Journal of Advances in Computer Research
Quarterly pISSN: 2345-606x eISSN: 2345-6078
Sari Branch, Islamic Azad University, Sari, I.R.Iran
(Vol. 6, No. 4, November 2015), Pages: 53-67
www.jacr.iausari.ac.ir

An Efficient Protocol for Data Aggregation In Wireless Sensor Networks

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Received: 2015/02/13; Accepted: 2015/05/01

Abstract

Sensor networks generally consist of a very great number of sensor nodes which will be spread into a vast environment and aggregate data out of it. The sensor nodes are afflicted with some limitations as follows memory, reception, communication as well as calculation capability, and battery power. The transmission of a great amount of extra data increases data transmission and proportionally increases the amount of energy and bandwidth for the data transmission. One solution for this issue is data aggregation. The results of aggregated data influence the accuracy and precision of the final result already gleaned from the base station. The main challenge in such networks is how to further elongate the network lifetime and among the factors doing so is the energy consumption or energy optimization. The clustering is one apt method in place for furthering the network life span. Respectively the clustering protocols have come up with a suitable method for the so called challenge or more simply put increasing the lifetime. In this paper the researchers attempt to bring forth yet another efficient protocol for data aggregation hinging around clustering which uses maximum residual energy and minimum distance for selecting the cluster-head to reduce the consumption of energy. The experimental results point to this very fact that Energy-Efficient Clustering Algorithm through Residual Energy and Average Distance (EECA-READ) attains very good performance.

Keywords: *Wireless sensor networks, Clustering, Data aggregation, Residual energy*

1. Introduction

Wireless sensor network consists of a set of cheap sensor nodes, expanded in physical environment to aggregate (collect) the received data, communicate with each other, use wireless communication and finally send the received data to base station for further processing through cooperation and collaboration [1]. Sensor nodes are mostly limited to calculations, communication sources and battery power [2]. Also, the nodes can locally communicate with each other to receive data form a cluster and schedule active / sleep times [3]. The low-cost sensor nodes are strictly limited to abilities such as receiving, calculating and communicating. It is important to minimize the transmission rate so that the average lifetime of sensor and total bandwidth accessibility could be improved [4]. Due to increasing the density of sensor nodes in WSN, neighboring sensor nodes often overlap in their sensing areas. Therefore, some similar data are produced that lead to a vast volume of network data. The transmission of great amount of redundant data, increases data transmission and accordingly increases the amount of energy and bandwidth for data transmission. One of the solutions for this issue is data aggregation [1], [4]. Data aggregation is a process of aggregating data from different sources by using aggregate function to limit the rate of increase of the transmitted data. Results of the aggregated data influence accuracy and precision of the final result gained from the base station. Data aggregation in the wireless sensor networks eliminates extras for the sake of betterment in bandwidth exploitation and energy efficiency [1]. Data stands for a process of summarization and combination of secure data in order to lower the rate of data transmission in the networks [4]. Data aggregation in the wireless sensor networks eliminates extras to improve bandwidth exploitation and energy efficiency [5]. In this paper, we tend to investigate the efficient protocol for data aggregation in wireless sensor networks. We introduce a new efficient protocol for data aggregation which uses residual energy and average distance to reduce the power consumption of sensors and therefore improve the clustering method of sensors. In this algorithm, each sensor has a neighborhood information table which will be updated when the node receive a neighborhood message. The nodes their residual energy meet the specified threshold, become candidates for being cluster-heads. Communication via cluster-heads leads to reduce the message passing and so reduce the energy consumption of wireless sensor network.

Here is what this paper aims to contribute:

(1) A new cluster head selection method is developed which uses message passing approach to determine a neighborhood and reduce the amount of data transformation between sensors.

(2) A new Energy-Efficient Clustering Algorithm by Residual Energy and Average Distance (EECA-READ) is presented.

The remaining of the paper is organized as follow:

In section 2, a discussion over the present studies germane to the energy saving problem in wireless sensor networks is leveled. Later a description of some of the most notable existing energy efficient secure data aggregation protocols which are based on Leach protocol is provided. Section 3 includes the definition and description of the ABC's and presents a primary model of energy saving protocol. Our new protocol and its flowchart are also touched in this section. Lastly an experimental study in section 4 is conducted and finally the whole study is concluded in section 5.

2. Related Works

Sensor nodes are mostly limited to calculations, communication resources and battery power [2]. Since the resource is limited to sensor nodes, it is important to minimize the amount of transmission of message so that the lifetime average of the node and availability of bandwidth would be improved [4]. Data aggregation in wireless sensor networks eliminates superfluities to improve the utilization of bandwidth and energy efficiency of sensor nodes [5]. 'Hop by hop data aggregation' and 'end to end data aggregation' are two methods of secure data aggregation which are used in wireless sensor networks [1] and [6].

ESPDA [7] is one of the secure hop by hop encrypted data aggregation protocols which is based on pattern codes and illustrates the characteristics of sensor data to aggregate the data. In this protocol, the pattern code will be sent instead of transmitted sensor data. Energy-Efficient Secure Pattern Based Data Aggregation called ESPDA has been presented in [5] and [7]. ESPDA improves the efficiency of bandwidth to 50% in comparison to other aggregation methods.

SRDA [3] is a secure hop by hop encrypted data aggregation protocol which is based on safe reference. The original idea behind SRDA is to transmit the differential data instead of received row data [3].

SDAP [8] is a secure hop by hop encrypted data aggregation protocol which is based on divide-and-conquer and commit-and-attest protocols. The advantage of this protocol includes applicability, multiple aggregation functions and adjustable detection rate, but the usage of energy and transmission overhead is high [1].

The CDA protocol is one of the secure end-by-end encrypted data aggregation protocols. Concealed Data Aggregation (CDA) [9] ,[10] is based on structural similarity (homomorphism) of symmetric concealed adjunct (additive) suggested by Domingo-Ferrer [11],[12].

CDAP protocol is one of the secure end-by-end encrypted data aggregation protocols. In this protocol, concealed data aggregation using structural similarity [13] is based on concealed asymmetric homomorphism.

HCDA protocol is one of the secure end-by-end encrypted data aggregation protocols. In this protocol, hierarchical concealed data aggregation for wireless sensor network [14] is based on elliptic curve cryptography.

Hierarchical routing protocols and data aggregation implicate a sensor-cluster based organization and as a result make data fusion and aggregation possible and lead to considerable amount of energy saving [15].

LEACH (Low Energy Adaptive Clustering Hierarchy): In presented protocols and clustering methods, LEACH is the most famous and desired protocol and the basis for many clustering methods [16]. LEACH is a dynamic clustering method [17] and has two phases. In the articles such as [16], [18], [17], [19], [20] and [21], the LEACH protocol were investigated. Heinzelman and his colleagues [20] introduced a clustering algorithm called Energy Adaptive Clustering Hierarchy. The authors allow a randomized rotation of cluster-head with the aim of reduction in energy consumption (in other words, extension of network lifetime) and balance distribution of energy load between sensors of the network [22]. All the procedure of LEACH protocol divides into rounds. Each round consists of set-up phase and steady-state phase. In cluster-formation phase, each sensor node selects a random number between 0 and 1. If the produced random number is less than the threshold, the node changes to cluster-head .Otherwise it will join a cluster as a member of that cluster. After the specific period of time passed in steady-state phase, the network enters into the formation phase to repeat clustering [18]. LEACH clustering does not produce good cluster-head distribution and assumes invariable energy consumption for cluster-heads. In addition, the idea of dynamic clustering brings extra overhead which might reduce optimality of energy consumption [18]. To overcome such shortcoming of LEACH, numbers of modifications were suggested in articles of [21], [23] and [24]. Some of them are: LEACH-C [21], PEGASIS [25], TEED [24], HEED [23] and so on.

HEED: in [23], the authors suggest a Hybrid, Energy-Efficient, Distributed (HEED) protocol to extend the lifetime of network which in this protocol the cluster-head may be selected based on their residual energy. HEED protocol is a modified energy-aware hierarchical approach of LEACH.

ERA: Energy Residue Aware (ERA) clustering algorithm [26] is energy-aware hierarchical approach. ERA utilizes the same plan for cluster selection which HEED uses but in order to select a “better” cluster-head, it cooperates in clustering cost calculation, finding the cluster-head based on maximum residual energy and providing an improved plan [18].

RRCH: [27] it forms the cluster only once in order to avoid high energy consumption during clustering phase. RRCH keeps the clusters fixed and uses round-robin method to select the cluster-head. RRCH has the same efficiency of LEACH; there is no guarantee for cluster quality [18].

To avoid the problem of cluster-head random selection, there are many other approaches which focus on the manner of selecting the appropriate cluster-head to achieve efficient communications [18].

LEACH-C: LEACH-C (Centralized LEACH) [21], instead of random self-selecting of the nodes as one cluster-head, a centralized algorithm will be executed by sink in LEACH-C. Sink collects the location information from the nodes and then informs them about the nodes themselves which are supposed to act as cluster-head. Generally, the function of LEACH-C is far better than LEACH because it transfers the responsibility of cluster formation to the sink. When the energy used to communicate with sink costs higher than the communication needed to form clusters, LEACH-C would not have proper function anymore [18]. Using a centralized controlling algorithm for clustering formation may produce better clusters through distribution of cluster-head nodes in whole network [19].

PEGASIS: it’s Power-Efficient Gathering in Sensor Information Systems. The communication between resembles to that of a chain. This clustering is a “chain-based protocol” and an advanced version of “LEACH”. Contrary to LEACH, the transmission distance for most of the nodes in PEGASIS becomes short. But its deficiency is that when one of the nodes becomes candidate to be a cluster-head, there is no idea about the location of base station for nodes’ energy [17]. PEGASIS limits the number of transmissions and performs better than LEACH and eliminates the dynamic overhead [19].

DSC: Dynamic/Static Clustering (DSC) [28], is an extension of LEACH-C. Making use of this plan, each node can access to its current location through Global Positioning System (GPS) and send the information of location and condition of energy to the sink. Then based on the gathered information, the sink determines the number of cluster-heads and broadcasts the result of clustering to each node. Anyway, it suffers from the same problems of LEACH-C [18].

EDASC: It is an Energy-efficient data aggregation protocol based on static clustering (EDASC) [29] which tries to decrease the overhead of dynamic clustering. This approach is similar to LEACH model. But EDASC uses sink. The main idea of EDASC is to form clusters in static state [18].

AHP: analytical hierarchy process (AHP) [30], performs the algorithm of cluster-head selection through sink. AHP supports mobile sensor nodes. AHP calculates local weight and global weight using three factors namely, energy, mobility and the distance from the center of gravity of involved cluster .Then it selects the cluster-head by mixing the results of these two weights. Comparing to LEACH, AHP improves the lifetime of the network, based on the time of last dead node [30]. AHP is much complicated than LEACH-C and the cost of communication between nodes and sink may result to a very high energy consumption [18].

EECA: similar to LEACH, the EECA [31] clustering algorithm utilizes the same rotation mechanism that each round of rotation divides to setting phase and steady operation phase. In setting phase, at first all the nodes will be organized as a cluster and then time slot cluster-head allocate the time division multiple access (TDMA) to the members of its cluster and at the same time, data aggregation trees will be established in the middle of cluster-heads. In steady operation phase, the member nodes of cluster send the data to cluster-heads according to data-allocated TDMA, and the cluster-heads send the collected information to sink node through data aggregation tree. When the residual energy of the nodes of cluster-head is lesser than a certain amount of threshold, new cluster-heads will be replaced and data aggregation tree will be re-established.

The protocols of cluster-head selected appropriately can provide better cluster quality but normally optimizing the selection of cluster-head and cluster formation needs more complicated plan and more overhead [18].

3. Energy-Efficient Clustering Algorithm by Residual Energy and Average Distance

The following suggestion is made regarding EECA [31] protocol. In energy-efficient clustering algorithm, the cluster-head is essentially selected with the residual energy of the node into consideration and also taking the average distance of the node with its neighbors in account, which ends with the structuring of an aggregation tree to save the energy while communication.

In EECA network model, it is an energy-efficient clustering algorithm (EECA) for data aggregation. Suppose that the network has "n" different types of sensor node, in which the area covered by network is a square area of "m x m" and the nodes also have the following hypothetical properties:

This is a high-density and static network in which, after spreading the nodes, they turn out to be static with the same primary energy and the sink nodes will be broadcast out of network area in a fixed exclusive position. The nodes are all programmed with data aggregation function and their sending ability is controllable, the information about the location of each node in the network could be discovered by global positioning system (GPS) as well as certain positioning algorithm.

Through the course of this work, a simple model will be engineered in which the radio expends "$E_{elec} = nJ/bit$" to execute sending or receiving circuits and expends "ε_{amp}" to transmit amplifier. Therefore, to send a "K" bit message in a "D" distance using the radio model, the following energy will be expended:

$$E_{TX}(k,d) = E_{TX-elec}(k) + E_{TX-amp}(k,d) = E_{elec}k + \varepsilon_{amp}kd^2 \quad (1)$$

And to receive this message, the following energy will be expanded:

$$E_{RX}(k) = E_{RX-elec}(k) = E_{elec}k \quad (2)$$

It is supposed that the channel is radio type and symmetric so that the required energy to send a message from node A to node B is the same as the required energy to send a message reversely from node B to node A. Moreover it is purported that all the sensors receive from environment with the fixed rate. Furthermore, data aggregation also consumes some amounts of energy and the consuming energy to aggregate a specified data signal will be presented as E_{DA}. Hence, the energy consumption of each node for data aggregation from the node itself and "m" of the neighboring node will be presented as follows:

$$E_c = (m+1)E_{DA}k \quad (3)$$

"K" denotes the amount of raw data, produced by each node.

A wireless sensor network with "n" nodes, summarized to a connected graph of G= (V, F) in which "V" displays the collection of nodes and "F" shows the bilateral relationship between two random accessible nodes. For the random node of$v_i \in V$, its residual energy is simply described as E_{ri} that its coordination could be defined as$L(x_i, y_i)$. Each one of the random nodes of $V_j(1 \leq j \leq m_i, i \neq j)$ in communication radius of $r(r < d_0/2)$ will be considered as the neighbor ofv_i.

m_i shows the total amount of the neighbor. $E_{i,threshold}$ is defined as the residual energy threshold of v_i node. As soon as its residual energy drops to less than$E_{i,threshold}$, the other nodes cannot partake any longer in the competition for being a cluster-head. According to send and receive modes, as well as to data aggregation cost, the amount of $E_{i,threshold}$ could be estimated somewhat by equation (4):

$$E_{i,threshold} = c \times \left[m_i k E_{elec} + (m_{i+}1)kE_{DA} + (1-\eta)(m_i+1)k\left(E_{elec} + \varepsilon_{amp} d^2\right)\right] \quad (4)$$

Therein "C" stands for the times of each data acquisition. η is respectively known as the density ratio of data aggregation. d introduces the distance between current cluster-head and its parent node. The first part $m_i k E_{elec}$ shows the energy costs through receiving package from m_i neighboring nodes. The second section $(m_{i+}1)kE_{DA}$ talks of the energy costs by the aggregation of packages from itself and the neighboring nodes. The third part, which is$(1-\eta)(m_i+1)k\left(E_{elec} + \varepsilon_{amp} d^2\right)$, indicates the energy costs for sending aggregated packages. Each node hence needs to keep a table of neighbor's information $T_{neighbor}$which consists of the following items say: sensor ID, neighborhood energy and the location of neighbor, etc. In wireless sensor networks, energy consumption of cluster-head nodes is much more than those of other nodes, for cluster-head nodes need to receive and aggregate the sensor data from other nodes. In order to equalize the energy load in all the nodes of the network, the cluster-head should rotate between the nodes. Identical to LEACH, EECA clustering algorithm also tends to select the same rotation mechanism that each round of rotation divides to setting phase and steady operation phase. In setting phase, primarily, all the nodes organize as a form of a cluster and then the cluster-head of time slot allocates the Time Division Multiple Access (TDMA) to the members of its cluster and concurrently data aggregation trees will be furnished among the cluster-heads. In steady operation phase, member nodes of the cluster send the data according to allocated TDMA to Cluster-head. And the cluster-heads send the aggregated data to the sink node through data aggregation tree. When the residual energy of cluster-head nodes falls to lesser than a certain amount of threshold, new cluster-heads will be opted for and data aggregation tree will be reestablished. The EECA algorithm divides the sensor network to a double-layer structure: Cluster-head nodes form the upper-layer of network structure nodes and the member nodes form the lower-layer of other nodes. Network infrastructure and data transmission model are depicted in figure 1.

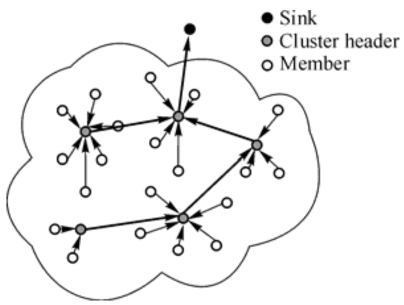

Figure 1- Data transmission model in a clustering network [31]

In cluster-head selection algorithm, the ratio of residual energy of the nodes to the average residual energy of all the neighboring nodes are evaluated as the main parameter for competition to be entitled as a cluster-head, besides the average transmission distance of the nodes and all its neighbors are considered as secondary parameter. The advantage is that the nodes with higher residual energy and lower average transmission distance change to cluster-head nodes more easily which in turn efficiently reduces energy consumption of data transmission and increases the lifetime of the network. The flowchart of EECA-READ is shown in figure 2.

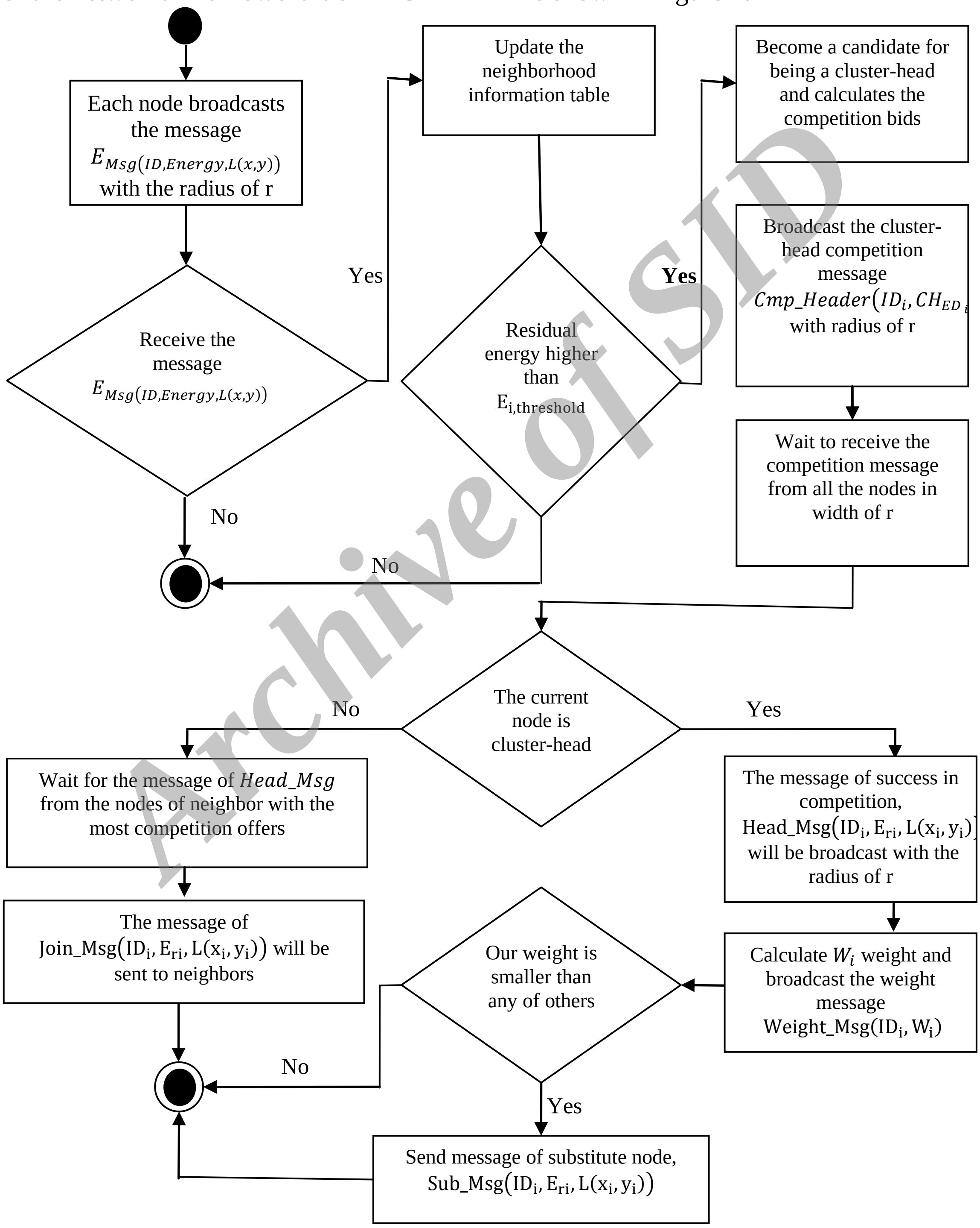

Figure 2- The flowchart of protocol

The procedure of EECA-READ clustering algorithm is as follows:

Step No.1: at the very beginning of each round of rotation, the nodes broadcast the message of $E_{Msg(ID,Energy,L(x,y))}$ with the radius of "r" which consists of ID sensor node, and residual energy and coordinate of the node. Any other nodes in communication radius of "r" are estimated as a neighbor from which the nodes receive the message and update the neighborhood information table.

Step No.2: each node with residual energy higher than $E_{i,threshold}$ can stand to win the chance of participating in the competition of being a cluster-head and consequently become a candidate for being a cluster-head which according to the updated table of neighbor information and considering equation No. 5, obtains the E_{ai} average residual energy from all the adjacent nodes.

$$E_{ai} = \sum_{j=1}^{m_i} \frac{E_{rj}}{m_i} \qquad (5)$$

The authors deem v_j as the neighbor of node v_i .E_{rj} prods to the residual energy of node v_j and m_i pinpoints the total amounts of neighboring adjoining nodes from v_i . The communication distance between node v_i and its neighbor nodes then comes out to be as such:

$$d_i = \sum_{j=1, j\neq i}^{m_i} \frac{d_{ij}}{m_i} \qquad (6)$$

d_{ij} means the distance between v_i and v_j.

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \qquad (7)$$

Step No.3: each cluster-head candidate calculates the competition bids of selection, using equation No. 8 in which, the amount of α and β will be determined by distribution of nodes in the cluster and location of their residual energy, and then the cluster-head candidate broadcasts the cluster-head competition message which is $\mathrm{Cmp\_Header}(ID_i, CB_i)$ with radius of "r".

$$CB_i = \alpha \frac{E_{ri}}{E_{ai}} + \beta \frac{1}{d_i} \qquad (8)$$

Step No.4: all the cluster-head candidates are in receiving position and waiting for a T time. The length of T will be determined in a manner to give the assurance that the nodes can receive the competition message from all the nodes in width of "r" communication radius. Communication formula is as proceeds:

$$T = \frac{k}{B} m_{max} \qquad (9)$$

K is the number of single package bit and B is the channel bandwidth. m_{max} indicates the maximum number of member nodes in a cluster.

Step No.5: after a specific period of T time, if no package is received by cluster-head candidate, it indicates that in the width of the covered area no other node exists to compete for being a cluster-head. Hence the node will broadcast the message of success in competition which means $\mathrm{Header\_Msg}(ID_i, E_{ri}, L(x_i, y_i))$ with the radius of "r". Otherwise, it compares the competition bids with all of the package competition bids in order to select the node with most bids cluster-head. Should the node of cluster-head is the current node, then the message of success in competition, $\mathrm{Head\_Msg}(ID_i, E_{ri}, L(x_i, y_i))$, will be spread with the radius of "r" and should not, it will wait for the message of Head_Msg from the nodes of neighbor with the most competition bids.

Step No.6: As soon as the nodes receive the message of Head_Msg from their neighbors, they stop competing for being the cluster-head. In the meantime, the message of $\text{Join\_Msg}(ID_i, E_{ri}, L(x_i, y_i))$ will be sent to the neighbors with the highest transmission ability and they will in return add them to the cluster, along with the cluster-head of the node.

Once the cluster is already formed, the EECA algorithm establishes data aggregation tree amongst cluster-head nodes just to avoid immediate communication between cluster-head nodes and sink nodes and therefore, it reduces data traffic so that the lifetime of network will be extended. Furthermore, to maintain a guaranteed connection between cluster-heads, transmission power of cluster-head nodes will be appropriately increased.

The Production algorithm of data aggregation trees is as comes next:

Step No.7: each cluster-head calculates W_i weight using the following equation:

$$W_i = \chi \frac{E_{ri}}{E_{max}} + \delta \frac{d_{min}}{d_{(i,s)}} \qquad (10)$$

In equation (10), E_{max} is known as the primary energy of nodes and d_{min} represents the closest distance between cluster-heads and sink nodes. $d_{(i,s)}$ introduces itself as the distance between v_i cluster-head and sink node and based on distribution of nodes in cluster and the extend of energy adjustment, the values of χ and δ will be adjusted. Equation (10) indicates that if the cluster-head nodes have high residual energy, the distance from sink nodes will be reduced and the weight will be increased.

Step No.8: if we assume the radius as “2r”, then the cluster-head nodes of message packet will broadcast the weight, $\text{Weight_Msg}(ID_i, W_i)$which consists of ID sensor information and weight information. Each cluster-head node compares its weight with the received weight of other nodes. If the weight of node is smaller, the node with the higher weight will be selected as parent node and the message of the substitute node, $\text{Sub\_Msg}(ID_i, E_{ri}, L(x_i, y_i))$, will be sent to introduce parent node. If the weight of node has the biggest value, then waiting for other cluster-head nodes to send the substitute node message to that is required. Finally, a data aggregation tree will be established.

The proposed EEAED in this plan is as such: in the third step of cluster structure for data aggregation, each cluster-head candidate calculates the selection competition bids with equation (11):

$$CH_{ED\,i} = \frac{E_{ri}/E_{ai}}{d_i} \qquad (11)$$

which are according to average residual energy and average distance. The cluster-head candidate broadcasts the competition message $\text{Cmp\_Header}(ID_i, CH_{ED\,i})$ and in the first step of cluster structure for data aggregation, each cluster-head node calculates the weight W_i through the following equation:

$$W_i = \frac{CH_{ED\,i}}{d_{(i,s)}} \qquad (12)$$

In equation (12), $d_{(i,s)}$ indicates the distance between v_i cluster-head node and sink node. Equation (11) and (12) claim that if cluster-head nodes have high residual energy, the distance from sink nodes will be reduced and the weight will be increased. Our algorithm is represented in figure 3.

STEP1

1.1. All the nodes broadcast the message $E_{Msg(ID,Energy,L(x,y))}$ with the radius of 'r".

1.2. Each node in communication radius "r" from which the nodes receive the message, is simply considered as a neighbor.

1.3. Update the neighborhood information table.

STEP 2

2.1. Each node with residual energy higher than $E_{i,threshold}$ participates in the competition of being a cluster-head and consequently becomes nominated as a candidate in order for being a cluster-head.

2.2. According to the updated table of neighbor information as well as considering the upcoming equation$E_{ai} = \sum_{j=1}^{m_i} \frac{E_{rj}}{m_i}$ it then manages to obtain the E_{ai} average residual energy from all the neighboring nodes.

STEP 3

3.1. Each cluster-head candidate calculates the competition bids of selection, using equation $CH_{ED\,i} = \frac{E_{ri}/E_{ai}}{d_i}$ and then the cluster-head candidate broadcasts the cluster-head competition message $Cmp\_Header(ID_i, CH_{ED\,i})$ with radius of "r".

STEP 4

4.1. All the cluster-head candidates are in receiving position and waiting for a $T = \frac{k}{B} m_{max}$time to give the assurance that the nodes can receive the competition message from all the nodes in width of "r".

STEP 5

5.1. If the node of cluster-head is the current node, then the message of success in competition,$Head\_Msg(ID_i, E_{ri}, L(x_i, y_i))$, will be broadcast with the radius of "r" if not, it will wait for the message of Head_Msg from the nodes of neighbor with the most competition offers.

STEP 6

6.1. As soon as the nodes receive the message of Head_Msg from neighbors, they stop competing for being the cluster-head and the message of $Join\_Msg(ID_i, E_{ri}, L(x_i, y_i))$ will be sent to neighbors and they will add them to the cluster, along with cluster-head of the node

STEP7

7.1. Each cluster-head calculates W_i weight using equation $W_i = \frac{CH_{ED\,i}}{d_{(i,s)}}$

STEP 8

8.1. If we consider the radius as "2r", the cluster-head nodes of message packet broadcast the weight, $Weight\_Msg(ID_i, W_i)$

8.2. Each cluster-head node compares its weight with the received weight of other nodes.

8.3. If the weight of node is smaller, the node with the higher weight will be selected as parent node and the message of substitute node, $Sub\_Msg(ID_i, E_{ri}, L(x_i, y_i))$, will be sent to introduce parent node

8.4. If the weight of node has the biggest value, wait for other cluster-head nodes to send the substitute node message to that.

Figure 3.Energy-Efficient Clustering Algorithm by Residual Energy and Average Distance (EECA-READ)

4. Experimental Results

The data aggregation protocol of EECA-READ (Energy-Efficient Clustering Algorithm by Residual Energy and Average Distance) is essentially known as a hierarchical protocol which is underpinned upon the improved fashion of LEACH as well as clustering; the so called protocol (EECA-READ) is principally driven out of the EECA protocol.

Using these protocols will result in energy efficiency, mainly because it aggregates the data and moreover it is based on cluster and uses the maximum residual energy and minimum distance for selecting the cluster-head. All of these leave their results in energy consumption reduction. Therefore, the researchers are using an efficient data aggregation protocol for decrease of energy consumption in wireless sensor networks. We use C# to simulate our protocol and we have considered the following parameters for simulation:

Table 1 – Values of Parameters

Parameter	Value
network range	**(50 , 50)**
n(number of sensor nodes)	**50**
Location BS	**(0,0)**
ϵ_{fs}	**10**
E_{elect}	**50**
L	**50**
d_0	**87**

Some points are as followings:

We have calculated the distance as two-dimensional which means:

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \qquad (13)$$

In similar articles, the following values have been used for simulation:

Circuit consumption energy of transmission = 50 E_{elect} or nJ/bit 45

The size of data package or number of transmission bit = bit 500 L

Free space coefficient= pJ/bit/m2 10 ε_{fs}

Multi-route coefficient= pJ/bit/m2 10 or pJ/bit/m4 0.0013 ε_{mp}

Threshold distance $d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}$ or 100 m or 87 m

The results of simulation are shown in figures 4 and 5.

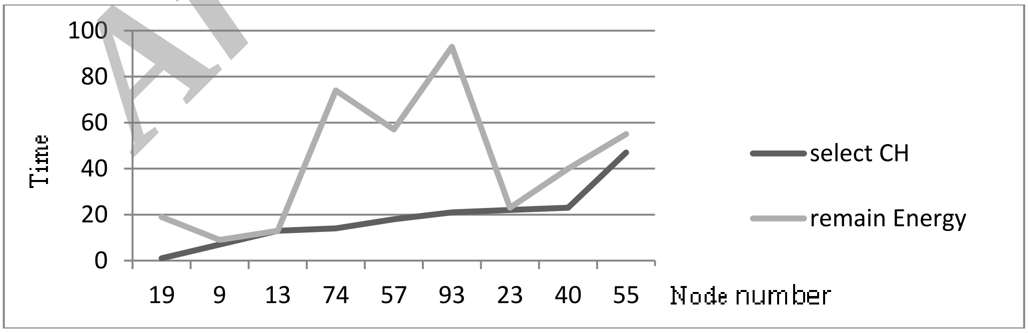

Figure 4- cluster-head selection in one cluster based on random selection

In Figure 4, selection of cluster-head in a cluster is made based on LEACH random selection

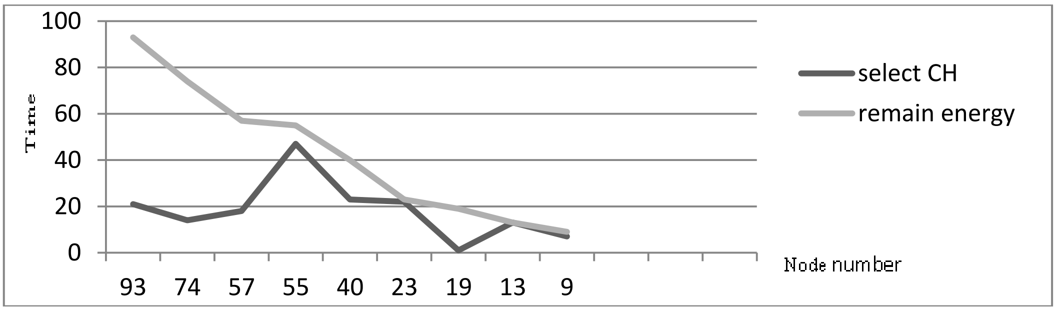

Figure 5- cluster-head selection based on maximum residual energy and minimum average distance

In figure 5, the selection of cluster-head in a cluster is determined based on maximum residual energy and minimum average distance. It is obvious that if selection of cluster-head could be based on maximum residual energy and minimum average distance, then the consumption of energy would be optimized. In addition to the parameter of energy, the parameter of distance also falls effective in energy consumption. It assumes that the lower the distance of nodes to sink or cluster-head, the lesser the amount of energy will be. If we consider both of these parameters, the maximum residual energy and the minimum distance, as the criteria for cluster-head selection, the data transmission will pass a shorter path to the destination and therefore, the amount of energy will be consumed far lesser. The maximum residual energy gives the assurance that the cluster-head node survives more than other nodes usually do. Because the death of a node results into loss of energy and if that very node could be the cluster-head, all the aggregated information until that moment will be lost then. The presented protocol named Energy-Efficient Clustering Algorithm by Residual Energy and Average Distance (EECA-READ), selects cluster-head nodes with high residual energy and less distance to sink.

Recently a novel energy saving protocol, LEACH-SAGA, for wireless sensor has been introduced which outperforms former protocols [35]. We compare our EECA-READ protocol and LEACH-SAGA protocol in two aspects: life cycle and energy consumption. Figures 4 and 5 put the life time and energy consumption of two protocols into display, respectively.

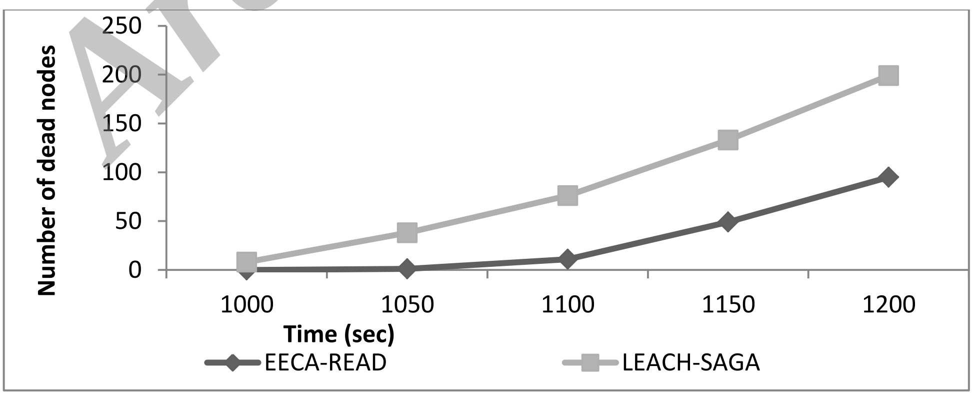

Figure 6- Number of dead nodes

Figure 6 shows that with the increase of rounds, the time of the first node dead of EECA-READ is later than LEACH-SAGA protocol. And the lifecycle of our protocol is longer than LEACH-SAGA.

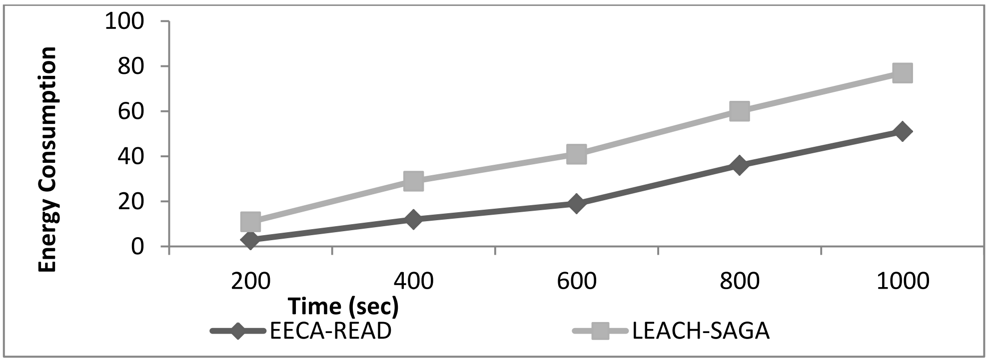

Figure 7- Energy consumption

In the Figure 7, it is clearly witnessed that the EECA-READ consumes less energy than LEACH-SAGA does at the same time, and the root cause can be searched in this fact that the cluster heads of EECA-READ considers the residual energy of sensor nodes. These experimental results and performance study prove that this algorithm outperforms substantially the best previously developed energy saving algorithms.

5. Conclusion

In this paper, the authors have investigated data aggregation protocols and secure data aggregation protocols. Then hierarchical protocols have been scrutinized in that their respective techniques lead to reduction in energy consumption and consequently increase lifetime of network. Most of the reviewed techniques have been practiced with LEACH protocol in mind and they manage to optimize it. Actually, LEACH is learned as the basis for many routing protocols in wireless sensor networks. Sensor nodes are afflicted with some limited resources among which energy limitation is the principal one. In this paper, it was partly tried to improve this issue. As long as a large amount of redundancy increases the amount of data transmission that in turn increases data consumption, henceforth in a wireless sensor network with limited source of energy it does not sound that efficient, so a data aggregation method was applied instead. To access management and decrease energy consumption in sensor nodes, sensor node grouping was used to create clusters. Clustering of sensor nodes is an effective method in the optimum use of node energy which extends the longevity of imposing energy on wireless sensor networks. In order to improve energy consumption in wireless sensor networks, we need to have energy balance and consumption decrease in sensor nodes. It was achieved by choosing the best cluster-head for clustering. The best cluster-head is chosen by selection of cluster-heads based on residual energy and distance average.

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