Available online at: www.basra-science-journal.org

ISSN –1817 –2695

A New Coverage Improvement Algorithm Based on LEACH Protocol

Ali Fadil Marhoon[1] Auhood Mokar Dyesh[2]

1. *Assist. Prof., Basrah University, College of Science.*
2. *B.S$_c$ Computer Science, Thi-Qar University, College of Education.*

Received 4-2-2013 , Accepted 8-5-2013

Abstract

Wireless sensor networks (WSNs) are used widely nowdays in many applications so it is desirable to improve their functionality, this can be done by overcoming over the drawbacks that may limit their performance.

Among these major drawbacks is the problem of the limited power supply since it is battery operated, many applications involve many other requirements besides energy keeping like gathering precise information and having active nodes in all parts in the network which can be referred as “network coverage”.

LEACH is one of the routing protocols in wireless sensor networks but it cannot provide many of the above mentioned requirements .

This paper presents a new algorithm which develops LEACH algorithm to improve the network coverage. This algorithm is called Extended Area Coverage Enhancement (EACE) and it provide a solution to the absence of coverage in some of the network parts since there is no near cluster heads to perform the tasks of data gathering and transmitting.

Keywords: WSNs, Coverage, LEACH and Advanced nodes.

1. introduction

Wireless sensor networks consist of large number of small nodes which have the capabilities of sensing, computation and wireless communications[1]. These nodes are deployed in the area where the data about the attribute of interest can be gathered.

Using of wireless sensor networks is increasing day by day because it is suitable for a large domain of applications such as military environment, disaster management, biological and explosive material, etc.[2].

Each node consists typically of many of physical components such as sensing

unit(one or more sensors), wireless communication device, small microcontroller and an energy source, in most cases energy source is a battery and this makes energy saving in the wireless sensor network play an important role in data transmitting and other nodes activities[3]. Routing schemes in wireless sensors networks should be designed in a way that makes energy saving one of its essential priorities besides other requirements that may be application dependent.

Coverage preservation is an important issue in WSNs especially when the application is interested in the quality of service (QoS) like battlefield surveillance and medical healthcare, etc, these applications require a network with fully functional to ensure the transferring of information with full coverage[4].

Sensor networks can be classified into two types; homogeneous and heterogeneous sensor networks. In the first type all nodes are identical in terms of battery energy and hardware complexity while in heterogeneous networks one or more different types of nodes are used with different energy source and functional capabilities[5].

Clustering is an effective approach to reduce energy consumption, in this approach many of adjacent nodes are grouped together to form a cluster, each cluster has a special node called a cluster head while other nodes will act as its members. The cluster head is responsible for scheduling its members then it will collects their information, aggregates them to remove data redundancy and sends this aggregated data to the sink.

Many of clustering routing protocols are suggested like PEGIES, TEEN and LEACH. LEACH is one of the most famous hierarchical routing protocols but it cannot provide a full coverage in all cases because it selects the nodes that will be cluster heads randomly.

In this paper, we proposed a development for Low Energy Adaptive Clustering Hierarchy (LEACH) protocol to provide a new algorithm which maintains coverage absence resulted from random selection and non-uniform distribution of clusters heads. The paper is organized as follows : section 2 related work (LEACH routing protocol with two other algorithms) are described, these two algorithms presented improvements on LEACH. Section 3 will cover the description of problem, ECAE algorithm and the radio energy dissipation model. At last, the simulation and results are listed in section 4.

2. RELATED WORK

At first, LEACH protocol is explained since it represented the basis that ECAE algorithm depends on, then two of its enhancements are summarized, these two enhancement suggest the using of a special type of the sensor nodes to perform a certain function in the routing process.

Heinzelman *et al.* [6] proposed an effective and popular routing scheme called LEACH (Low Energy Adaptive Clustering Hierarchy), LEACH protocol achieves data gathering through number of rounds, each round is divided into two main phases:

- set-up phase
- steady phase

➢ **set-up phase:**

it is also subdivided into advertisement phase and cluster set-up phase.

A- advertisement phase

Sensors elect themselves to be local cluster heads at any given time with a certain probability according to the following equation:

Each node selects a random umber between 0 and 1, if the selected number is less than a specific threshold computed in equation (1) then this node will be cluster head.

$$T(x) = \begin{cases} \dfrac{P}{1-P\,(r \bmod (1/P))} & \text{if } n \in G \\ 0 & \text{otherwise.} \end{cases} \qquad (1)\ [6]$$

Where :
r denotes the current round,
p is the percentage of cluster head in all nodes , its value is less than 1 and it represents the percentage of nodes that should be elected as cluster head with regard to the total number of nodes in the network(for example, p=0.04 or p=0.05).

The variable G represents the set of nodes that have not been selected to become cluster heads in the last (1/p) rounds.

Nodes with numbers less than the above threshold announce themselves as cluster heads by sending a broadcasting message, we call them ”hello message”, to their neighbors in order to start the clusters formation, non-cluster heads nodes pick the cluster heads messages depending on the strength of the received signal.[3]

B- Cluster set-up phase:

Members nodes inform one of the cluster heads that they become members in its cluster by sending a special message “join message”, Each sensor node determines to which cluster it wants to belong by choosing the cluster head that requires the minimum communication energy by depending on the strength of the received signals.

- **Steady-state phase**

It is data transmission phase, at first, cluster heads should start the scheduling of their members by sending a TDMA (Time Division Multiple Access)scheduling message. Each TDMA message allocates a time slot for the member nodes that received it to send data it has to the CH.

Members nodes send their data during their allocated TDMA slots to the CH. The radio of each non-cluster head node can be turned off until the nodes allocated its TDMA slot.

When the CH has been collected the data from its members, it aggregates these data and sends them to the sink.

Using of advanced nodes(nodes with more energy resources and communication capabilities) is introduced in[7], some of these nodes, which are called CAG(nodes selected as Cluster heads or Gates), may act as cluster heads and their selection depends on LEACH strategy.

All CAGs nodes that are not selected as CHS become gateways to transfer data received from the CHs, non-CAG CHs, to the sink in order to reduce the distance between the CHS and sink.

In [8], to deal with the heterogeneous energy circumstance, the node with the higher energy should have the larger probability to become the cluster head. In this paper, each node must have an estimate of the total energy of all nodes in the network to compute the probability of its becoming a cluster head.

3. The proposed algorithm

The coverage problem in WSNs is explained first, then some of the necessary assumptions are introduced. The algorithm is detailed in section(3.C).

3.1 Problem description

Coverage in WSNs:

Each sensor device has a physical sensing range that it is able to perform data gathering operation with this range [9].

In most cases coverage means area coverage which means that every point in the monitored field is covered by at least one sensors. it is desired to ensure that the entire physical space (or large fraction of it) is within the sensing range of the active sensors in the network. On the other hand, t is hard to guarantee full coverage for a randomly deployment area since the effectiveness of sensor networks is influenced by small coverage holes[10].

As it explained earlier, LEACH strategy depends on random number generation at each node to select cluster heads and because of this dependence LEACH protocol suffers from absence of coverage in some parts of the network since there is no control on the number and distribution of cluster heads. LEACH also assumes that the node that acts as CH in a round (r) will not be chosen as CH during the next (1/p) rounds , this gradually reduce the number of nodes competing to be cluster heads resulting in forming few clusters leaving large area of the network uncovered.

3.2 Network Model

Consider a heterogeneous network with N normal nodes are deployed randomly in two dimension area and M advanced nodes that can be deployed either randomly or manually according to the application or environment.

other assumptions are :

- All the advanced nodes know their locations.
- Sink node knows the locations of the advanced nodes (advanced nodes can send their locations information to the sink before the algorithm has been started).
- If we assume that the network area is divided into many of equal parts using a number of vertical and horizontal lines, each part should contain a sufficient number of advanced nodes.
- Sink, normal and advanced nodes are stationary.

3.3 ECAE algorithm

The presence of the advanced nodes in this algorithm is utilized as "*coverage indicators*", in other word, the advanced nodes delays their work until the completion of LEACH set-up phase (clusters formation phase), if they did not receive any "advertisement message", this means that there is no cluster head in the region of their coverage. Then they should take the responsibilities of cluster heads to provide coverage for their area.

The main functions of this algorithm are the network partitioning and query sending mechanisms, network partition is necessary to control the coverage in all the network parts, while applying the query strategy is to reduce the energy consumed by the normal nodes that were not working in LEACH because there are no cluster heads among their neighbors. Since the number of nodes that send data is increased in the proposed algorithm because of the formation of new clusters in the uncovered parts, query mechanism is used to transfer data from the nodes that sense only critical information, this will help in gathering the required data without exhausting the nodes energy.

Depending on the sink knowledge about the network size and the communication ranges of both normal and advanced nodes, the sink divides the network area into a number of equal parts. Networks with small areas, for example, may need only the division into two parts using either one virtual horizontal or vertical line. When the network size increases,

the sink can partition the whole network into four or more of equal sized parts using number of horizontal and vertical lines. At each number of rounds (θ rounds), the sink selects two non-adjacent advanced nodes from each part of the partitioned network. To avoid the redundancy of data transferring, the algorithm suggests that only one of these two active nodes will be responsible for data gathering from its fixed cluster at each round and in an exchangeable manner as it be explained in details in the algorithm below, Figure (1) shows an example to this partitioning, in this example the network is divided into four equal parts and two advanced nodes are selected by the sink to be active during the next θ rounds.

The reselection of active advanced nodes after each θ rounds occurs for specifying the application requirements, such as the changing of the parts the user is interested to collect the information from, or to balance the energy consumption of the advanced nodes and the normal nodes that will belong to their clusters

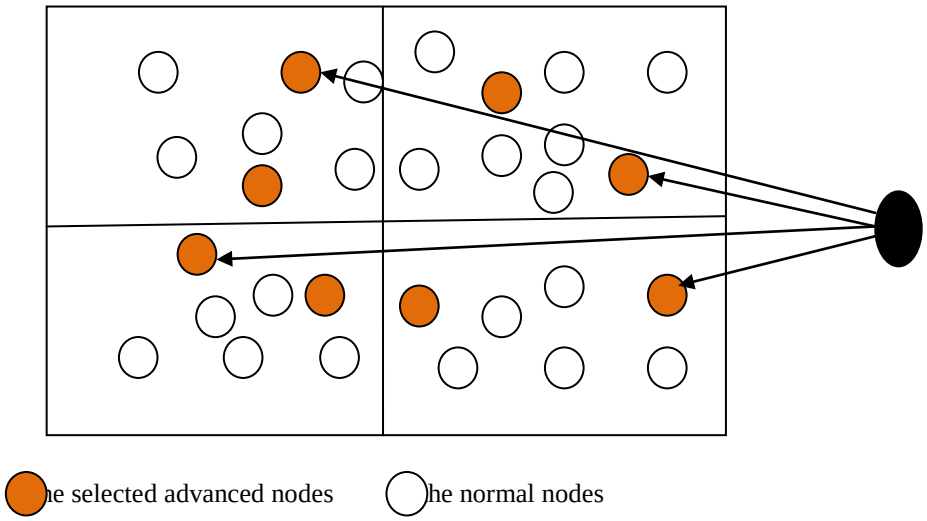

Figure 1 .network partitioning, sink selects two advance node at each quarter

Let AN1 and AN2 be two non-adjacent advance nodes lying at the same part of the partitioned network, d1, d2 are thresholds for distances where (d2<d1). d1, d2 are varied according to the network size.

Suppose that NN represents the set of all the normal nodes in this network part, TN1 and TN2 are subsets of NN and they represent the sets of normal nodes lying at a distance less than or equal to d1 from AN1 and AN2 respectively.

TN1 is subdivided into PN1(primary neighbors) and SN1 (secondary neighbors), TN2, on the other hand, is also subdivided into PN2 and SN2, where PN1 and PN2 are the sets of all members nodes lying at distance less than or equal to d2 from either AN1 or AN2. SN1 and SN2 is the sets that contains the nodes lying at a distance larger than d2 and less than or equal to d1 from either AN1 or AN2. Figure 2. shows these sets and the distances in one of the network parts

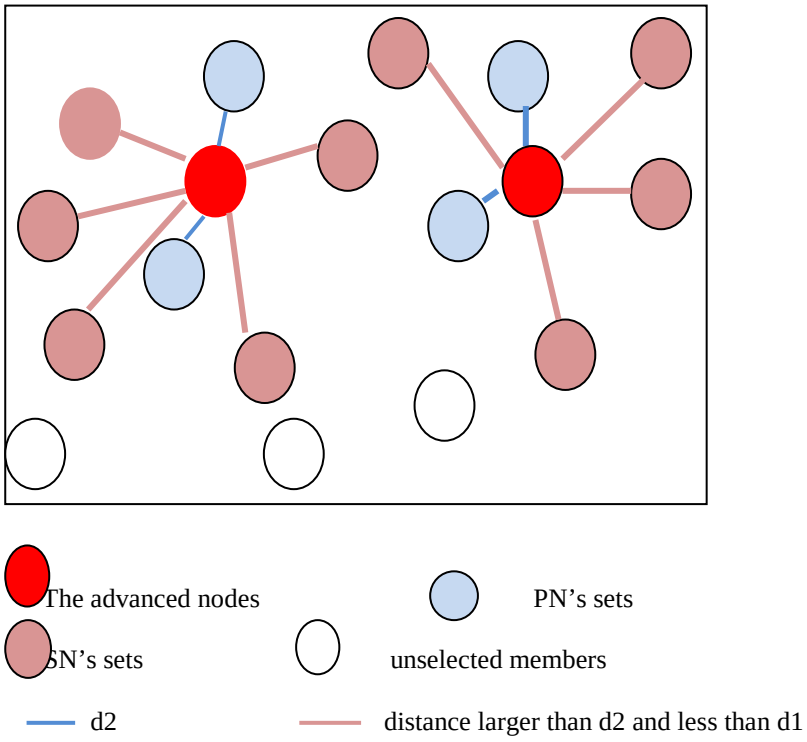

figure 2. nodes division in the network parts

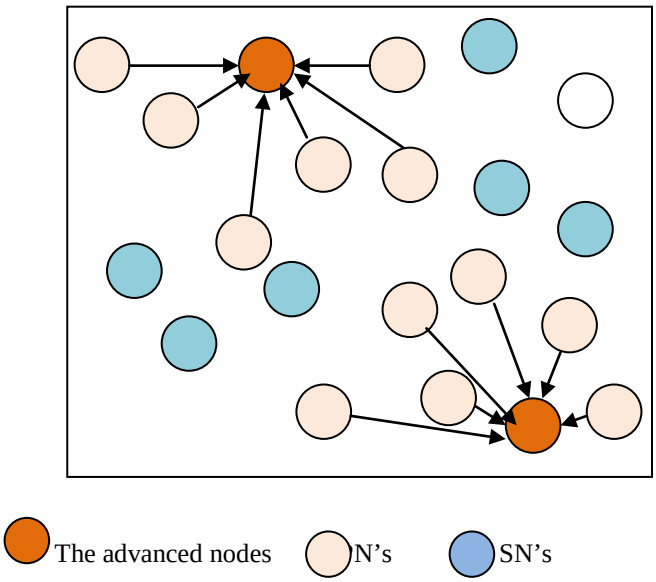

Figure 3. Two fixed clusters are formed

For each θ rounds and before **LEACH** set-up phase starts, do steps (1-5):

1. The sink node selects **AN1** and **AN2** and inform them by sending a message to **AN1**.
2. **AN1** sends a message to **AN2** to inform it about its being as "coverage indicator" for these **θ** rounds.
3. **AN1** and **AN2** send "neighbors sensing" messages to all nodes in **NN** lying at a (**d1**) distance from them.
4. Members in **PN1** sets send "join message" to **AN1**, **PN2** members replay **AN2** with "join message" also. After all "join messages" have been received, two fixed clusters will be created (Figure 3).
5. Members in **SN1** and **SN2** will used only to inform **AN1** and **AN2** in case of their being as cluster heads during **LEACH** set-up phase in order to prevent **AN1** and **AN2** from data gathering because of the existence of a cluster head in the near area.
6. While (**θ** has not been reached) do steps (7-11), otherwise go to 1.
7. **LEACH** set-up protocol will start as normal.
8. For each two successive rounds (r,r+1):
   at the round r: **start** =**AN1**, **second= AN2**
   at the round r+1 : **start** = **AN2** , **second** = **AN1**
9. ***If*** **start** receive no "advertisement messages" from it's **PN** or **SN** members (i.e. no near cluster heads), ***then*** **start** sends a query message to all its **PN** members. This message contain the threshold value (**T**) that the required information is equal or larger it.
   Else it sends a "check message" to **second**.
   if **second** received no "advertisement message", it send "query messages" to the members of it's own **PN**,
   Else, no action is done.
10. Normal nodes that receive "query message" send "replay messages" if they sense a value larger than or equal to **T**.
11. The advanced nodes that received the "replay message" aggregates the received data and sends them to the sink node.

4. radio energy dissipation model

we use the same radio energy dissipation model used in [11], the radio spends $E_{Tx\text{-}elec} = E_{Rx\text{-}elec} = E_{elec} = 50nJ/bit$ energy to run receiver and transmitter electronics. Therefore the transmission cost to transfer a-bit message to a distance d is given by equation (2)

$$E_{Tx}(a,d) = \begin{cases} aE_{elec} + aE_{fs}\, d^2 , & d<d_0 \\ aE_{elec} + aE_{mp} d^4 , & d>=d_0 \end{cases} \quad (2)\ [11]$$

Where:
a is the number of the transmitted bits,
d0 is a distance threshold that the sensor turns ON it's amplifier circuit when the communication distance is larger than it.
$E_{fs} = 10pJ/b/m^2$.
and E_{mp} denotes the energy consumed that the radio spends to run its amplifier circuit and this value equal to $(0.0013pJ/b/m^4)$.
Similarly, the receiving cost can be given by equation (3)

$$E_{Rx}(a) = aE_{elec} \quad (3)\ [11]$$

5. Simulation and results:

OMNeT++4.1 simulator is used to simulate LEACH protocol and ECAE algorithm, OMNeT++ stands for Objective Modular Network Tested in C++ and it is a new and powerful simulator which was developed by András Varga.

A network with one type of nodes (normal nodes) is used to simulate the original LEACH protocol while the proposed algorithm requires the using of a heterogeneous network with a suitable number of the advanced nodes besides the normal nodes with the same number and location of those in the first network.

The simulation parameters are the same in both of the two above described networks and the results are recorded for three different executions of the simulation. This repetition of the execution is to provide a reliability to the results.
The simulation parameters are:
The number of the normal nodes in both of LEACH and ECAE networks is 75 nodes, the number of the advanced nodes in the heterogeneous network is 17, the communication range of the normal nodes is 25 m, the communication range of the advanced nodes is 30 m, the size of all the transferred packets are 400 bits, P (the percentage of the nodes that will act as cluster heads) is 0.004.

Each of the three simulation runs consists of many of round as it explained in the description of LEACH protocol. In each round, the number of the nodes that sent their data to the sink node -either normal or advanced cluster heads- is recorded to be compared between the LEACH and the proposed enhancement. These nodes will be referred to as active nodes, the number of the active nodes represent one of the main factors to evaluate the proposed algorithm efficiency because the formation of the new cluster heads in the network parts that was suffering from coverage absence due to random cluster heads selection depended by LEACH.

The second factor in ECAE evaluation is the energy levels of the normal nodes. As it explained earlier, ECAE suggests the using of the advanced nodes to take the cluster heads responsibilities in case of the

existence of no cluster head in their communication ranges. This mean that the normal nodes belong to the advanced nodes clusters will have a new data gathering tasks and this should not have a great effect on their energy levels. The energy levels of the normal nodes after the last rounds in each simulation run is recorded in both of LEACH and ECAE in order to perform the comparison between them.

The distances between nodes are needed to be calculated in order to use these values in the calculation of the energy consumed using the radio energy model described in section(3.D). As in [12], the Euclidean distance rule is used.

$$d= \sqrt{(X2-X1)^2+(Y2-Y1)^2} \qquad (4)$$

where is (X1,Y1) be the coordination of the source node, (X2,Y2) is the coordination of the destination.

Figures (4,6,8) show the numbers of the active nodes in the first, second and the third simulation run respectively while the energy level in these runs is clarified in figures(5,7,9).

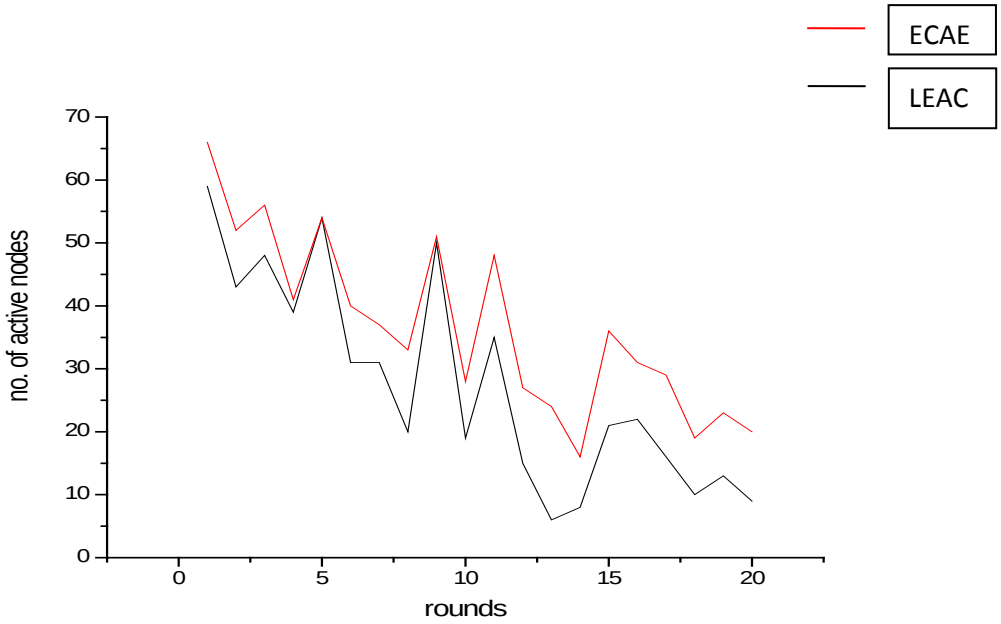

Figure 4. The number of the active nodes in LEACH and EACE in the first run.

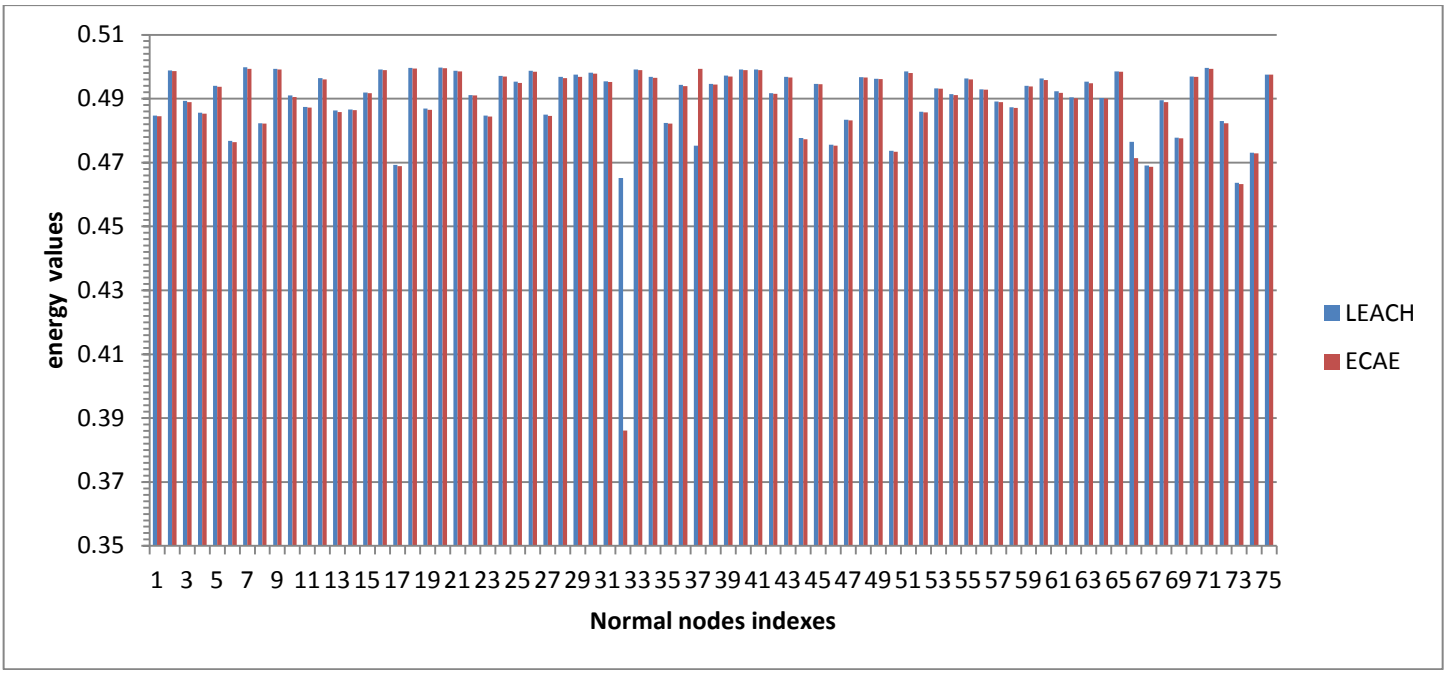

Figure 5. the energy levels of the normal nodes after the last simulation round in the first run

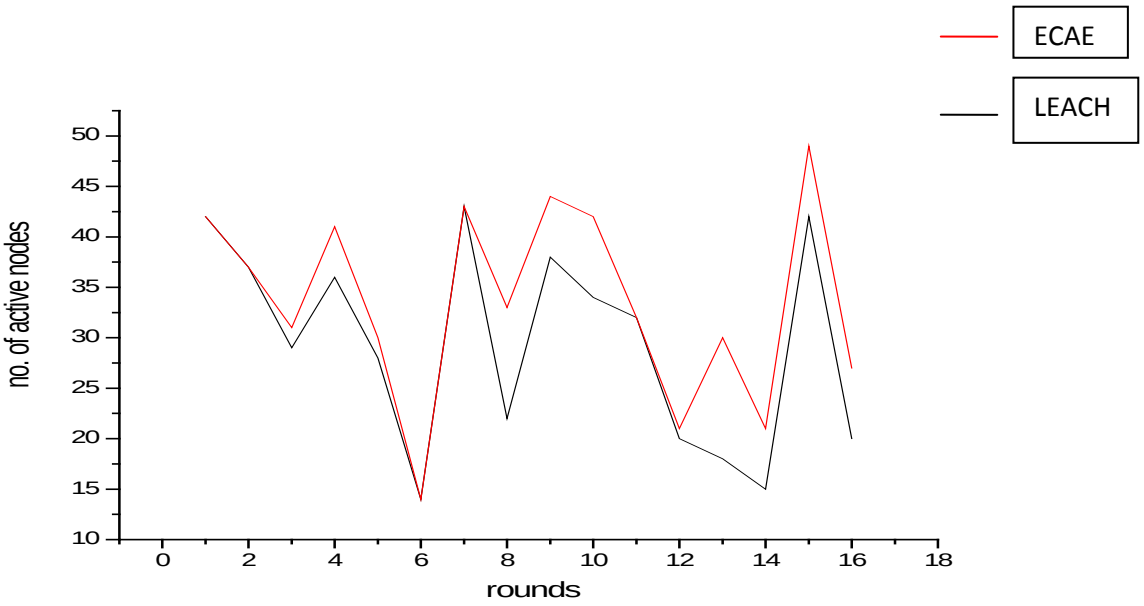

Figure 6. The number of the active nodes in LEACH and EACE in the second run.

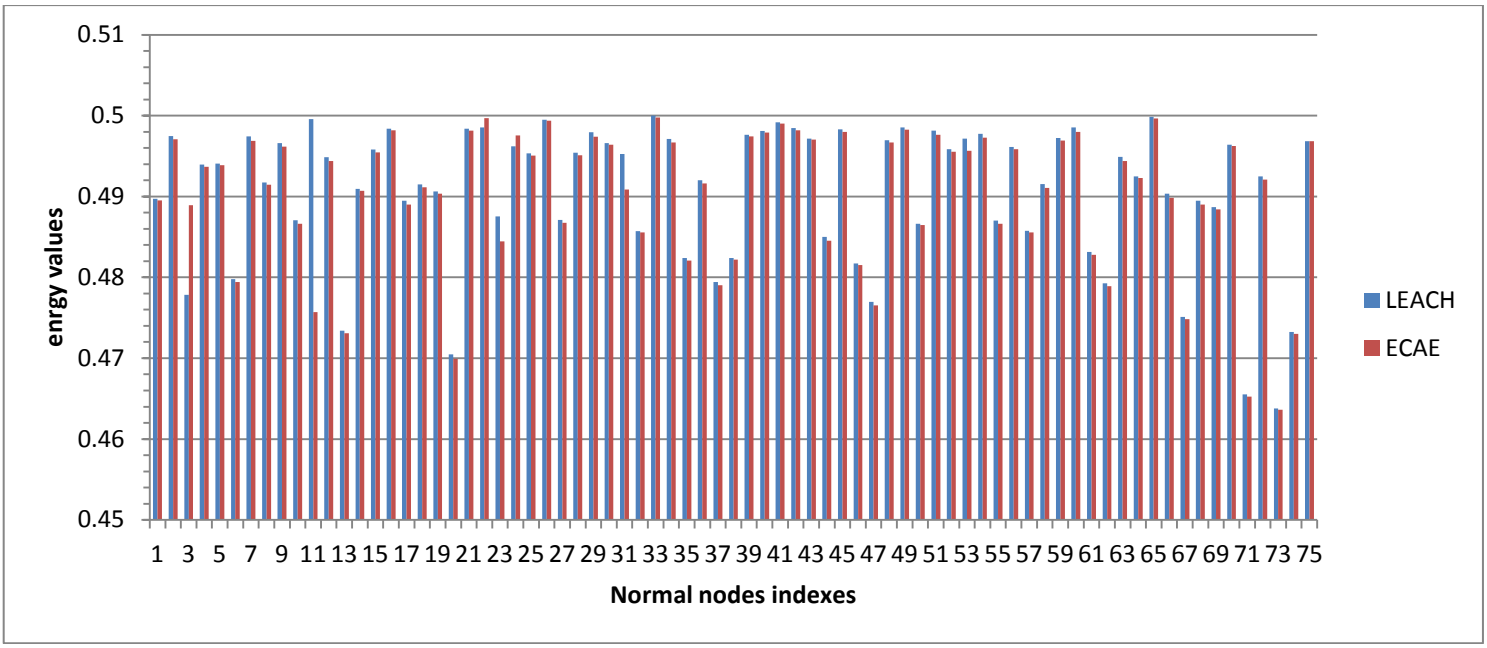

Figure 7. the energy levels of the normal nodes after the last simulation round in the second run

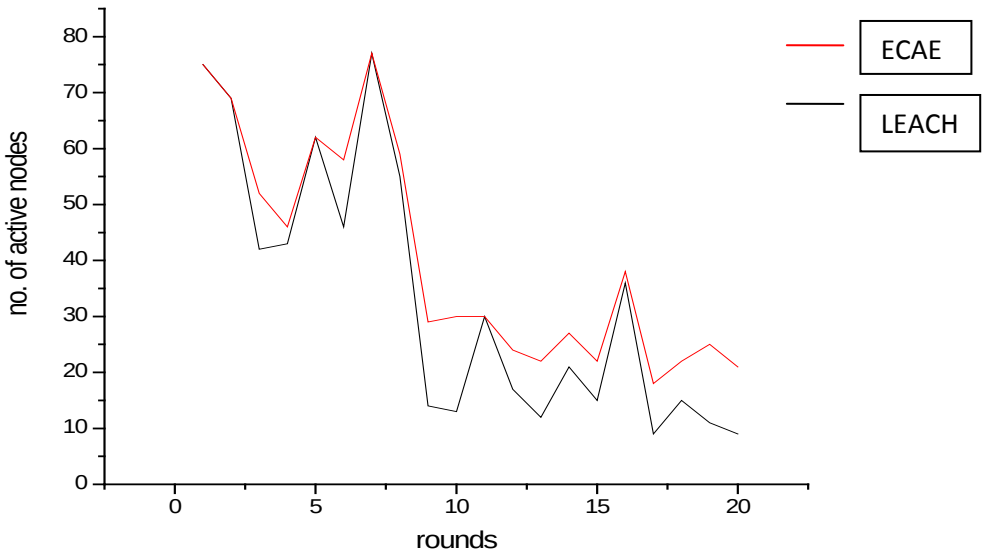

Figure 8. The number of the active nodes in LEACH and EACE in the third run.

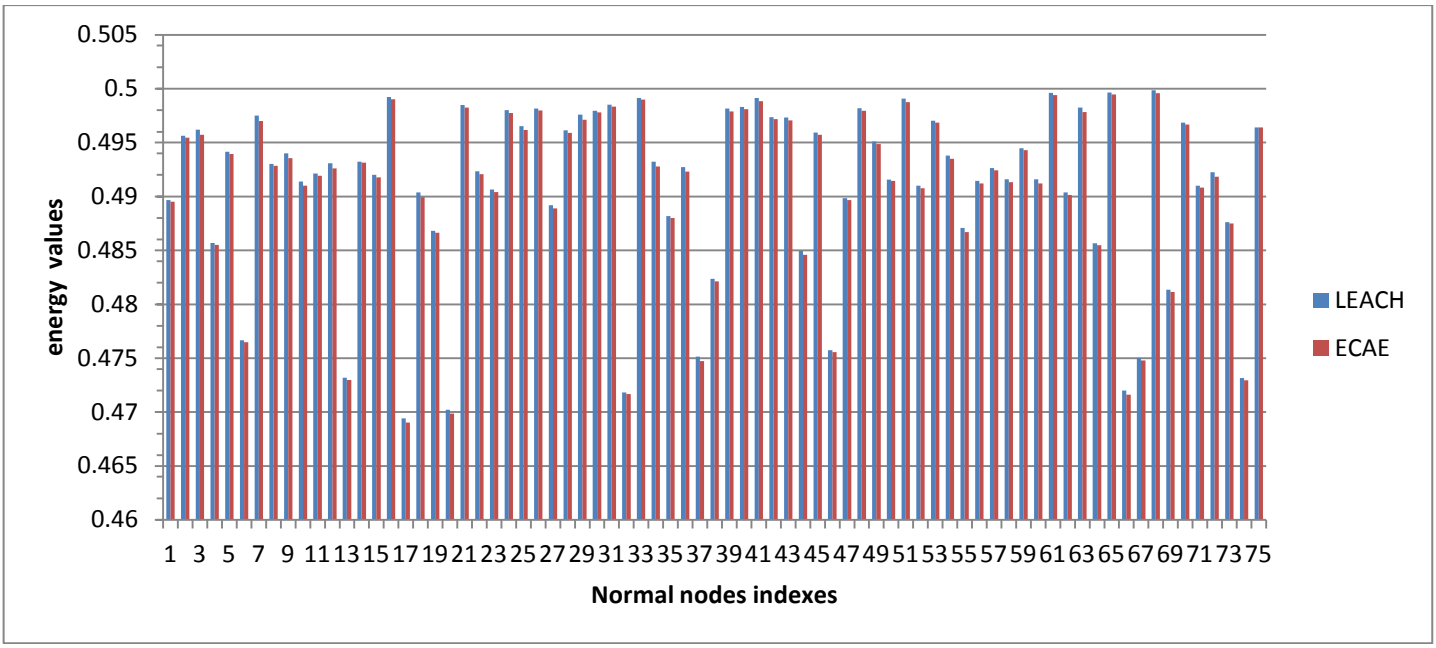

Figure 9. the energy levels of the normal nodes after the last simulation round in the third run.

Conclusions:

As it is clear from the results, number of nodes that worked at each round in the new algorithm is increased compared to that in LEACH, this provide more covered areas and gather more information in parts of the network that could not send their data in LEACH since there is no near node that acts as cluster head and provides a gateway to communication with the sink.

We can notice also that the energy levels are not hardly affected by the activities of the nodes in non covered area because transmission to the base station, which consumes more energy compared to the local communication inside cluster because of the large transmission distance, is done by the advance nodes.

[1] Al-Karki J. and Kamal A, "routing techniques in wireless sensor networks-a survey", **December 2004**.

[2] Patel R., Pariyani S. and Ukani V., "energy and throughput of hierarchical routing protocol (LEACH) for wireless sensor network", **April 2011.**

[3] Yassein M, Al-zoubi A., khamayseh Y. and Mardini W., "improvement on LEACH protocol of wireless sensor network (VLEACH)", International journal of digital content technology and its application, Vol. 3, No. 2, **June 2009**.

[4] Joe-air jaing, Tzu-shiang lin, chenf-long chuang and chai-pang chen, "A QoS-guaranteed coverage precedence routing algorithm for wireless sensor networks", Sensors journal, **March 2011**.

[5] Mhatre V. and Rosenberg C., "homogenous vs heterogeneous clustered sensor networks: A comparative study", IEE communications society, **2004**.

[6] Heinzelman W, Chandrakasan A. and balakrishnan H.,"energy efficient communication protocol for wireless microsensor networks", 33rd conference on system sciences, **2000**.

[7] Abdellah E., Benalla S., Hissane A. and Lacen M., "advanced low energy

adaptive clustering hierarch", international journal on computer science and engineering, **2003**.

[8] Heinzelman W., Chandrakasan A. and Balakrishnan H.,"an application-speciefic protocol architecture for wireless sensor networks", IEE transactions on wireless sensor communication, **October 2002**.

[9] Rajagopar lyengar, Koushik kar and Suman Banerjee, "low-coordination topologies for redundancy in sensor networks", **2009**.

[10] Ming liu, Jiannong cao, Guihai chen and Xiamin wang,"an energy-aware routing protocol in wireless sensor networks" Sensors journal, **2009**.

[11] Zhang jain-wu, Ji ying, Zhang ji-ji and Yu cheng-lei, "a weighted clustering algorithm based routing protocol in wireless sensor networks", international colloquium on computing, communication, control and management, **2008**.

[12] Jarah N., "efficient routing in Ad-hoc Wireless Network using connected dominating set", journal of Basrah researches (sciences), Vol. 4, **2012.**

خوارزمية تطوير التغطية في شبكات التحسس اللاسلكية

علي فاضل مرهون[1] عهود موكر دايش[2]

1. *استاذ مساعد دكتور, جامعة البصرة كلية العلوم.*
2. *بكالوريوس حاسبات, كلية التربية جامعة ذي قار.*

الخلاصة

شبكات التحسس او الأستشعار اللاسلكية أصبحت واسعة الانتشار في عصرنا الحالي لاستخدامها في العديد من التطبيقات لذا فأن من الضروري العمل على زيادة فعاليتها و يتم ذلك من خلال العمل على التغلب على العقبات التي تحد من انجازيتها.

من بين المشاكل الاساسية في شبكات الاستشعار اللاسلكية هي مشكلة الطاقة المحدودة كونها تعتمد على البطاريات كمجهز للطاقة. هناك بعض التطبيقات تحتاج الى بعض المتطلبات الخاصة مثل جمع المعلومات الدقيقة من جميع أجزاء الشبكة و توافر عقد قادرة على ارسال البيانات من جميع اجزاء الشبكة والتي يشار اليها بتو فير التغطية في الشبكة.

احدى بروتوكولات توجيه البيانات في شبكات الاستشعار اللاسلكية يسمى (بروتوكول التجميع الهرمي لتقليل الطاقة) و هو من البروتوكولات الجيدة لكنه لايستطيع توفير كل المتطلبات اعلاه.

هذا البحث يقدم خوارزمية تعتبر تطوير لبروتوكول التجميع الهرمي لتحسين التغطية في الشبكة.

الكلمات المفتاحية: شبكات التحسس اللاسلكية, التغطية, بروتوكول LEACH و العقد المطورة.