Global Journal of Computer Science and Technology
Volume 11 Issue 4 Version 1.0 March 2011
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 0975-4172 & Print ISSN: 0975-4350

A Novel Energy Efficient, Distributed, Clustering Based Network Coverage Method For Enormous WSN

By Mohammad Mehrani, Ali Shaeidi
Islamic Azad University, Iran.

Abstracts : There are some limitations for wireless sensor networks that energy consumption is from the most important ones. This means energy factor has to be considered in all the sensor network activities. Coverage is one of the most important purposes of such networks. In this paper we want to enhance the coverage power of an entire network by using an energy efficient distributed method which works with a clustered network. This new coverage method is based on our last works presented for wireless sensor networks. The presented method uses FEED clustering method (our last work presented for network clustering) for partitioning the sensors in some groups. Then, some pivot nodes will manage the inter cluster coverage. Selecting just a node to act as the covering active node in each sub-area leads its neighbors to switch to standby mode and save energy. This is done in all over the network region thus energy saving happens in all over the network and consequently network life time increases as well.

Keywords : *Coverage, clustering, sub-area, lifetime*

Classification: *GJCST Classification: H.3.3, C.2.4*

A NOVEL ENERGY EFFICIENT, DISTRIBUTED, CLUSTERING BASED NETWORK COVERAGE METHOD FOR ENORMOUS WSN

Strictly as per the compliance and regulations of:

© 2011. Mohammad Mehrani, Ali Shaeidi. This is a research/review paper, distributed under the terms of the Creative Commons Attribution-Noncommercial 3.0 Unported License http://creativecommons.org/licenses/by-nc/3.0/), permitting all non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

A Novel Energy Efficient, Distributed, Clustering Based Network Coverage Method For Enormous WSN

Mohammad Mehrani[1], Ali Shaeidi[2]

Abstract : There are some limitations for wireless sensor networks that energy consumption is from the most important ones. This means energy factor has to be considered in all the sensor network activities. Coverage is one of the most important purposes of such networks. In this paper we want to enhance the coverage power of an entire network by using an energy efficient distributed method which works with a clustered network. This new coverage method is based on our last works presented for wireless sensor networks. The presented method uses FEED clustering method (our last work presented for network clustering) for partitioning the sensors in some groups. Then, some pivot nodes will manage the inter cluster coverage. Selecting just a node to act as the covering active node in each sub-area leads its neighbors to switch to standby mode and save energy. This is done in all over the network region thus energy saving happens in all over the network and consequently network life time increases as well.

Keywords : Coverage, clustering, sub-area, lifetime

I. Introduction

To introduce wireless sensor networks some elements are to be mentioned. Wireless Sensor Networks (WSN) consists of a huge number of sensors with energy resource limitations, dispersed in a region. The task of network nodes is to sense data from the region and sending them to a base station. The network nodes should try to consider all over the region to receive all of its information. In usual wireless sensor networks each node just knows about sensing region of its own. Every node tries to cover all over it's around area and send the information to its cluster head or base station. The area that each node covers can be assumed as a circle. So, there are a number of circles belonging to all the network nodes.

The overlap areas between covering circles will have negative impact on the energy factor. It is because of the possibility of repeating same messages. Clustering technique can be used to withhold overlap areas. A clustering method partitions nods into non-overlapping groups and some of the nodes are the representatives for each cluster members. Thus, the probability of creating overlapping areas and sending same messages reduces such that energy saving will be a consequent event of this method. Also, in parallel with covering any point of the region by using the minimum number of nodes, network connectivity increases.

In clustering a node with best situation is chosen as cluster head. Each clustering method has its own way to choose some nodes as cluster heads. Like [1] some of clustering algorithms selects cluster heads according to a probability formula but some other ones try to select cluster heads by paying attention to energy and distance factors [2].

Some other cluster head selection methods like our last work presented for network clustering [3], rather than energy and distance factors pay attention to some important ones like centrality factor, etc. After choosing cluster head other nodes give data to cluster head and then cluster head forwards data to base station. By doing such, energy consumption of network nodes reduces very well and just cluster head has more energy consumption. Selected nodes for covering the network make a set which name is dominating set. We try to denote a sub-area manager for each small sub-area from dominating set. Also we are eager in choosing just one active node for each sub-area to act as covering node for that sub-area, thus other nodes can switch to standby mode and save energy until they receive an activation message from their manager.

Outline. In section 2 we mention the related works that are used as the platforms of our new method. Then is section 3 we describe our Novel Energy Efficient, Distributed, Clustering based Network Coverage Method for Enormous WSN. Also some figures and tables are used.

II. Related Works

In this section we consider the related works that are used as platforms for the new presented coverage method.

a) FEED clustering method

FEED [3](FEED: Fault Tolerant Energy Efficient Distributed Clustering for Wireless Sensor Networks) selects the cluster heads based on some factors such as: energy, density, centrality and distance between

About [1] : Islamic Azad University, Shoushtar Branch, Shoushtar, Iran
E-mail : m.mehrani@iau-shoushtar.ac.ir
About [2] : Faculty Member of PNU Department of Information and Communication Technology, Iran
E-mail : ali.shaeidi@gmail.com

©2011 Global Journals Inc. (US)

nodes. In FEED, energy factor is the remaining energy of a node while density factor shows the number of neighbor nodes of the node; centrality factor means how much the node is at the center of its neighbors. To calculate the centrality factor, FEED presents an algorithm which can achieve at this factor easily. Also, FEED pays attention to distance between nodes as a useful factor.

After transmitting some messages between nodes and after having some calculations by the nodes the mentioned factors will be used to getting and taking scores by nodes. Each node will be aware about its final score and decides to act as a cluster head, a pivot cluster head, a supervisor nodes or a regular node. This algorithm improves the network lifetime in a significant way in comparison with two well known clustering algorithms LEACH [1] and HEED [2]. Furthermore, FEED algorithm leads the network to be fault tolerant. Fig. 1 shows the improvement of network lifetime by FEED in comparison with LEACH and HEED algorithms. In FEED when the remaining energy of a cluster head falls below a threshold, its supervisor node will replace it and the cluster can continue its activity by having a new cluster head. This property leads network to be fault tolerant. According to Fig. 1, FEED algorithm improves network lifetime in comparison to two other algorithms. Supervisor node replacement can be a reason for this enhancement.

Fig. 2 shows the percentage of total remaining energy of the network nodes after 1, 20 and 50 rounds. After one round, HEED algorithm outperforms the rest, but in later rounds FEED algorithm performance is the best. After round 300 only FEED algorithm is still executing, but LEACH and HEED algorithms have terminated. Fig. 2 shows that FEED significantly improves the network energy consumption.

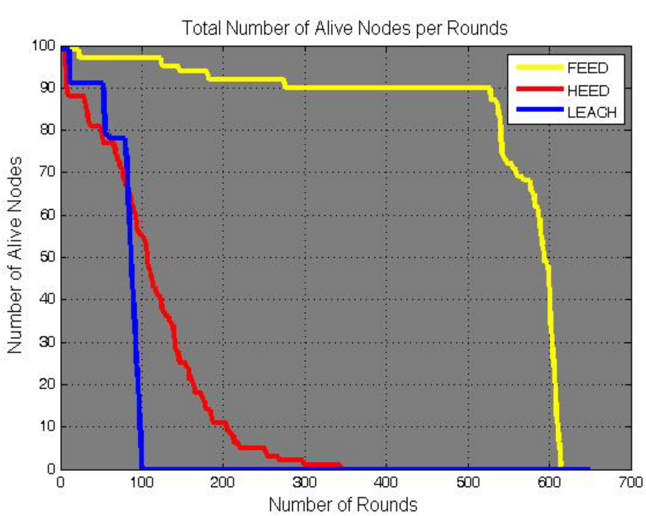


Figure 1 : Total Number of Alive Nodes per Rounds

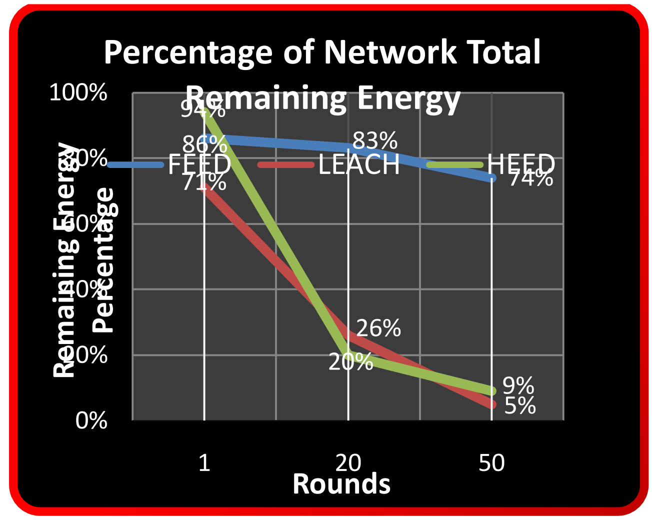


Figure 2 : Percentage of Total Remained Energy of the Network Nodes

b) The FEED based coverage method

[4] presents an energy efficient coverage method on the platform of FEED algorithm.

At the beginning of this coverage method each cluster head divides its covering area of its cluster into four parts each one as a quarter of an assumed circle that we name it *circle1* which radius is *r* that is equal to the distance between cluster head and its hindmost member. Then *circle2* is assumed by cluster head into *circle1* with radius *r/2*.

Each cluster head is in charge of covering its corresponding area by employing its members. So cluster head makes a strategy to cover each quarter of the *circle1* during network functioning. All of four quarters of both of *circle1* and *circle2* should be covered completely whenever all its cluster members are alive. There is a group for each circle. Each node whose distance from cluster head is less than *r/2* will be put in *group2* and if the distance of a node from cluster head is more than *r/2* it would be put in *group1*. If the energy of the node is more than this threshold (assume: threshold = 0.05*initial energy), cluster head decides to contribute it in covering the area of the cluster.

Based on Fig. 3 always 8+1 nodes (8 regular nodes and a cluster head) in each cluster are in active mode (black, red and blue circles) while others are slept because their neighbors can represent their tasks instead themselves. The green circles in Fig. 3 are belonging to those of nodes that are in charge of covering the holes. The covering region of the cluster head is presented by a blue circle at the center of the cluster. By doing such, all over of each cluster will be covered and consequently all over the network will be covered as well. Suppose *n* be the number of network nodes. The desired percentage of clusters is equal to

©2011 Global Journals Inc. (US)

*0.05*n*. So, there will be about twenty nodes in each cluster. As we said just 9 nodes should be in active mode in each time and 11 nodes can go to sleep mode in a 20 member cluster.

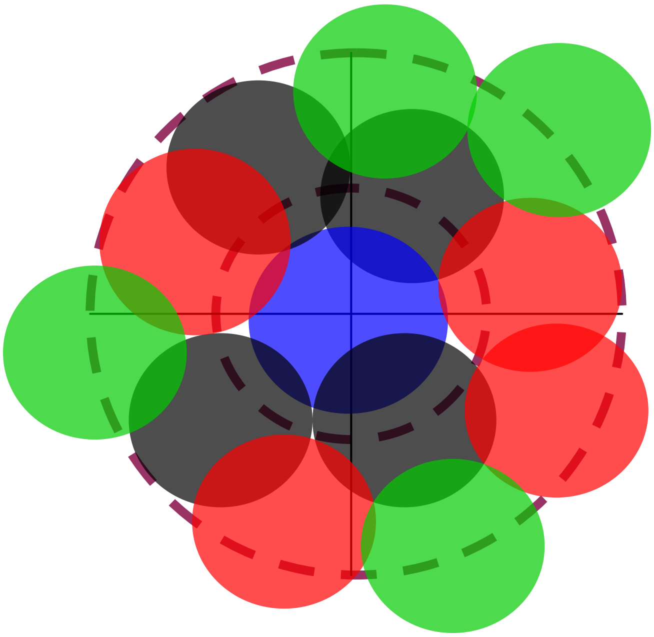


Figure 3 : A part of region covered by a cluster

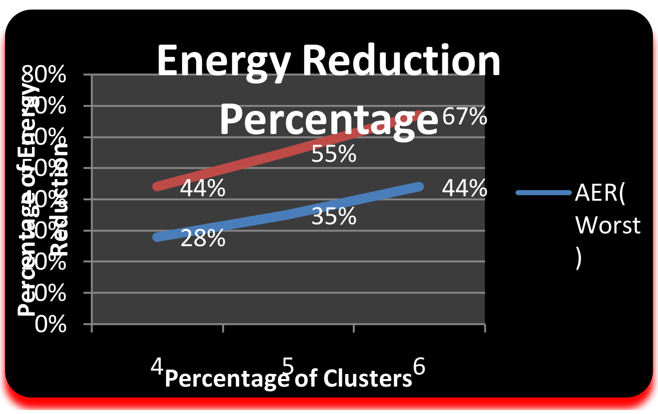


Figure 4 : The results of the FEED based coverage algorithm

The results of this method are shown in Fig. 4. According to this chart, this method can save energy from %28 to %67 during coverage, which is a good outcome.

III. Presented Algorithm

In this section we want to focus on the fundamentals of the proposed new energy efficient distributed coverage method. This method works on the platform on the our last works and enhances some ideas to achieve at full coverage in an energy efficient way such that it leads energy saving for networks nodes and consequently increases network life time. First, the network is clustered by FEED algorithm. Then like [5] the network nodes will be partitioned in some sub-areas. FEED denotes a sub-area manager for each sub-area and assumes two substitute nodes for that manger. Assuming two substitute nodes for each sub-area manager will have a significant affect on fault tolerance factor of the entire network. Also it has a significant improvement on the reduction of existing load on the cluster head. This can be seen in Fig 5. As mentioned in FEED cluster head elects the best nodes in different parts of cluster to be in charge of receiving data from the nodes existing in the corresponding sub-area and then forwarding them to the cluster head. These are the ones that we call *sub-area managers.*

This algorithm has more applications in crowded networks. Because, in such networks an enormous mass of data are transmitted from regular nodes to cluster head, so the load on the cluster head increases rapidly and makes a very rapid energy losing for cluster head. In new algorithm, regular nodes first send data to sub-area managers and then the mentioned managers send data to the cluster head after aggregation.

Cluster head knows about the position and energy of its members. As shown in Fig 6 cluster head assumes its corresponding area as a grid to elect a sub-area manager for each cell of the grid. Fig 7 shows the different states of the grid that can be assumed for the cluster. Based on this figure, the corresponding area of each area can be divided into 5, 9, 17, 25, 33 and 45 distinguished areas with separate sub-area managers. This figure shows the sub-area managers by blue circles while the first and second spares (substitute nodes) are appeared by red and yellow circles, respectively. It should be noted that cluster head in this figure is assumed also as a sub-area manager while having its substitutes.

As mentioned before, reducing cluster head load is a result of this method because the mentioned load is to be divided on the sub-area managers. The cluster head load reduction can be seen in Fig 5. In this figure load reduction of cluster head after using different kinds of grids with different number of separate parts and different number of nodes existing in the cluster is shown. According to this figure, the cluster head's load decreases between 10% and 97.5% which is a very significant outcome. Fig 5 shows that the smaller number of denoted sub-areas has more affect in cluster head's load reduction because whatever this number is bigger the number of sub-area managers is bigger which means the number of nodes that send data to cluster head is bigger which leads having more load on the cluster head.

©2011 Global Journals Inc. (US)

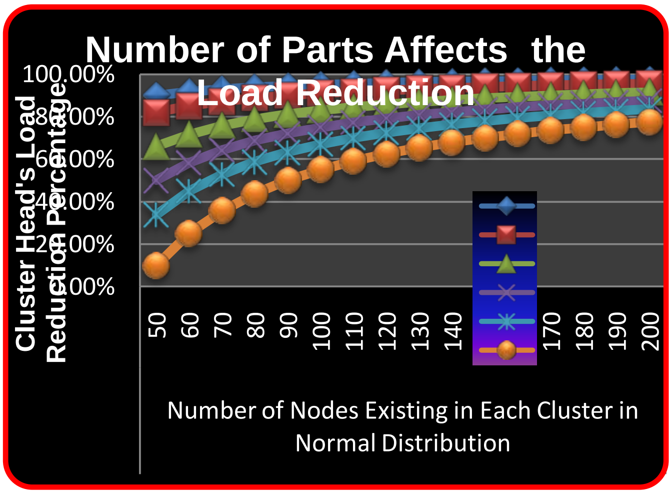
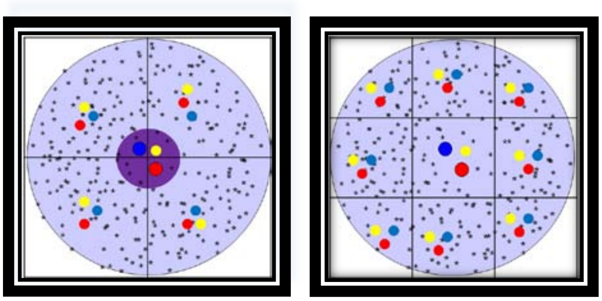


Figure 5 : Load Reduction On the Cluster Head

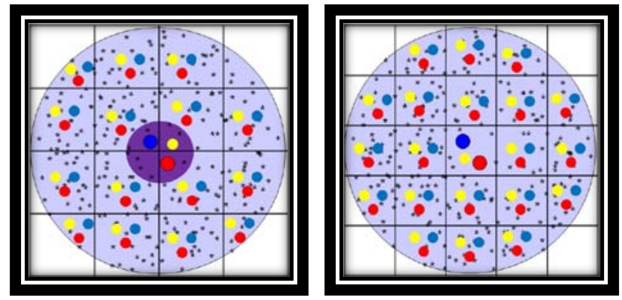
Using each one of the different presented grids by Fig 6 will have a different affect on functionality of proposed coverage algorithm. The distance between part's sub-area managers and their cluster heads has direct affect on the functionality of this method. All the network nodes (but those who are in the cluster head's sub-area that send data to cluster head directly) send the sensed data to their sub-area managers that are so much nearer then cluster head. This leads energy saving for active nodes. Energy consumption for sending a message has direct relation with square of distance that the message takes. Thus, using multi partitioned form for a clustered area will lead some significant affects in energy saving for network nodes.

Applying the different types of grid shown in Fig 6 leads satisfying results as following. Using Fig 6 *a, b, c, d, e* and *f* have 35%, 78.22%, 72.9%, 60.72%, 73.87% and 93.56% energy saving, respectively. Fig7 shows the mentioned results much better in a graphical shape.

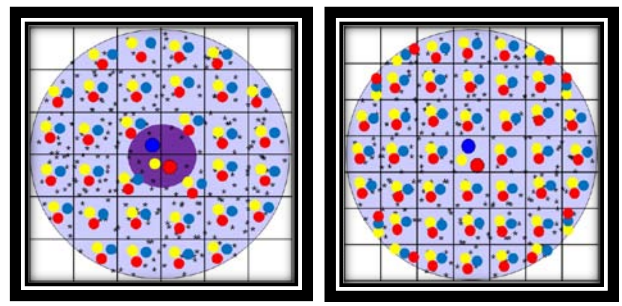
As can be seen in Fig 7 the minimum percentage of energy saving is when there are 5 separate parts in each cluster. In this circumstances there is about 35% energy saving for almost all the normal nodes but sub-area managers.



a) b)



c) d)



e) f)

Figure 6 : A Partitioned Cluster with Different Grids

In other hand, the maximum possible amount of energy saving occurs when a grid with 45 separate sub-areas is used. This leads more than 93% energy saving for the network which is a very satisfying outcome.

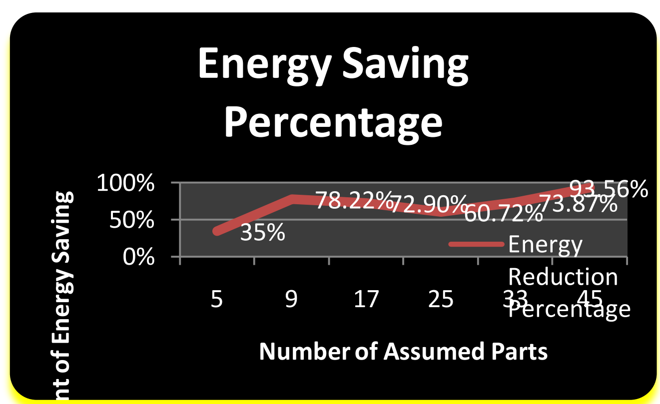


Figure 7 : Network Overall Energy Saving

Now the overall introduction of new proposed coverage method which contains some previous platforms is as following. First the network is being clustered by FEED clustering algorithm. So there would be some clusters with some cluster heads in the network. Then each cluster head uses our last coverage method [5] for partitioning its corresponding area. As can be considered in Fig 6 the cluster head assumes its area as some different grids in different implementations. So there is a sub-area manager for

Global Journal of Computer Science and Technology Volume XI Issue IV Version I March 2011

©2011 Global Journals Inc. (US)

each denoted sub-area. The presented idea in this paper is to use just one active node in each sub-area to avoid overlapping. Because if all the nodes existing in each sub-area of each cluster in the network try to sense region data and send them to their sub-area managers then two problems may happen: firstly, all the nodes will be active and consequently they all consume energy. This can lead unnecessary energy consumption and reduces network efficiency. Secondly, active nodes send the received region data to their sub-area managers; this leads increasing over head on the sub-area managers and also these managers lose energy as well because of receiving several messages from their nodes. Note that overlapping causes sensing each part of the region more than once. Thus, the sensor nodes placed in an entire local sub-area send same messages one after another. It is not necessary for network nodes to sense same areas, thus if an entire region part of a node can be covered by its neighbours then that node can switch to standby mode until it receives the activation message from its sub-area manager. This means the task of covering an entire sub-area can be shared between all the nodes existing in that sub-area in different time slices. By doing such, all over the network region which consists of some clusters with some sub-areas will be full covered by network nodes in all the separated time slices, as well. Also, reducing network overall energy consumption can be satisfied.

In the new coverage method one of six kinds of grids shown in Fig 6 can be used. The functionality of this algorithm is related to two important factors: number of clusters in the network and also the grid form selected from Fig 6. Having different number of clusters is so crucial. The low amount of clusters will lead making big clusters in which the distance between cluster heads and their members and also the distance between sub-area managers and their members will be long. In the other hand, if the wireless sensor network consists of many clusters then the mentioned distances decrease. This means a suitable balance for number of clusters should be considered. Also, using each grid of the Fig 6 has its especial affects on the functionality of the network coverage method because these figures show different amount of assumed grids in the clusters that affect the distances between cluster heads, sub-area managers and regular nodes.

As mentioned before, an important point is the number of clusters which can be also called the percentage of clusters assumed for the network. Usually, this amount is equal to *0.05n*, but it may change to *0.04n* or *0.06n* in some rounds. In means in ordinary implementations of wireless sensor networks five percent of all the nodes are cluster head while others are just regular nodes. By the way, this percentage of clusters and cluster heads can take different amounts.

By changing the percentage of clusters the radius of the network clusters per round will change which is because of altering the regions belonging to the clusters. In parallel with these changes, the assumed sensing ranges change and lead to over energy consumption or under energy consumption for active nodes.

Table I shows the affect of changing the percentage of clusters on the radius of the clusters, when the normal distribution is supposed.

Table I : The clusters percentage affect on cluster's radius

percentage of clusters in the network	radius of each cluster
4	36
5	28
6	20

As mentioned before, like the percentage of clusters, applying each one of the grids shown in Fig 6 has a different affect on the network functioning. So we consider both the mentioned affects to evaluate our new coverage method. We calculate the energy consumption reducing of the proposed method made by mixing each one of the grids shown in the Fig 6 with using different percentage of clusters.

Suppose the percentage of the made clusters in the network is equal to 4 and different shapes of Fig 6 are used. Thus, the radius of each cluster in normal distribution is equal to 36 meters. The changing of some basic factors can be seen in the Table II. Note that the sensing range is achieved after considering the sub-areas of the Fig 6. Also the usual sensing range of the nodes in the FEED clustering algorithm is 8 meters, so changing in the radius of sensing range can be calculated easily and consequently changing in the energy consumption of active nodes can be calculated by dividing the square of sensing range by square of changing in the radius of sensing range. So by applying the new proposed method, changing in the energy consumption of an active node in the cluster when the percentage of clusters is equal to 4 and Fig 6 (b) is used will equal to 225% which is not good. But if Fig 6 (d) is used this factor will equal to 77% which means 77% reduction of energy consumption of an active node in comparison with normal situation without using the new method.

©2011 Global Journals Inc. (US)

Global Journal of Computer Science and Technology Volume XI Issue IV Version I March 2011

Table II : The affect of basic factor when cluster's percentage is 4

Some basic factors for active nodes when the percentage of clusters is equal to 4 and Fig 6 (a-f) are used					
Sensing range (m)					
Fig 6(a)	Fig6(b)	Fig 6(c)	Fig 6(d)	Fig 6(e)	Fig 6(f)
18	12	9	7	6	5
changing in the radius of sensing range (m)					
Fig 6(a)	Fig6(b)	Fig 6(c)	Fig 6(d)	Fig 6(e)	Fig 6(f)
18-8=10	12-8=4	9-8=1	7-8=-1	6-8=-2	5-8=-3
Changing in the energy consumption (%)					
Fig 6(a)	Fig6(b)	Fig 6(c)	Fig 6(d)	Fig 6(e)	Fig 6(f)
500%	225%	126%	77%	56%	39%

Now we consider the situation of having 5% of network nodes as the number of clusters. Now the radius of each cluster in normal distribution is equal to 28 meters. Table III shows the happened changes of the basic factors.

Table III : the affect of basic factor when cluster's percentage is 5

Some basic factors for active nodes when the percentage of clusters is equal to 5 and Fig 6 (a-f)are used					
Sensing range (m)					
Fig 6(a)	Fig6(b)	Fig 6(c)	Fig 6(d)	Fig 6(e)	Fig 6(f)
14	9.3	7	5.6	4.7	4
changing in the radius of sensing range (m)					
Fig 6(a)	Fig6(b)	Fig 6(c)	Fig 6(d)	Fig 6(e)	Fig 6(f)
6	1.3	-1	-2.4	-3.3	-4
Changing in the energy consumption (%)					
Fig 6(a)	Fig6(b)	Fig 6(c)	Fig 6(d)	Fig 6(e)	Fig 6(f)
300%	135%	77%	49%	34%	25%

The other situation that we estimate is having 6% of network nodes as the number of clusters. In this condition the radius of each cluster in normal distribution equals to 20 meters. Table IV exhibits the occurred changes of the basic factors.

Table IV : the affect of basic factor when cluster's percentage is 6

Some basic factors for active nodes when the percentage of clusters is equal to 6 and Fig 6 (a-f)are used					
Sensing range (m)					
Fig 6(a)	Fig6(b)	Fig 6(c)	Fig 6(d)	Fig 6(e)	Fig 6(f)
10	6.6	5	4	3.3	2.8
changing in the radius of sensing range (m)					
Fig 6(a)	Fig6(b)	Fig 6(c)	Fig 6(d)	Fig 6(e)	Fig 6(f)
2	-1.4	-3	-4	-4.7	-5.2
Changing in the energy consumption (%)					
Fig 6(a)	Fig6(b)	Fig 6(c)	Fig 6(d)	Fig 6(e)	Fig 6(f)
156%	68%	39%	25%	17%	12%

Based on the results of Tables II, III and IV the best situation for active nodes in the matter of energy saving occurs when the number of clusters are 6% of amount of network nodes and Fig 6(f) is used. In this situation by using the new proposed coverage method active nodes will have 88% energy saving to sense their corresponding sub-areas in comparison with the condition of last situation in which the new coverage technique was not used. Fig 8 shows the results of the method in a chart for better understanding. According to results of Tables II, III and IV using Fig (a) is not recommended because using this kind of grid increases energy consumption in an unnecessary way, so this shapes is omitted of the chart of Fig 8.

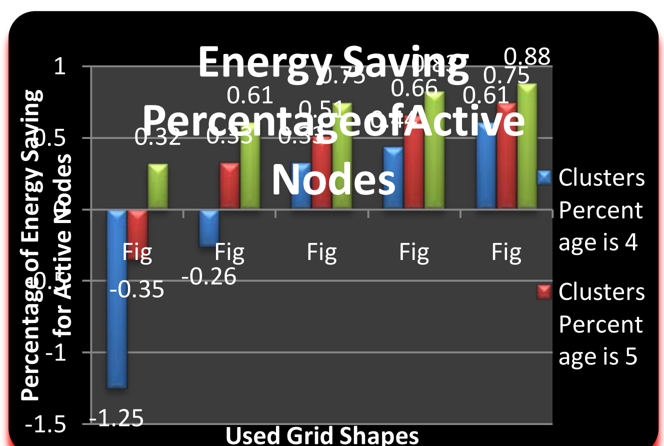


Figure 8 : The Percentage of Energy Saving

The chart of Fig 8 shows the affect of the new proposed coverage method on the energy consumption of active nodes in a graphical shape. In this chart the negative amounts represents the bad functionality of the proposed method while the positive numbers exhibits the good outcome of our method. Thus, whatever the number of made clusters increases and also whatever

©2011 Global Journals Inc. (US)

the number of assumed grids in the clusters increases, the new method acts better.

Meanwhile, there is one another factor needed to be estimated. In the new proposed method some grids are assumed for each cluster such that always in each sub-area there are just two active nodes: sub-area manager and a regular active node which is in charge of sensing that sub-area. Other nodes are slept in standby mode and save energy. This means using new coverage method leads 32% to 88% decreasing in energy consumption and also other nodes can sleep until receiving an activation message. This is a very good outcome of the new method which leads so much energy saving for both of the active and slept nodes.

By the way, whatever the number of network nodes is bigger the chance of an entire regular node for being chosen as an active node decrease which means decreasing in energy consumption and increasing network lifetime. So this method is more active for big and huge wireless sensor networks.

References Références Referencias

1. W. Heinzelman, A. Chandrakasan and H. Balakrishnan, "Energy-efficient communication protocol for wireless microsensor networks," in Proc. of the 33rd Annual Hawaii International Conference on System Sciences (HICSS), Maui, HI, Jan. 2000, pp. 3005 – 3014.
2. O. Younis and S. Fahmy, "HEED: A Hybrid, Energy-Efficient, DistributedClustering Approach for Ad-hoc Sensor Networks", sponsored in part by NSF grant ANI-0238294 (CAREER) and the Schlumberger Foundation
3. M. Mehrani, J. Shanbehzadeh, A. Sarrafzadeh, S. J. Mirabedini and C. Manford, "FEED – Fault tolerant Energy Efficient Distributed Clustering for Wireless Sensor Networks", The 12th International Conference on Advanced Communication Technology (ICACT2010), Phoenix Park, Korea.
4. J. Shanbehzadeh, M. Mehrani, A. Sarrafzadeh and Zahra Razaghi, "An Energy Efficient Coverage Method for Clustered WSN", Proceedings of the International MultiConference of Engineers and Computer Scientists 2010 Vol II, IMECS 2010, March 17-19, 2010, Hong Kong
5. M. Mehrani, A. Shaeidi, M. Hasannejad and, A. Afsheh, "a New Network Coverage Algorithm for Enormous Clustered Wireless Sensor Networks", accepted for publication, 2011 International Conference on Intelligent Information Networks (ICIIN 2011)
6. F. Dai and J. Wu. "constructing k-connected k-dominating set in wireless networks", Proceedings of IEEE International Parallel & Distributed Processing Symposium (IPDPS), 2005.
7. F. Dai and J. Wu. "constructing k-connected k-dominating set in wireless ad hoc and sensor networks", Journal of Parallel and Distributed Computing, pp. 947–958, 2006.
8. C. Glaber, S. Reith, and H. Vollmer. "The complexity of base station positioning in cellular networks", Discrete Applied Mathematics, pp. 1–12, 2005.
9. F. Kuhn, T. Moscibroda, R. Wattendorf, "Fault-tolerant clustering in ad hoc and sensor networks", Proceedings of the 26th IEEE International Conference on Distributed Computing Systems (ICDCS 06), page 68, 2006.
10. L. D. Penso, V. C. Barbosa, "A distributed algorithm to find k-dominating sets", Discrete Applied Mathematics, pp. 243–253, 2004.
11. K. Akkaya, M. Younis" A survey on routing protocols for wireless sensor networks" Ad Hoc Networks 3, pp. 325–3, 2005.
12. D. Bein, "Fault-tolerant k-fold Pivot Routing in Wireless Sensor Networks", Proceedings of the 41st Hawaii International Conference on System Sciences, 2008.
13. K. Matrouk , B. Landfeldt, "RETT-gen: A globally efficient routing protocol for wireless sensor networks by equalising sensor energy and avoiding energy holes", Ad Hoc Networks 7, pp. 514–536, 2009.

©2011 Global Journals Inc. (US)

This page is intentionally left blank

©2011 Global Journals Inc. (US)