heads in 50-nodes network.

	Energy consumed by the adjacent CHs in LEACH (Joule)	Energy consumed by the adjacent CHs in RNCHE (Joule)
First simultion run	0.00301	0.001153
Second simulation run	0.002899	0.0008
Third simulation run	0.003994	0.003034

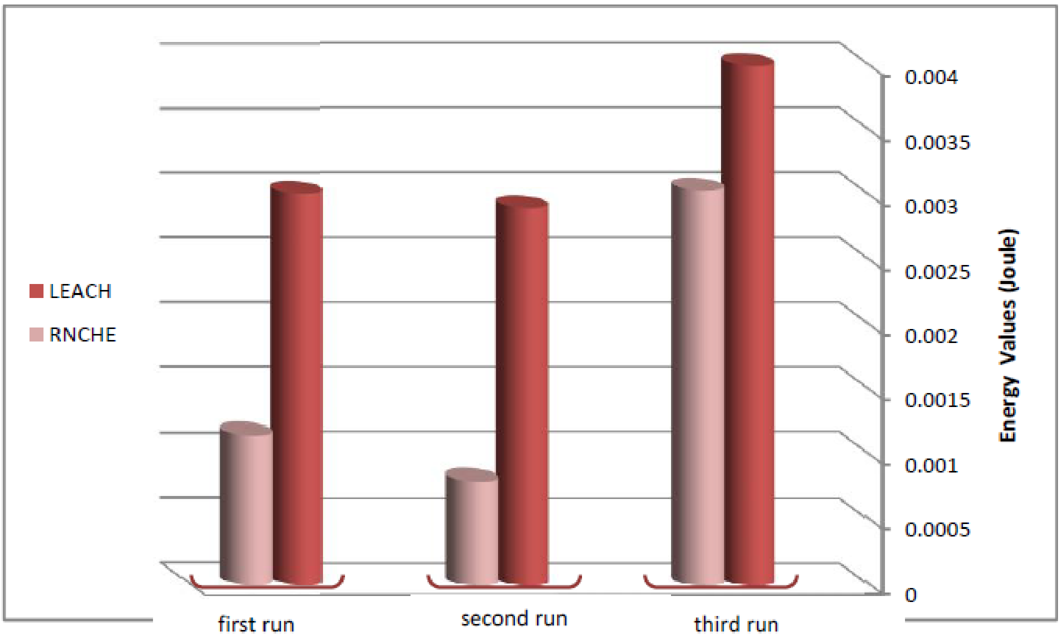

Figure 3: The results of the 50-nods network.

Table 2: The energy values of the adjacent cluster heads 75-nodes network.

		Energy consumed by the adjacent CHs in LEACH (Joule)	Energy consumed by the adjacent CHs in RNCHE (Joule)
First simultion run	First merging case	0.001593	0.001053
	Second merging case	0.002795	0.002226
Second simulation run	-----	0.003436	0.002599
Third simulation run	First merging case	0.003233	0.00261
	Second merging case	0.00212	0.001922

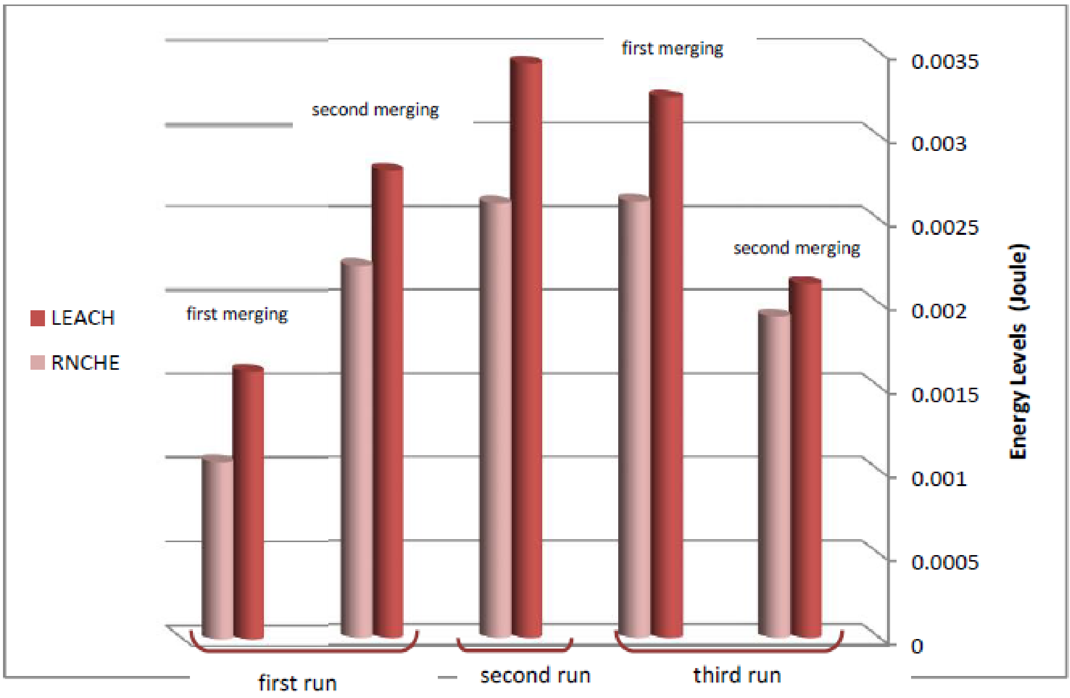

Figure 4: The results of 75-nodes network.

Table 3: The energy values of the adjacent cluster heads 100-nodes network.

		Energy consumed by the adjacent CHs in LEACH (Joule)	Energy consumed by the adjacent CHs in RNCHE (Joule)
First simultion run	First merging case	0.00423	0.003995
	Second merging case	0.001327	0.001129
Second simulation run	First merging case	0.00227	0.001781
	Second merging case	0.001377	0.001115
Third simulation run		0.001327	0.001129

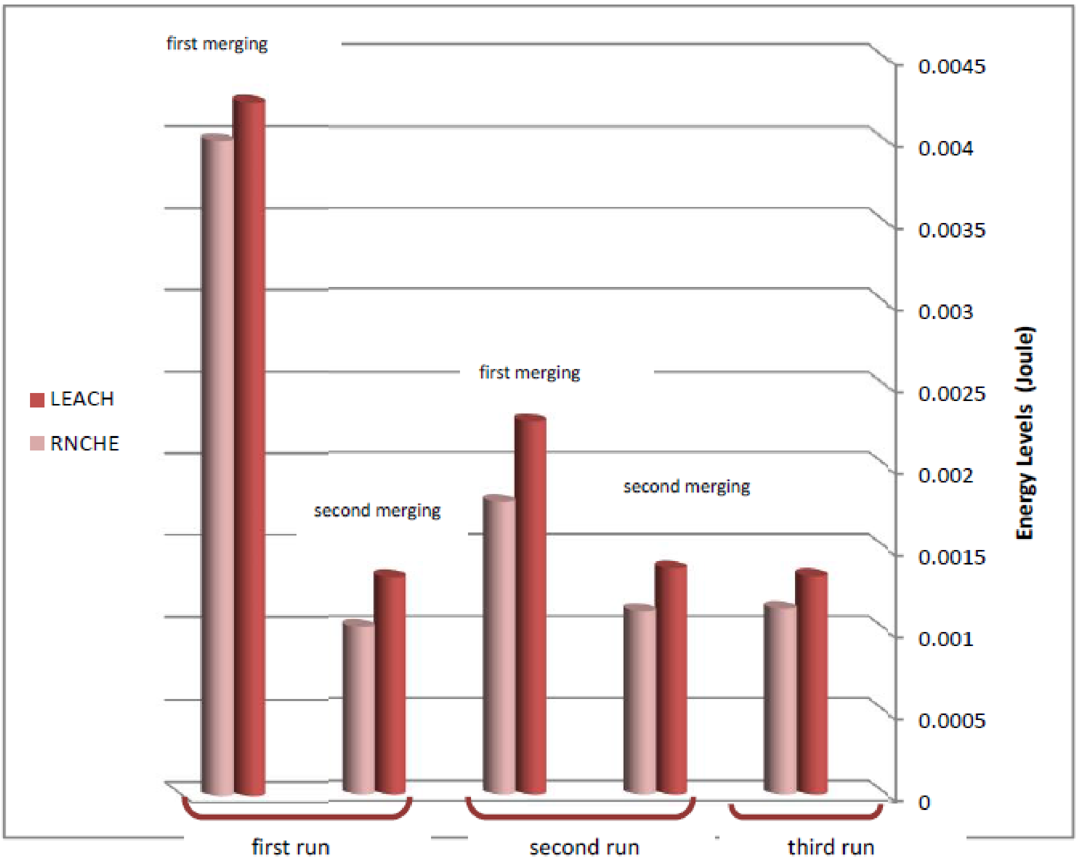

Figure 5: The results of 100-nodes network.

It is clear from the above charts that there is a significant difference in the total consumed energy by the two algorithms, this makes RNCHE helps in energy saving. It can easily concluded from the values of the consumed energy shown in Tables (1, 2 and 3) that there is a difference between the energy consumed by the adjacent cluster heads before and after their merging. Although these differences are in the third or fourth decimal points but this values are significant compared to the initial value of the sensor's energy (0.5) which is expected to work during long periods of time, besides that these differences represent the saved energy at single round and it will be increased by the reputation of the merging cases during the whole the network lifetime.

It can be noticed also that the amount of energy saved is varied from one merging case to another and this mainly depended on the numbers of the nodes that both of the cluster heads could give up when they applied the clusters area partitioning.

In the first and second merging cases in Table (1), the amount of the energy needed to transfer data from the cluster heads after the applying of RNCHE is very small compared with that was spending by them before merging. This occur because the number of the member nodes in cluster with low energy level is small or lying in adjacent locations.

By the increasing of nodes density, the number of merging cases is increased and this will have a good effect on the total consumed energy at each simulation run even when the amount of the saved energy in each single merging case is not very large. In Table (2), the total saved energy (the summation of the differences between consumed energy before and after merging) in the two merging cases at the first simulation run is (0.001109) which represent approximately 60% of the energy needed by the cluster heads in the second merging case before their merging which is equal (0.001593). the is also true in the (100-nodes) network where the amount of the total saved energy in the first simulation run is (0.000433) which represents (1/3) of the energy consumed by the two adjacent clusters before merging.

It is important to take into account that:

- In simulation runs that contain more than one merging case the results of only merging cases are presented, the additional merging cases will help in keep more amount of the network energy.
- Data aggregation strategy has a great effect on the results. In this work it is assumed that the (1/3) of the received data is redundant, the results can be improved when the user applies another parameter or aggregation function. If the used aggregation function is MAX, for example, the energy required by the cluster head of the cluster formed from clusters merging (the cluster head with high energy level) to transmit the (MAX) value will be the same before and after its merging with another cluster head since it represents a single value. This will make RNCHE algorithm reduce the energy needed by the merged cluster heads to half of the energy before merging.

6. Conclusions

Sensors spent more of their energies in messages transferring and according to the radio dissipation energy model, the amount of the consumed energy is highly affected by the distance between the source and the destination of the communication.

Reduction of the number of the nodes that send data for large distances, i.e. towards the sink, is the basic concept that depended by clustering protocols and it is one of the main factors of the efficiency of these protocols. In clustering, only one node at each cluster sends the data of its neighbors to base station, this will prevent data transferring from all the nodes. The idea is applied in RNCHE, in the algorithm the merging cases reduce the number of the communications with the sink while the normal nodes in the newly covered parts will be used only for intra – cluster communication.

7. Future Works

RNCHE algorithm can be extended to include the combination of more than two adjacent clusters using any other suitable merging conditions. And also can be combined with a powerful data aggregation algorithm to achieve more energy saving. Fuzzy logic mechanism can be considered as a mean of providing new conditions in the adjacent clusters merging.

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