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Prolonging sensor networks lifetime using convex clusters

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Abstract

Reducing the energy consumption of nodes in sensor networks and prolonging the network life time has been proposed as one of the most important challenges facing researchers in the field of sensor networks. Therefore, designing an energy-aware protocol to gather data from network level and transmitting it to sink is placed on the agenda at this paper. After presenting an analysis of the processes of clustering in sensory networks and investigating the effect of sending interval on the amount of energy consumption, We have shown that if the use of convex static casters be done such as all the communications within the cluster with the sending distance less than the optimal threshold, it Will help to increase the lifetime of nodes. also have shown that if we create a virtual backbone between cluster heads to transfer far cluster heads data from sink to sink , will has a significant impact on increasing the network lifetime. For this reason, a detailed discussion on how to determine the size of clusters and partitioning of the network environment to them is presented in Chapter 4.Simulation results show considerable improvement of the proposed algorithm.

Keywords: *Sensor Network, Energy Consumption, Lifetime, Clustering, Convex Set*

1. Introduction

Due to the design constraints, sensor nodes must be made cheap and small. Therefore from the standpoint of the type of power supply used and due to steady much work, they frequently faced with some problems. One way to solve this problem is simultaneously using a large number of sensor nodes in one area.

Topology of sensor networks [1], although in some cases is predetermined and with replacement of the nodes are tried to reduce the cost of communication between nodes, but in most cases, the sensor nodes without considering a specific topology and randomly are distributed in environment[2, 3]. One of the major challenges facing sensor networks is incapability of recharging batteries of nodes. According to the release random of nodes in network environment, as well as their low cost, recovery and recharging of the nodes are economically unjustified. So, some parts of the work done in the world of wireless sensor networks have been assigned to the area of reducing energy consumption of

nodes. Reducing energy consumption of a node is interconnected with another concept known as increasing lifetime of the network. The life of a sensor network depends on the life of its nodes. Life of a node is defined as the time during which the node is able to perform its duties. Up to now various solutions have been proposed for reducing energy consumption in sensor networks in which has presented based on clustering [4,5,6] and multilevel clustering [7,8] solutions and using a virtual backbone [9, 10].

In this paper, what we follow it, is presenting a new clustering solution based on the concept of convex sets so that all inter-and intra-cluster communication be done with the communication distance less than optimal threshold.

The rest of the paper is organized as follows: The second section, investigates the model of energy consumption in sensor nodes. The third section reviews the related works. The fourth section presents a detailed explanation of the proposed method and In Section fifth simulation results are presented. Also sixth section presents the conclusions and recommendations for future work.

2. Energy Consumption Model

As noted earlier, the energy consumption is one of the most important challenges facing protocol designers of wireless sensor networks. The nature of sensor networks which tends to smaller and cheaper nodes prevents a permanent solution to this challenge. Hence, researchers are always looking for ways to reduce the energy consumption of nodes in performing different protocols.

Energy consumed in an active node is composed of three parts, the energy consumed for sending a message (P_T), the energy consumed for receiving a message (P_R) and the energy consumed for augmenting or processing a message (P_{cpu}). It is worth noting that an active node is a node which is involved in performing network operations and protocols, and it is responsible for a part of performing network

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activities. If we assume that a transmitter requires to consume energy with an amount of E_{elec} (in terms of joules) to set up its radio circuit for sending one bit, then the amount of energy consumed in transmitter radio circuit for sending data with an amount of k bit, it needs a receptor in d meter which is shown with $P_T(k)$. This is calculated according to Eq.(1).

$$P_T(k)=E_{elec}\times k+E_{amp}\times d^{\gamma}\times k \qquad (1)$$

In Eq. (1) E_{amp} is energy consumed in amplifier to boost sending signal so that the received signal can be decoded at the receiver. Dissipation power of the distance has also been shown by γ.

Accordingly, the energy consumed at the receiver to receive a k-bit data packet which is shown by $P_R(k)$, can be calculated by Eq. (2).

$$P_R(k)=E_{elec}\times k \qquad (2)$$

Also, if we show the energy consumed in the processor of a sensor node for processing one bit by E_{cpu}, then the energy consumed in sensor node for processing a k -bit packet which is shown by $P_{cpu}(k)$ can be calculated according to Eq. (3):

$$P_{cpu}(k)=E_{cpu}\times k \qquad (3)$$

3. Clustering algorithm LEACH

In LEACH [26] that is a two-level hierarchical protocol, the clusters form in a distributed and self-configured manner. This led to increasing of scalability of the protocol. In LEACH, discrete time has been considered, which means that the time has been divided into small parts that is called time frames. Running LEACH algorithm carried out alternatively in the number of rounds (each round consists of a number of time frames). This algorithm has two phases, Setup Phase and Steady State Phase which in turn are executed in each round.

In Setup Phase, at first the number of nodes as cluster heads are chosen randomly. The number of Nodes of cluster heads, is calculated according to equation (4).

$$k_{opt}=\frac{\sqrt{N}}{\sqrt{2\pi}}\sqrt{\frac{E_{fs}}{E_{amp}}}\frac{M}{d_{toBS}^2} \qquad (4)$$

In this equation, N is the number of network nodes, E_{fs} is energy consumption in radio circuit to amplify the transmitted signal in space model multi-path propagation, E_{amp} is Energy Consumption in radio circuit to amplify the transmitted signal in free space model, M is the side length

of the network and d_{toBS} is also the distance between each node to the sink.

LEACH has no assumption about how to select cluster heads except establishing the balance between energy consumption in network nodes through the equality in the number of the times of being cluster heads. In other words, in LEACH, the probability of being cluster head in a node increases over time (Over a period of time from the running of algorithm).LEACH by doing it in this way tries all nodes be selected in the same number of time as the cluster head.

4. Proposed Solution

LEACH algorithm suffers from numerous difficulties, one of their most fundamental is the large distance in the most of the cluster nodes from sink. The large distance between cluster nodes, particularly in the case of nodes far from sink, is an effective factor in the energy consumption of a cluster node. Another problem of this algorithm is non-uniform distribution of cluster heads. As regards to this point that cluster heads are selected completely at random, It is possible that the density of cluster heads to be high in one part of network zone and in another one to be low and as each node of cluster heads selects its cluster head according to their distance, so the number of member of different clusters would be different.

After presenting LEACH algorithm, improvements like E-LEACH [6], H-LEACH [11] and HEED [5] algorithms have been presented in which all of them were significantly successful in improving network lifetime. But each of these algorithms have solved only part of the problem. And none of them not have guarantees about the distance between cluster heads and just do trying the distance to be convey at least possible.

We believe that creating clusters which establish following condition led to prolonging network lifetime:

- Reducing the distance of inter-cluster communication such that the distance of each node to communicate with cluster head be less than maximum of radius of the neighborhood of the optimal (d_{opt})

- Creating a chain of cluster heads such that each cluster heads get help from the head cluster between itself and the sink for transmitting data to sink instead of communicating directly to the sink.

- Reducing the distance of intra-cluster communications such that the distance of each cluster heads to communicate with the next cluster head be less than maximum of radius of the neighborhood.

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- Appropriate distribution of cluster heads in all network environments.

The proposed algorithm to establish four conditions in above presents two phase of clustering and set up in the order that will be explained.

- **The clustering phase**

  To provide the clusters with the above condition with the assumption of possessing square-shaped clusters the size of the side of cluster should be such that the maximum distance of two nodes inside it not more than $d_{opt.}$ Consider fig 1.
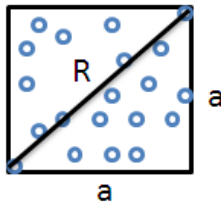

Fig. 1 a view of the proposed cluster

The maximum distance between two nodes in such cluster will be equal to the diameter of the square. This means that to meet the first condition, that is, reducing the distance of inter cluster communication to some extent is less than maximum of radius of the optimal neighborhood, relation (5) should be established.

$$\sqrt{2}a = R \le d_{opt} \tag{5}$$

The maximum of the size of the side of the cluster equals:

$$a = \frac{d_{opt}}{\sqrt{2}} \tag{6}$$

But it doesn't end in this point. There is still one more important condition that will affect on the cluster size. As mentioned before, in the proposed solution the intra cluster communications also should be established with the transmission distance less than the maximum of radius of the optimal neighborhood. Consider fig 2.
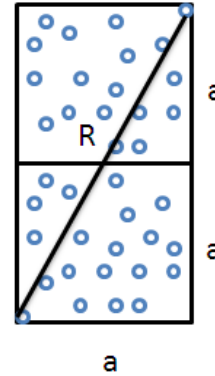

Fig. 2 a view of two adjacent cluster

As you see, to fulfill this condition, the farthest distance of two points within two adjacent cluster must be less than the maximum of radius of the neighborhood of the optimal. So according to Pythagorean theorem we have:

$$\sqrt{5}a = R \le d_{opt} \tag{7}$$

The maximum of the size of the side of the cluster equals:

$$a = \frac{D_{opt}}{\sqrt{5}} \tag{8}$$

Therefore to meet both of these two conditions, relation (8) should be established.

In the proposed algorithm, the size of the cluster has the direct proportion to the maximum of radius of the optimal neighborhood. It means whatever the size of the maximum of radius of the optimal neighborhood be greater, the cluster size will be larger, as a result the number of clusters has the direct proportion to the size of the network area. The relation (9) represents the number of clusters in the proposed algorithm. In this relation, M represents the size of the sides of a square-shaped network environment.

$$N_{Clusters} = \left(\frac{\sqrt{5}M}{d_{opt}} \right)^2 \tag{9}$$

Equations (8) and (9) show that the number of clusters formed by proposed algorithm depends on the hardware characteristics of the sensor node. Our recommendation to reduce the communication cost of far nodes from the sink with the sink is based on the use of several virtual backbone.

Figure 3 shows the data flow between cluster heads to deliver the data to the sink.

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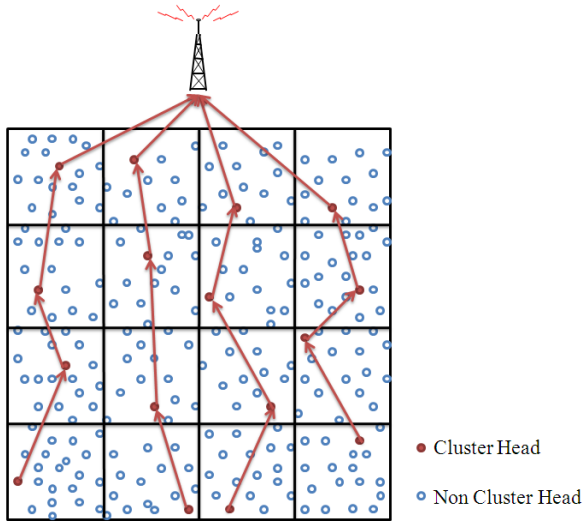ISSN : 2322-5157
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Fig. 3 the data flow between cluster heads to deliver the data to the sink.

In set up phase, after network clustering, must be decided to determining the cluster heads in each cluster. The priority of becoming cluster heads in proposed algorithm is with nodes that have further remaining energy. Therefore at the beginning of this phase, each node according to the difference in the amount of their remained energy from its initial one adjust a counter and then proceed to countdown. Each node which ends the counting earlier introduce itself as the cluster head with the sending a message for its cluster member nodes.

Node of the cluster head then start to build a TDMA schedule and inform it to the other nodes. Using TDMA schedule will prevent the occurrence of inter cluster interferes. The application of this method with the assumption that nodes always have data to transfer, it will have the best performance. It also assumes that the last time slice for sending data to cluster head in the timeline above is related to the downwards node of the cluster head.

- **Steady State Phase**

This phase is quite similar to the steady-state phase in LEACH algorithm. Each node based on the TDMA schedule announced by the cluster head, send their data to the cluster head. Cluster head after receiving the data from nodes of downwards cluster and cluster head, aggregate them and send the final data for upwards cluster. Upwards cluster head to the last row of the cluster heads, is sink. As regards this is possible that nodes of adjacent clusters be simultaneously sending data to their cluster heads, there is a possibility of interference inherently. In the proposed solution such as LEACH algorithm has been assumed that nodes use broad-spectrum method with direct sequence and also each cluster use a unique code to expanding the transmitted data in access spectrum.

As we mentioned the criteria for determining the cluster heads in each cluster is their remaining energy. Using this criterion, however, may cause the number of clustering in some of the nodes increase than another part of the network but eventually helps justly distribution of energy consumption.

Figure(4) shows the order of clustering phases implementation and steady state in the proposed algorithm. As you can see in this figure, the steady-state phase can include one or more time slice. Increasing the interval length of the steady-state phase helps to reduce the size of the message exchange in order to determine cluster heads, but on the other hand, it led to increasing energy consumption concentration on a specific group.
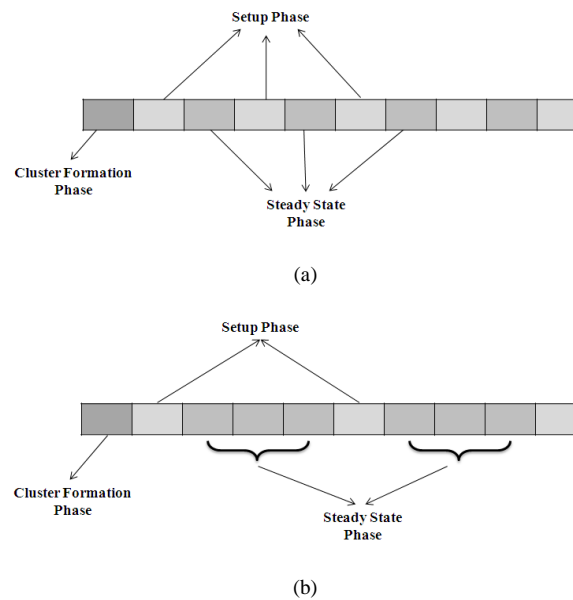

Fig. 4 a view of the order of implementation of triple phases in the proposed algorithm

5. Simulation results

In this section we intend to provide groundwork of creating a simulation of the proposed algorithm to evaluate the performance of the proposed algorithm. to this end, First, we will examine the simulation details and environment and then using the figures obtained from simulation implementation We will show that the proposed algorithm has been caused significant improvement, especially in areas with higher density.

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a. Simulation environment

In order to evaluate the performance of the proposed method has been done a simulation round with the MATLAB software that its result will be discussed in the next section. For this purpose, four hundred sensor nodes have scattered randomly and with uniform distribution in a square-shaped network environment in 120 meters to the side. All nodes have been considered contain the same hardware and software characteristics, in the other words, the network is a homogeneous network. Table (5-1) has provided physical characteristics of the nodes and simulation environment.

Table 5.1: Simulation Parameters

Network Grid	A square area of 120×120 m
Initial Energy	0.5 j
Data Packet Size	1000 bit
Control Packet Size	200 bit
E_{cpu}	7 nj
E_{elec}	50 nj/bit
E_{mp}	0.0013 pj
E_{fs}	10 pj
d_{opt}	75 m
Sink	(60, 175)

The simulation process is repeated 10,000 times and in the same condition and after the result averaging have been presented in Figure 5. In this diagram, the horizontal axis shows passing the time based on time slice and vertical axis indicates the number of live nodes at any time. The phase length of steady state for both algorithms has been considered in the size of a time slice.
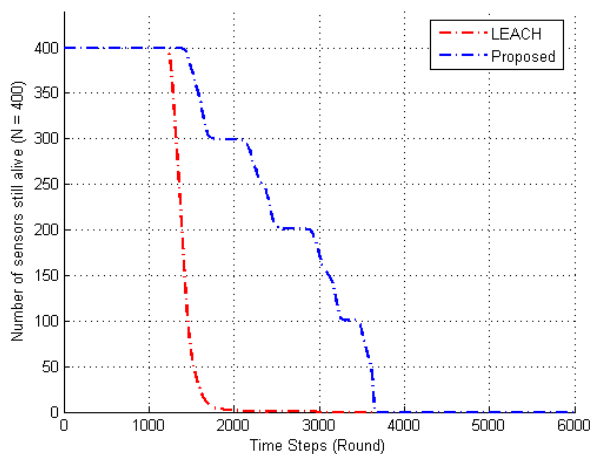
As you can see in this diagram, The proposed algorithm has achieved a significant improvement compared to the LEACH algorithm and this performance difference between the proposed algorithm and LEACH algorithm has been more and more in over time.

As we noted in Chapter 2, there is no attributable definition of network lifetime and the it is generally defined by the type of application of sensor network. But the above diagram shows the network lifetime in the proposed algorithm, for each definition of lifetime, has had a better performance.

The diagram presented in Figure (6) has compared the amount of energy of the most energetic node in the rounds from 100 to 500 between two proposed algorithm and LEACH. As you can see, in all cases, the remained energy of the most energetic node in proposed algorithm is more than the most energetic node in LEACH algorithm.
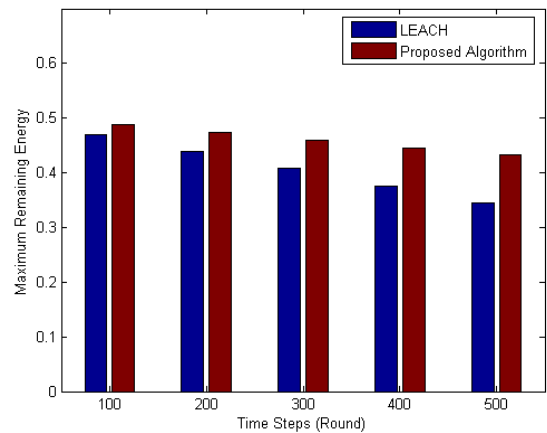

Fig. 6 Comparison of the energy of the most energetic nodes in proposed algorithm and LEACH algorithm in rounds from 100 to 500 (N = 400)

Fig. 5 Comparison of network lifetime in the proposed algorithm and LEACH algorithm (N = 400)
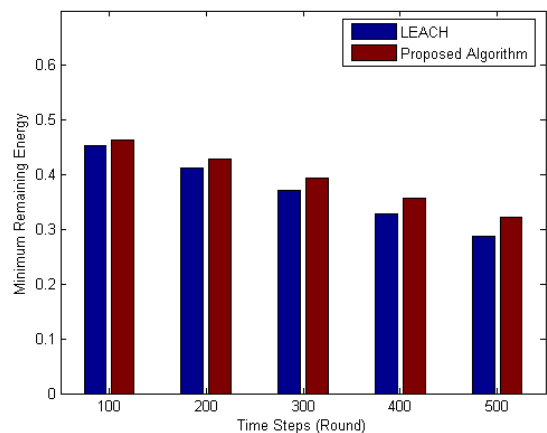

Fig. 7 Comparison of the energy of very low energetic nodes in proposed algorithm and LEACH algorithm in rounds from 100 to 500 (N = 400)

Also Figure (7) has provided a comparison of the energy of very low energetic nodes and the most energetic nodes in rounds from 100 to 500 (N = 400). Again we see that the situation of the proposed algorithm in this case, also is better than the LEACH algorithm.

In sequence, have been implemented the above simulation for networks with different densities which obtained results have shown in Figures (8),(9),(10)and (11). As you can see, in the proposed algorithm in networks with higher densities, the situation is more acceptable and the amount of lifetime network improvement is much better in networks with higher density.

Therefore ,overall the proposed algorithm in networks with lower density has had better performance than LEACH algorithm but this improvement is more evident when for a while the first node to be passed away.
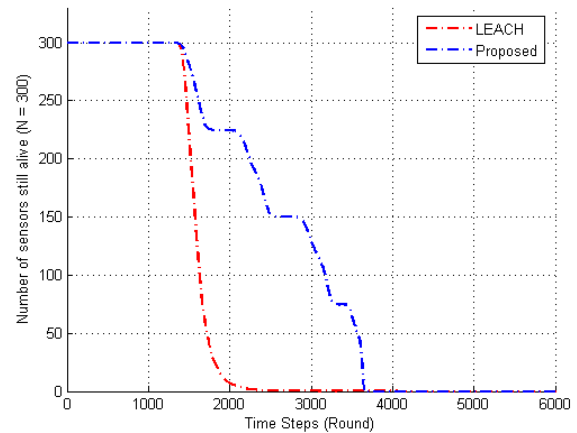

Fig. 10 the comparison of the network lifetime in the proposed algorithm and LEACH algorithm(N = 300)
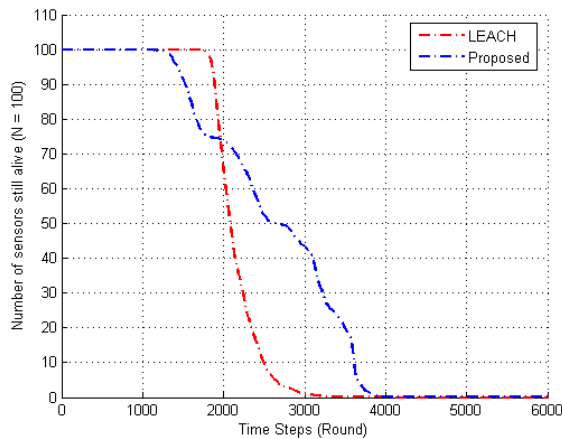

Fig. 8 the comparison of the network lifetime in the proposed algorithm and LEACH algorithm(N = 100)
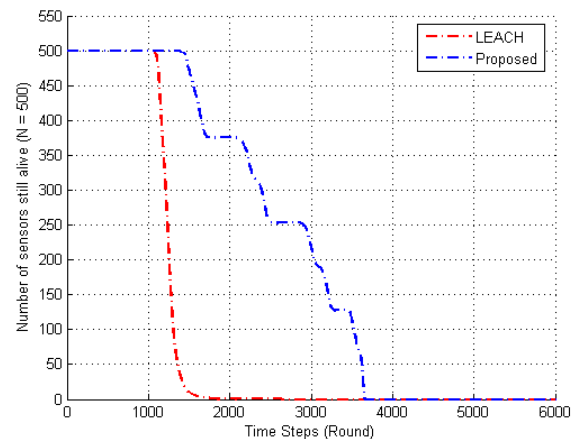

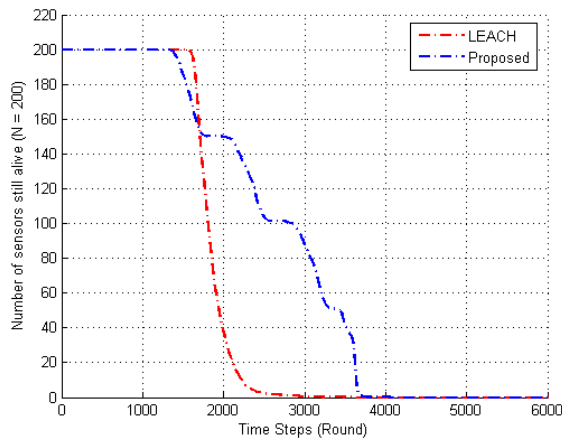Fig. 11 the comparison of the network lifetime in the proposed algorithm and LEACH algorithm(N = 500)

Fig. 9 the comparison of the network lifetime in the proposed algorithm and LEACH algorithm(N = 200)

On account of the proposed algorithm improvement than LEACH algorithm in some networks with the higher density it must be said that as the result of the distribution of the task of clustering on the more of the nodes, the consumption energy of a node during a given period of the life of the network decreases. As before mentioned, in proposed algorithm increasing the number of nodes does not affect in the number of clusters. So by increasing the network density, the number of clusters doesn't change, and therefore the clusters density increases as network density does.

In sequence, a simulation round was applied in order to evaluate the effect of the size of the control package on the performance of the proposed algorithm compared to LEACH algorithm. For this purpose, a network with 400 sensor node and the simulation parameters embed in Table 1 were considered and the simulation operations of 10,000 implementation round and the results after averaging were inserted in the fig. 12.
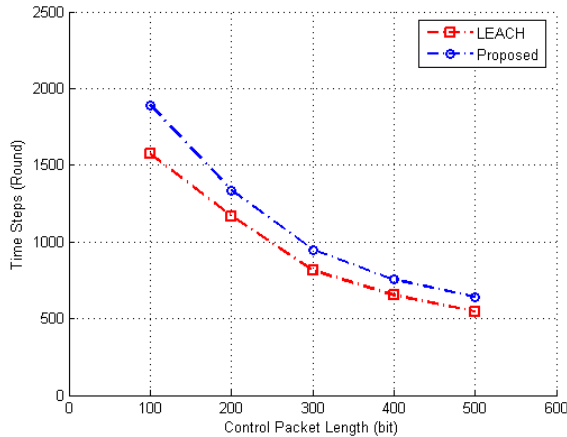
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Fig. 12 survey the effect of increasing the length of control packets on network lifetime (N = 400)

More of the dynamic clustering algorithms due to the repetition of clustering process requires a lot of control packet exchanges that their size has a significant effect on increasing and decreasing of nodes and network lifetime. Figure (12) illustrate the horizontal axis of the size of control package length and the vertical axis shows passing the time based on time slices. As you can see, both of the proposed algorithm and LEACH algorithm simultaneously with the increasing of the control package length have faced with the severe low efficiency and that means performance dependence of both of algorithms to the length of the control package which is not desirable. It should be noted that in this diagram has been used this definition that "the network lifetime, is a period of time which lasts until the first node of the network die.

6.   Conclusion and Future Work

  Energy consumption in wireless sensor networks due to design constraints have been considered among researchers. One of the most important factors in the amount of energy consumption is the distance between the sender node and the receiver node such that if this distance is not more than d_{opt} with the power of 2 and otherwise with the power of 4 will apply in relation of the energy consumption.

In this paper, after an overview of the LEACH algorithm and survey its various aspects the solutions based on the use of convex clusters to reduce the communication distance between the sensor nodes were proposed. in the proposed solution, assuming that the sensor nodes are equipped with GPS, each node will be able to determine their cluster. After clustering, the cluster heads which are selected periodically, in turn and based on the amount of remained energy perform the operation of collecting received data and eventually using the inter cluster relation send cluster data to the sink. The simulation results demonstrate well the

amount of the improvement obtained from using the clusters convex. As a suggestion for future work, recommends combining the methods based on cooperation and k-means methods in constructing cluster heads.

References

[1] M. Li et al., "A survey on topology issues in wireless sensor network," *in Proceedings of the 2006 International Conference on Wireless Networks,* las vegas, Nevada, USA, pp. 503-509, 2006.
[2] K. Kar et al., Node Placement for Connected Coverage in Sensor Networks, *in Proceedings of Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks (WiOpt),* 2003.
[3] C. Bettstetter et al., The Node Distribution of the Random Waypoint Mobility Model for Wireless Ad Hoc Networks, IEEE Transactions on Mobile Computing, v.2 n.3, p.257-269, March 2003.
[4] W. R. Heinzelman et al., "Energy efficient communication protocol for wireless microsensor networks ," *in Proceedings of the 33rd Hawaii International Conference on System Sciences (HICSS'00)*, Maui, USA, 2000.
 [5] O. Younis et al., "HEED: A hybrid, energy-efficient, distributed clustering approach for ad-hoc sensor networks," *IEEE Transactions on Mobile Computing,* vol. 3, no. 4, pp. 366-379, 2004.
[6] F. Xiangning et al., "Improvement on leach protocol of wireless sensor network," *in Proceedings of International Conference on Sensor Technologies and Applications (SensorComm'07),* Valencia, Spain, pp. 260-264, 2007.
[7] S. Bandyopadhyay and E. Coyle, "An Energy Efficient Hierarchical Clustering Algorithm for Wireless Sensor Networks", *Proc. INFOCOM 2003*, vol. 3, pp.1713 -1723
[8] S. Banerjee and S. Khuller, A Clustering Scheme for Hierarchical Control in Multi-Hop Wireless Networks, *Proc. IEEE INFOCOM,* Apr. 2001
[9] J. He et al., "Constructing a load-balanced virtual backbone in wireless sensor networks," *in Proceedings of the International Conference on Computing, Networking and Communications (ICNC' 12),* Maui, USA, pp. 959-963, 2012.
[10] Z. Liu et al., "A survey on connected dominating set construction algorithm for wireless sensor networks," *Journal of Information Technology,* vol. 9, no. 6, pp. 1081-1092, 2010.
[11] G. R. Wairagu, "Extending leach routing algorithm for wireless sensor networks," M.SC Thesis, Faculty of Computing and Information Technology, Markerere University, 2009.