ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

A NEW CLUSTERING ALGORITHM FOR WIRELESS SENSOR NETWORKS

[1]ALI JORIO, [2]SANAA EL FKIHI, [3]BRAHIM ELBHIRI, [1]DRISS ABOUTAJDINE

[1]LRIT, Unité associée au CNRST, URAC 29, FSR, Université Mohammed V Agdal, Rabat, Morocco

[2]ENSIAS, Université Mohammed V Souissi, Rabat, Morocco

[3]EMSI-Rabat, Rabat, Morocco

E-mail: [1]jorio.ali@gmail.com, [2]elfkihi@ensias.ma m, [3]elbhirij@yahoo.fr

ABSTRACT

Wireless sensor networks have recently become an attractive research area. However, saving energy and, thus, extending the wireless sensor network lifetime entails great challenges. For this reason, clustering techniques are largely made use of. In this paper we propose a new algorithm based on the principle of spectral clustering methods. Especially, we use the K-ways spectral clustering algorithm. The main characteristic of our proposal is that it defines the optimal number of clusters and dynamically changes the election probabilities of the cluster heads based on their residual energy. Up on analyzing the impact of node density on the robustness of the proposed algorithm as well as on its energy and lifetime gains, simulation results show that the approach actually improves the lifetime of a whole network and presents more energy efficiency distribution compared to Low-Energy Adaptive Clustering Hierarch, Centralized Low-Energy Adaptive Clustering Hierarch, and Distance-Energy Cluster Structure approaches.

Keywords: *WSN, Energy consumption, Spectral clustering, Graph theory, K-ways, Classification.*

1. INTRODUCTION

Wireless Sensor Networks (WSN) are one of the innovative technologies that are widely used today. They have many advantages, namely the ease of deployment and the capacity of self-organization. However, the main challenge of these networks concerns the limited resources in terms of energy, communication and computation. Yet, focus in the present paper will be on the former challenge (i.e. energy consumption). To deal with this issue, a number of proposals have been put forward, among these are clustering algorithms that are widely used to save WSN energy.

In fact, though sensors are usually powered by batteries, it is not always practical to recharge or replace them because they are often deployed in hostile environments. Furthermore, in a WSN a large part of energy is consumed when communications are established [1]. Hence, frequent and long distance transmissions should be minimized to extend the lifetime of the network [2]. To this end, an effective approach would be to divide the network into several clusters; each of these elects one node as its cluster head (CH) [3]. The CH collects data from the same cluster nodes, aggregates them and transmits them to the base station (BS). Many routing protocols based on clustering in which CHs are elected periodically and alternately [4, 5], have been designed; otherwise, the CH dies quickly. Moreover, the most commonly used approach for clustering is the Low-Energy Adaptive Clustering Hierarch (LEACH) algorithm [6]. In addition, many clustering protocols, based on the principle of this algorithm, have been developed in the two categories of Wireless Sensor Networks: homogeneous and heterogeneous WSNs. In the first category, all nodes have the same initial energy whereas in the second set, they have different energies. For the first category we give some homogeneous clustering protocols: centralized LEACH (LEACH-C)[7], Power-Efficient Gathering in Sensor Information Systems (PEGASIS)[8], and Distance-Energy Cluster Structure Algorithm (DECSA)[9]. Concerning the second category, we cite the examples of Developed Distributed Energy-Excient Clustering (DEEC) [10], Equitable Distributed Energy-Efficient Clustering (EDEEC) [11], and Stochastic and Balanced Distributed Energy-Efficient Clustering (SBDEEC) [12].

The main idea of the LEACH algorithm is to randomly and alternately select the CHs. After CHs are elected, each node in the WSN will receive

Journal of Theoretical and Applied Information Technology
31st March 2013. Vol. 49 No.3

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

warning messages from all CHs. From the signal-to-noise ratio of the received messages, each node will choose to join the CH which has the highest signal quality. Nevertheless, the main problem of LEACH protocol is the random selection of the CHs. Indeed, all CHs can be located in a small region of the network. To deal with this problem and to define CHs so that they could be fairly localized, we propose to consider methods of spectral clustering [13, 14]. The latter have drawn attention over the past few years in many applications, such as image segmentation [15] and social networks analysis [16]. They usually take into account the top eigenvectors of some matrix based on some properties between points and then use them to cluster the various points [17]. But, two problems are brought about: (1) what is the optimal number of clusters to consider? and (2) how can we define CHs? To deal with these problematic issues, and to improve the lifetime of a WSN, our purpose in this paper is to propose a novel clustering protocol based on the optimal spectral clustering approach called k-ways.

The remainder of this paper is organized as follows: Section 2 outlines the problem of extending the whole network lifetime of a WSN. Section 3 details the four steps of the new proposed homogenous clustering approach. In particular, it explains how the optimal number of clusters is determined and the CHs are elected. Then, Section 4 evaluates the performance of our proposal compared to other algorithms. Finally, conclusions and perspectives are drawn in Section 5.

2. PROBLEM FORMULATION

Periodically, the wireless sensor network nodes sense the environment and transmit data to the BS. The latter analyzes data and gives some conclusions about the activities in the supervised area. In our work, we use the energy mode and analysis that are presented in [6, 7]. The radio energy dissipation model is illustrated in Figure 1 (extracted from [6]).

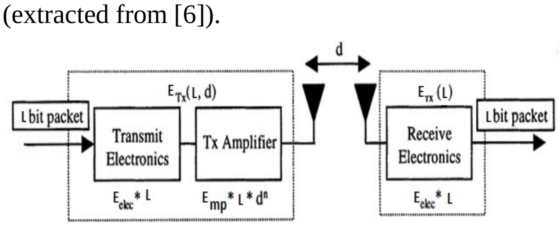

Figure 1: Radio Energy Dissipation Model

In this figure, $E_{Tx}(L,d)$ presents the energy spent to transmit L-bits over a distance d, and E_{rx} is the energy spent to process L-bit message. The parameter E_{elc} denotes the energy per bit dissipated to run both the transmitter and the receiver circuits. This parameter depends on many factors such as digital coding, modulation, filtering, and the spreading of the signal [7].

The energy spent by the radio transmitter is:

$$E_{Tx}(L,d) = \begin{cases} L.E_{elec} + L.E_{fs}.d^2 & \text{if } d < d_0 \\ L.E_{elec} + L.E_{mp}.d^4 & \text{if } d \geq d_0 \end{cases} \quad (1)$$

where E_{fs} and E_{mp} present the amplifier energy respectively in a free space (with d^2 power loss) and in a multipath fading (with d^4 power loss) channel models. They depend on the distance between the transmitter and the receiver. If this distance is less than a threshold d_0, then the free space model is used; otherwise, the multipath model is used. The value of the threshold d_0 has been given by Heinzelman et al. in [7]. It is defined as follows:

$$d_0 = \sqrt{\frac{E_{fs}}{E_{mp}}} \quad (2)$$

In addition, once a sensor node runs out its energy, it is considered as dead. Thus, due to the sensor's limited power, innovative techniques improving energy efficiency to extend the network lifetime, are highly required. In this aim, the hierarchical routing approaches are mostly used. The main idea of these algorithms consists in a random/rotate selection of the CHs, and a balancing energy consumption through the network.

Furthermore, considering a WSN which consists of N nodes uniformly distributed the total dissipated energy during a round is determined by:

$$E_{Round} = \sum_{k=1}^{K} E_{\mathrm{CH}_k} + \sum_{j=1}^{N-K} E_{\mathrm{NCH}_j} \quad (3)$$

where E_{CH_k} is the consumed energy when the CH of the cluster labelled k, receives, aggregates, and transmits data to the base station. Whereas E_{NCH_j} is the consumed energy by a non CH labelled j, and K is the total number of cluster heads.

On the one hand, the E_{CH_k} is defined by:

$$E_{CH_k} = E_{CHtoBS_k} + E_{Recept_k} + E_{Aggreg_k} \quad (4)$$

where,

$$E_{CHtoBS_k} = L.E_{elec} + L.E_{mp}.d^4_{toBS_k} \quad (5)$$

$$E_{Recept_k} = |S_k|.L.E_{elec} \quad (6)$$

$$E_{Aggreg_k} = |S_k|.L.E_{DA} \quad (7)$$

with:

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

- E_{CHtoBS_k} is the energy consumed when the cluster head of the cluster labelled k transmits data to the base station.
- E_{Recept_k} is the total energy consumed when the cluster head of the cluster k receives data from its own cluster nodes.
- E_{Aggreg_k} is the total energy needed, by the CH of the cluster k, to process data.
- $|S_k|$ is the cardinal of the set enclosing nodes of the cluster labeled k.

On the other hand, in the network, there are N-K non cluster heads. Some of the latter operate on the free space mode while the others operate on the amplification mode. Let l be the number of the latter category of nodes. We have:

$$\sum_{j=1}^{N-K} E_{NCH_j} = (N-K).L.E_{elec} + (\sum_{i=1}^{l} d_i^4).L.E_{mp} + (\sum_{j=1}^{N-K-l} d_j^2).L.E_{fs} \quad (8)$$

where $d_j<d_0$ and $d_i \geq d_0$.

From the equations above, we conclude that the total dissipated energy during a round, in a given WSN, is defined by:

$$E_{Round} = L(2N.E_{elec} + N.E_{DA} + K.E_{mp}.d_{toBS}^4 + (\sum_{i=1}^{l} d_i^4).E_{mp} + (\sum_{j=1}^{N-K-l} d_j^2).E_{fs}) \quad (9)$$

In a WSN, one of the most important challenges consists in reducing the total consumed energy of each round with the aim to enlarge the whole network lifetime. Besides, two main problems must be considered when defining a clustering method. These are summed up in: (1) what is the optimal number of clusters (K)? and (2) how the cluster heads can be selected? To deal with these questions, we propose a new protocol using a spectral clustering approach. The next section details the proposed solution.

3. THE PROPOSED ALGORITHM

In this section, a new homogenous clustering protocol for WSN is presented. It is based on the spectral clustering that included a variety of methods based on the notion of similarity matrix and using the eigenvectors differently. The k-ways approach is one of these methods and consists in dividing data into K disjoint classes based on the K eigenvectors related to K largest eigenvalues of a Laplacian matrix. In our study, we consider a network with N nodes, uniformly distributed within a M×M square region. Moreover, we assume that the network topology remains unchanged over time.

The four steps of our proposal are:

3.1 Pre-processing step

So as to avoid that each node needs to know the global knowledge of the network (which is quite unrealistic for WSN), in the proposed algorithm, the base station collects the different node positions and applies the clustering process. We note that each node knows its own location, which can be obtained at a low cost by a Global Positioning System or by using other localization systems [18, 19]. Then, the WSN nodes transmit their location in a short message to the Base Station.

Each WSN can be represented by its corresponding undirect graph G(V,E). Where V is the set of vertices (nodes) representing different sensor nodes and E is the edge set enclosing all dependencies between the nodes. Each vertex of V is identified by an index i ∈ {1,...,N}. We assume that G is a graph without loops or multiple edges. Let $A \in R^{N\times N}$ be the adjacency matrix of the graph G. Each value of A is associated to each pair of the graph nodes (i,j). This value is of Gaussian type and the matrix A is given by equation (10).

$$A = [a_{ij}] = \begin{cases} e^{\left(\frac{-1}{2\sigma^2} d^2(i,j)\right)} & i \neq j \\ 0 & otherwise \end{cases} \quad (10)$$

The total weight of edges incident to node i is given by $d_{ii} = \sum_{j=1}^{N} a_{ij}$. The degree matrix $D \in R^{N\times N}$ of G is a diagonal matrix defined by $D=[d_{ij}]$ and the N×N Laplacian matrix of the graph is defined by:

$$L = D^{-\frac{1}{2}} A \, D^{-\frac{1}{2}} \quad (11)$$

3.2 Pre-processing step

The objectives of the current step are to define the optimal number of clusters and to form them.

Based on the Laplacian matrix L defined above, we form a new matrix U composed of the K eigenvectors related to K largest eigenvalues of L. In order to determine the K clusters of the WSN, we apply the classification algorithm k-means to the matrix U.

Nonetheless, the most important question raised by the proposed strategy concerns the optimal number of clusters (K) to be used. With the aim to respond to this question, we consider the

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

total consumed energy in each round (equation (9)).We note that by considering K cluster, this energy depends on the distances between the CH and the non cluster heads of each cluster. i.e. E_{Round} is minimal if the quantity:

$$(\sum_{i=1}^{l} d_i^4).E_{mp} + (\sum_{j=1}^{N-K-l} d_j^2).E_{fs} \quad (12)$$

is minimal. However, it is known that the amplifier energy in a multipath fading channel models is greater than the amplifier one in a free space model (i.e. $E_{fs} \leq E_{mp}$). In addition, we have $d_j < d_0 \leq d_i$. Thus, to minimize the formula given in equation (12), all non CH nodes must operate in a free space model.

The objective function that allows to decide whether to reconsider the partitioning process or not of the WSN, is defined by the distance matrix M_{dis}^k ($M_{dis}^k = [dis_{ij}^k]$; with dis_{ij}^k is the distance between the node i and the node j of the cluster labelled k) of each cluster. The allowed threshold to this function is d_0. Hence, if at least one element of any M_{dis}^k is greater than d_0, the considered number of clusters will be incremented (K+1) and the k-mean algorithm will be reused. Otherwise, the optimal number of clusters is K.

Note that in the proposed algorithm we first determine the clusters before specifying the CHs. Besides, the optimal number of cluster partitions is as well defined automatically. Therefore, our algorithm is completely different from the others (such as LEACH, LEACH-C, DECSA, ...).

3.3 Cluster head election step

Once the clusters are determined, the next step consists in defining the CHs. Note that numbered node id (identification) will be in some random position on the cluster. Thus, the cluster head in each round of communication will be at a random position on the cluster. It is so important that nodes die at random locations of the network. The rational idea behind this is to make the sensor network robust to failures. Moreover, by taking in consideration the nodes id in clusters, the possible cluster heads will be determined. Indeed, in the round r of the simulation, we use the number c_k=(r mod $|S_k|$) to select the suitable cluster head for the appropriate cluster; where $|S_k|$ represents the total number of nodes in a defined cluster k. Besides, if the residual energy Eng_{ck} of the node, with id=ck, is greater than a threshold Θ_{Eng}, this node will be the CH of the cluster k in the round r. We define Θ_{Eng} as the minimum residual energy required for a given node to be a CH. It is the summation of the energy needed to receive and process data coming from the appropriate cluster nodes, and to transmit towards the base station. This Θ_{Eng} is given below:

$$\Theta_{Eng} = L.((|S_k| + 1).E_{elec} + |S_k|.E_{DA} + E_{mp}.d_i^4) \quad (13)$$

where d_i is the distance between the node i and the BS.

Nevertheless if the residual energy Eng_{ck} of a possible CH is less than the threshold Θ_{Eng}, this node must send a short message informing the node with id = c_k + 1 to be the new possible cluster head at the iteration r, and so on. Consequently, each cluster head will be able to collect data from the cluster nodes and will transmit the aggregate information to the BS. Thus, the number of the direct transmissions is efficiently reduced and the whole network lifetime is extended. In addition, energy consumption will be distributed with more equitability between all nodes.

3.4 Data transmission

Once clusters and cluster heads are created, each CH knows which nodes it is supervising. Based on the node's id in the appropriate cluster, a Time Division Multiple-Access MAC protocol schedule assignment will be generated automatically. If we suppose that the node id=i is elected as CH, the node id = (i + 1 + $|S_k|$)mod $|S_k|$ will take the first time slot to transmit; where $|S_k|$ is the total number of nodes in cluster k. Here, we avoid the techniques applied by traditional algorithms which consume more energy and ask for more synchronization when the CHs are elected. Moreover, this technique guarantees that there are no collisions among data messages and also allows the radio components of each non-cluster head node to be turned off at all times except during its transmit time, thus reducing the energy consumed by the individual sensors [7].

Assuming that all nodes can transmit, with enough power, to reach the BS, if the distance between any node and the BS is less than the distance between this node and its corresponding CH, the node will transmit data directly to the BS. Now, each non cluster head sends its data during its allocated transmission time to its respective CH. The latter must keep its receiver on to receive all data. When all data is received, the CH performs signal processing functions to compress the data into a single signal. Once this phase is completed, each CH sends the aggregated data to the BS. In this sub-phase, each non CH can turn off to the sleep mode in order to reduce the consumed energy.

By using our proposed schema based on spectral clustering approach, the total consumed energy of each round is given by equation (14).

Journal of Theoretical and Applied Information Technology
31st March 2013. Vol. 49 No.3

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

$$E_{round}^{SCapproach} = L(2N * E_{elec} + N * E_{DA} + K * E_{mp} * d_{toBS}^4 + (\sum_{j=1}^{N-K} d_j^2) . E_{fs}) \quad (14)$$

where $d_j < d_0$.

In a given WSN, note that:

- If all non cluster heads operate in a non free space mode, the total dissipated energy during a round is determined by:

$$E_{round}^1 = L(2N * E_{elec} + N * E_{DA} + K * E_{mp} * d_{toBS}^4 + (\sum_{i=1}^{N-K} d_i^4) * E_{mp}) \quad (15)$$

where $d_i \geq d_0$.

- If at least one non cluster head operates in a non free space mode, the total dissipated energy during a round is determined by:

$$E_{round}^2 = L(2N * E_{elec} + N * E_{DA} + K * E_{mp} * d_{toBS}^4 + K * E_{mp} * d_{toBS}^4 + (\sum_{i=1}^{l, l\neq 0} d_i^4) * E_{mp} + (\sum_{i=1}^{N-K-l, l\neq 0} d_j^2) * E_{fs}) \quad (16)$$

where $d_j < d_0$ and $d_i \geq d_0$.

- If all non cluster heads operate in a free space mode, which is exactly our case, the total dissipated energy during a round is as the same as the one given by equation (14).

Consequently,

$$E_{round}^{SCapproach} \leq E_{round}^2 \leq E_{round}^1 \quad (17)$$

We conclude that the total dissipated energy during a round is minimal when the new proposed approach is used.

4. SIMULATION AND RESULTS

All simulations are based on the following protocol. We consider many wireless sensor networks with N nodes randomly distributed in a 200m×200m area. Besides, we ignore the effect caused by the signal collision and the interference in the wireless channel. Since the nodes have limited energy, they consume their energies during the course of simulations. Once a node runs out of energy, it is considered as dead and cannot transmit or receive data. The radio parameters used in our simulations are shown in Table 1.

Table 1: Specifications Of The Used Radio Model

Parameter	Value
E_{elec}	50 nJ/bit
E_{fs}	10 pJ/bit/m2
E_{mp}	0.0013 pJ/bit/m
E_0	0.5 J
E_{DA}	5 nJ/bit/message
d_0	87.70 m
message size	4000 bits

We notice that for these simulations, the energy of a node decreases each time it sends, receives or aggregates the data.

We propose to compare our proposed method detailed above to:

- The LEACH-C protocol.
- The LEACH-C protocol; which is the centralized version of the LEACH algorithm. In particular, we chose this protocol because our method is considered as a centralized one.
- Method1: Here, we define a modified version of our proposed approach. It consists in considering the k-ways algorithm with K equals to 5% of the total number of nodes in the WSN; 5% is the optimal number of CHs proposed in [6]. Our purpose is to highlight the importance of the number of the considered clusters.
- DECSA: It is based on the classic clustering routing algorithm LEACH. Besides, it considers both the distance and residual energy of nodes [9].

We consider a network with N=500 nodes randomly distributed. Figure 2 presents the different clusters of the network by using our proposed method and Method1.

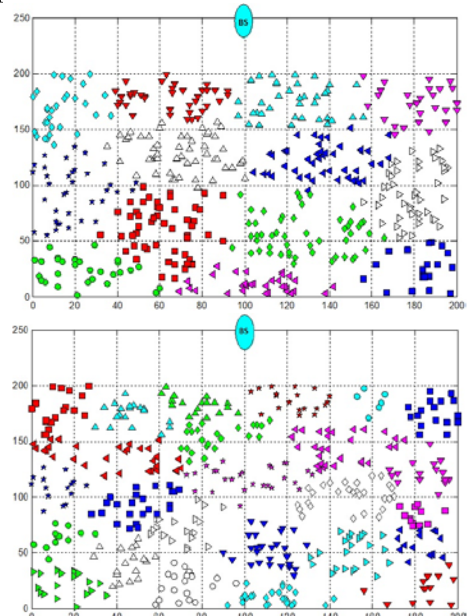

Figure 2: Clustering Results With N=500. (Top) The New Proposed Method. (Bottom) Method1.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

When the new proposed protocol is used, we note that the network is subdivided into thirteen clusters that are correctly distributed over the sensing area. There is no intersection between the different clusters. For the other compared methods the number of clusters is equal to twenty five (5% of number of the network nodes).

Figure 3 gives the curves of the number of nodes alive over time for the five compared protocols. This figure shows an improvement of Method1 in terms of enlarging the round number of the first node dies. Furthermore, our proposed protocol presents a most significant improvement of the all compared approaches. Indeed, it is obvious that the stable time of the new method is extended for the whole network compared to the four other algorithms. Here, it is shown that the first node death for N = 500, occurs at the 359 round by using our approach whereas this value is about 181, 83, 179, and 20 when the Method1, the DECSA, the LEACH, and the LEACH-C algorithms are used. Moreover we can see that the unstable region of our algorithm is larger than the ones of the other protocols.

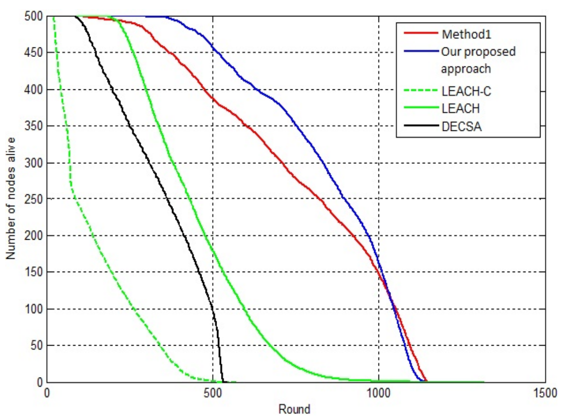

Figure 3: Number Of Nodes Alive Over Time Of The Compared Protocols For N=500.

Now we propose to evaluate the robustness of the different compared protocols for different values of the node density N.

The Figure 4 shows the effects of the node density on the compared clustering techniques as well as on the network's stable regions (First Node Dead "FND"). As shown in this figure, for different values of N equal to 500, 600, 700, and 800, our algorithm presents an improvement of the performance compared to Method1, DECSA, LEACH, and LEACH-C algorithms. For example, for N = 700, the mean of the first node dead occurs at the 454 round by using our approach whereas this value is about 218, 77, 170, and 21 when Method1, DECSA, LEACH, and LEACH-C methods are used. It follows that even if the node density increases the new proposed approach still gives best results compared to the others protocols.

The robustness of the new proposed algorithm is certainly due to the fact that the clustering process is firstly used before the process of the cluster head election. And because of the considered number of clusters that is based on the minimization of the consumed energy in the WSN. Also, it is due to the fact that the residual energy of nodes is considered in the cluster head election step.

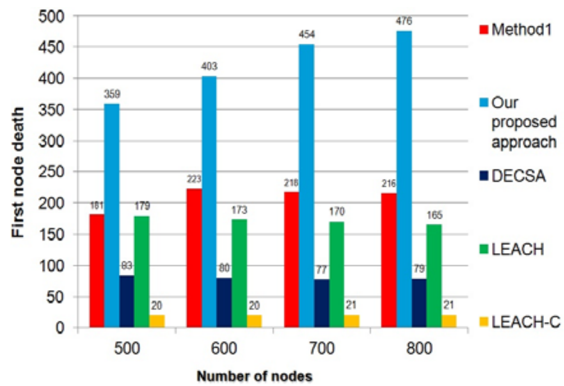

Figure 4: Impact Of The Node Density N On The Performances Of The Compared Algorithms.

We notice that the main problem of the LEACH and the LEACH-C protocols is the random selection of cluster heads. Because of this problem the probability that the determined cluster heads are unbalanced exists. Indeed, all the elected cluster heads may be located in a small part of the network making the rest of this last unreachable.

As far as Method1 and DECSA approaches are concerned, the main problem is the number of clusters that is not optimal.

In addition, Figure 5 shows the performances of the compared protocols by using different initial energies. It gives the FND round depending on the quantity of the node initial energy.

Once more, it is shown that for different values of the energy, the new proposed approach presents a significant improvement compared to the other protocols. We note that the rational raison behind this is the ways of choosing clusters and cluster heads; and the optimal number of clusters. Besides, requiring nodes to work in the free space communication mode, allows improving the network lifetime.

Journal of Theoretical and Applied Information Technology
31st March 2013. Vol. 49 No.3

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

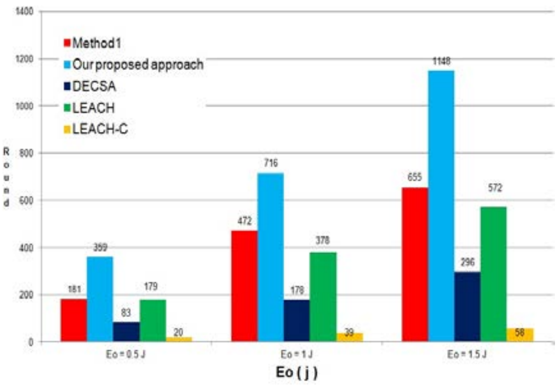

Figure 5: Impact Of The Initial Energy Quantity On The Performances Of The Five Compared Algorithms.

We conclude that the new proposed protocol gives a significant performance improvement in terms of energy and lifetime gains, compared to Method1, DECSA, LEACH, and LEACH-C protocols.

5. CONCLUSION

In this paper, we proposed a new approach to deal with the clustering problem in a given wireless sensor network. We have presented in details the proposed protocol which is based on a spectral classification method. This proposal is centralized as the network base station computes the adjacency and the Laplacian matrices of the network graph to run the protocol. By using the latter, we demonstrated that a robust clustering depends only on node positions, coverage range, and the node density. Moreover, thanks to the central control algorithm, we can avoid the complexity of charge of treatments generated by all network nodes. The approach put forward also takes into account the residual energy of cluster heads while electing the CH. Its introduced strategies allow to improve the network performances by saving more energy and extending more efficiently the network lifetime.

In fact, we measured and compared robustness and performance between our algorithm and four others. The study revealed that the former approach presents a more significant performance in terms of both energy and lifetime gains.

As a short term perspective, we will study other spectral classification techniques which may be more efficient in this kind of applications. Selecting the most robust protocol will, actually, be the primordial step in the coming work.

REFRENCES:

[1] Intanagonwiwat, C., Govindan, R. and Estrin, D. "Directed diffusion: Ascalable and robust communication paradigm for sensor networks", Proceedings of the 6th Annual ACM/IEEE International Conference on Mobile Computing and Networking (MobiCom00), Boston, MA, USA, pp. 56-67, August, 2000.

[2] Al-Karaki, J., N. and Kamal, A., E. "Routing techniques in wireless sensor networks: a survey", IEEE Wireless Communications, issue 6, pp. 6-28, December, 2004.

[3] Handy, M., J., Haase, M. and Timmermann, D. "Low energy adaptive clustering hierarchy with deterministic cluster-head selection", Proceedings of the IEEE International Conference on Mobile and Wireless Communications Networks (MWCN 2002), Stockholm, Sweden, pp. 368-372, September, 2002.

[4] McDonald, B. and Znati, T. "Design and performance of a distributed dynamic clustering algorithm for Ad-Hoc networks", Proceedings of the Annual Simulation Symposium, pp. 27-35, Seattle, WA, USA, 22-26 April 2001.

[5] P., N.H. Vaidya, M. Chatterjee, D. Pradhan, A, "Cluster-based approach for routing in dynamic networks", ACM, SIGCOMM Computer Communication Review, pp 49-65, 27 (2), 1997.

[6] Heinzelman, W., R., Chandrakasan, A. and Balakrishnan, H. "Energy-efficient communication protocol for wireless microsensor networks", Proceedings of the 33rd Hawaii International Conference on System Sciences (HICSS-33), pp. 3005-3014, January 2000.

[7] Heinzelman, W., R., Chandrakasan, A. and Balakrishnan, H. "An application specific protocol architecture for wireless microsensor networks", Transactions on Wireless Communications, Volume: 1, Issue: 4, pp: 660-670, October 2002.

[8] Lindsey, S., and Raghavenda, C.S. "PEGASIS: power efficient gathering in sensor information systems", Proceeding of the IEEE Aerospace Conference}, Big Sky, Montana, March 2002.

[9] Yonga, Z. and Peia, Q., "A Energy-Efficient Clustering Routing Algorithm Based on Distance and Residual Energy for Wireless Sensor Networks", International Workshop on Information and Electronics Engineering (IWIEE), Harbin, China, March 10-11, 2012

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[10] Qin, L., Zhu, Q. and Wang, M. "Design of a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks", ELSEVIER, Computer Communications, volume 29, number 12, pp: 2230-2237, 2006.

[11] Elbhiri,B., Saadane, R., Pagès-Zamora, A. and Aboutajdine, D.. "Equitable Distributed Energy- Efficient Clustering (EDEEC) for heterogeneous wireless sensor networks", International conference NGNS'09, Rabat, 4-6 June 2009.

[12] Elbhiri,B., Saadane, R., Pagès-Zamora, A. and Aboutajdine, D.. "Stochastic and Equitable Distributed Energy-Efficient Clustering (SEDEEC) for heterogeneous wireless sensor networks", INFOCOMP Journal, Volume: 8, Issue: 3, pp:11-20, 2009.

[13] Luxburg and Von, U. "A tutorial on spectral clustering", (MPITechnical Reports No. 149). Tubingen: Max Planck Institute for Biological Cybernetics, August 2006.

[14] Luxburg and Von, U. "On Spectral Clustering: Analysis and an algorithm", In Advances in Neural Information Processing Systems, 14, pp. 849-856, 2001.

[15] Shi, J. and Malik, J.. "Normalized cuts and image segmentation", IEEE Transactions on Pattern Analysis and Machine Intelligence (PAMI)}. Volume 22, Issue 8, pp: 888-905, August 2000.

[16] Newman, M., Watts, D., Strogatz, S.. "Random graph models of social networks". Proceedings of the National Academy of Sciences of the United States of America Proceeding, National Acad Sciences, Volume 99, Number: Suppl 1, pp: 2566-2572, 2002.

[17] Verma, D. and Meila, M., "A comparison of spectral clustering algorithms", University of Washington, technical report, 2001.

[18] Savvides, A., Han, C. and Srivastava, M. B. "Dynamic fine-grained localization in ad hoc networks of sensors", Proceeding of ACM International Conference on Mobile Computing and Networking (MOBICOM 01), pp: 166-179, Rome, Italy, July 16-21, 2001.

[19] Bulusu, N., Heidemann, J. and Estrin, D.. "Gps-less low cost outdoor localization for very small devices", IEEE Personal Communications Magazine, October 2000.