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An Energy-based Cluster Head Selection Algorithm to Support Long-lifetime in Wireless Sensor Networks

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Abstract. *The recent advancements in the wireless sensor networks (WSNs) are mainly motivated by developing in the micro electromechanical systems technology. One of the major issues in WSNs is to develop an energy efficient routing protocol which has a significant impact on the overall lifetime of sensor networks. In this paper, a novel scheme of an energy-based cluster head selection algorithm (ECHA) to support long-lifetime in WSNs is proposed to improve the Low Energy Adaptive Clustering Hierarchy (LEACH) protocol. In the proposed method, the number of the selection cluster heads (CHs) is optimized based on the effect of the distances from the member nodes to the CH, from the CHs to the base station (BS) and the high energy of each CHs. The simulation results show that the proposed scheme outperforms LEACH and LEACH-C by 35% and 5% in saving power consumption for prolonging network lifetime respectively. The impacts of parameters of density of nodes and weighting probability are verified to find out the best cases for ECHA applications.*
Keywords: Wireless sensor networks; ECHA, LEACH, LEACH-C protocol; Cluster, Cluster head

1. **Introduction.** A wireless sensor networks consists of sensor nodes whose number is from few hundreds to thousands to collect environmental information for applications [1], Each sensor node is composed of typical parts of a radio transceiver, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting [2]. Sensor networks have been widely applied such as in habitat monitoring, agriculture research, fire detection and traffic control [3-8]. However, sensor networks have constraints with resources as energy, bandwidth, and computational capabilities [9]. Therefore, sensor networks performance depends upon MAC, routing and other higher layer protocols. Specifically, routing protocols highly affect the performance of WSN. Currently, many routing protocols have been proposed in order to achieve energy efficiency in WSN [7], [10-11]. These routing protocols can be divided into flat routing and hierarchical clustering routing [12]. Flat routing protocols such as Fig.1is

like sensor protocol for information via negotiation (SPIN), directed diffusion, and rumor routing are not efficient in energy conservation as compared to the hierarchical clustering routing protocols such as Fig.2 is like low energy adaptive clustering hierarchy (LEACH) [13], leach-centralized (LEACH-C) [14]. In hierarchical clustering routing protocols, clus-

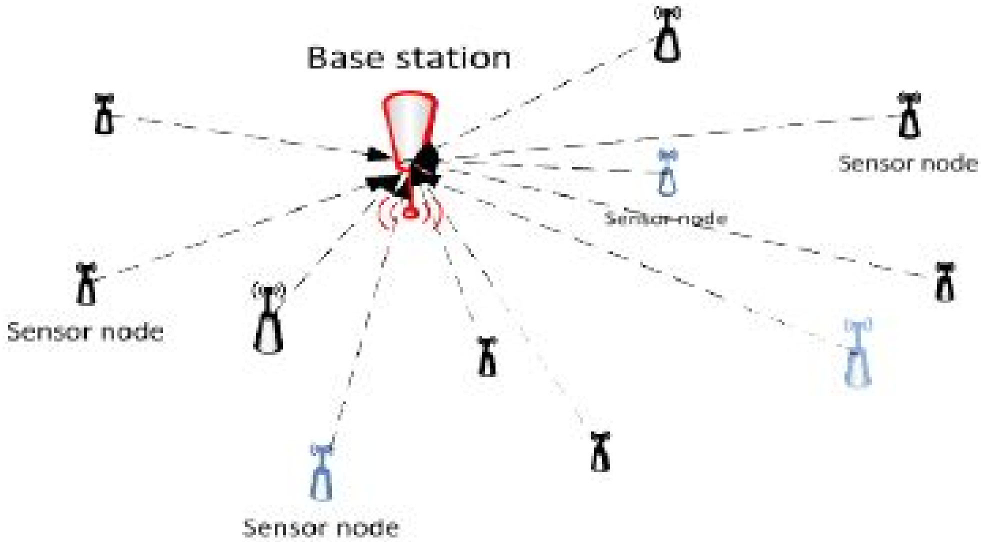

FIGURE 1. An example of wireless sensor network with flat routing

ters are created and a cluster head (CH and CH node is used interchangeably in this work) is assigned to each cluster. These CHs have the responsibilities of collecting; aggregating the data from their respective clusters, and transmitting these data to the BS. The aggregation of data at CHs greatly reduces the energy consumption in the network by minimizing the total data messages to be transmitted to the BS. Also, the CHs act as local sinks for the data, so that data are transmitted over a shorter transmission distance [13]. One issue affecting the performance of sensor network routing is the distribution of energy load in the network [13], [6], [15]. In order to achieve fair distribution of energy load in the network, popular routing protocols such as LEACH and LEACH-C divide the network into a number of clusters, [1, 13, 14]. However, these protocols dont have intelligent CH selection methods, resulting in increased energy consumption. To overcome these drawbacks in LEACH and LEACH-C protocols, routing protocol of wireless sensor networks based on dynamic setting cluster selects CHs dynamically [15]. In this paper, the new scheme of an energy-based cluster head selection algorithm (ECHA) is proposed to modify the LEACHs cluster-head selection algorithm to reduce energy consumption to enhance lifetime performance.

The rest of the paper is organized as follows. In Sections 2, the related works of routing protocols for WSNs is reviewed. In Sections 3, the new proposed scheme of an energy-based cluster head selection algorithm is presented. In sections 4, the simulation of proposed scheme results is analyzed. Finally, conclude this paper is summarized in Section 5.

2. **Related works.**

arious routing protocols have been proposed in order to achieve the energy conservation goal in WSNs[13, 14, 16-19]. However, hierarchical clustering routing protocols are proven to perform best in conserving the energy as compared to flat routing protocols [1]. LEACH proposed in [13] is a popular hierarchical routing approach for

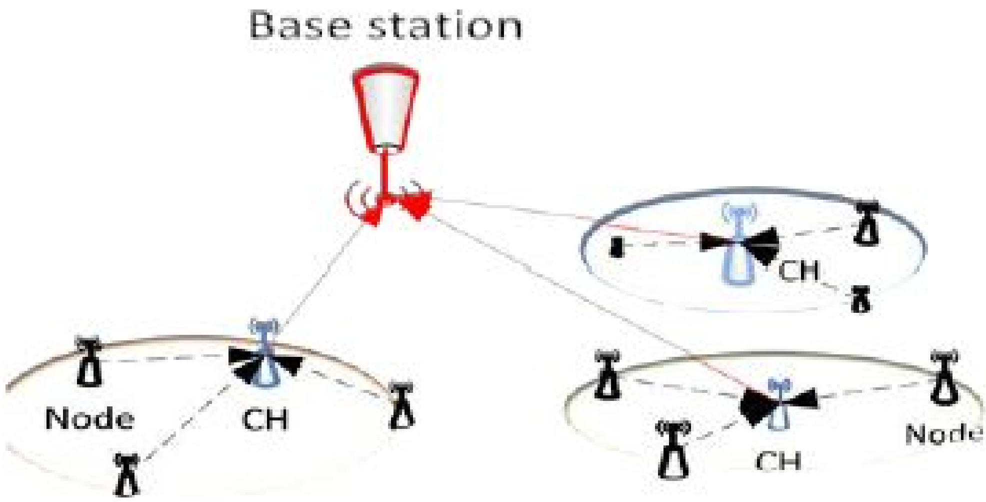

FIGURE 2. An example of wireless sensor network with hierarchical clustering routing

sensors networks that obtains energy efficiency by using clustering of sensor nodes to reduce the distance between source nodes and sink and the number of data messages to be transmitted to the BS. LEACH randomly selects a several sensor nodes as cluster heads (CHs) and rotates this role to evenly distribute the energy load among the sensors in the network. In LEACH, the cluster head (CH) nodes compress data received from nodes that belong to the respective cluster, and send an aggregated packet to the base station in order to reduce the packet amount to the base station. The basic topology of the LEACH protocol is shown in Fig. 2. The operation of LEACH is organized into rounds, where each round consists of a setup phase and a steady state phase as shown in Fig. 3. During the setup phase, the nodes organize themselves into local clusters, with one node acting as the local BS or CH. Nodes elect themselves as CHs with certain probability. These CH nodes broadcast their status to the other nodes in the network. Node chooses a cluster as belong to whom in the network with which the node can communicate with minimum energy. The role of the node as a CH is turned to next CH node in each round. LEACH uses randomized rotation of the high-energy CH position such that it rotates among the various sensors in order not to drain the battery of a single sensor. The cluster head selection is described as a sensor node chooses a random number from 0 to 1, with considering a threshold value $T(n)$.

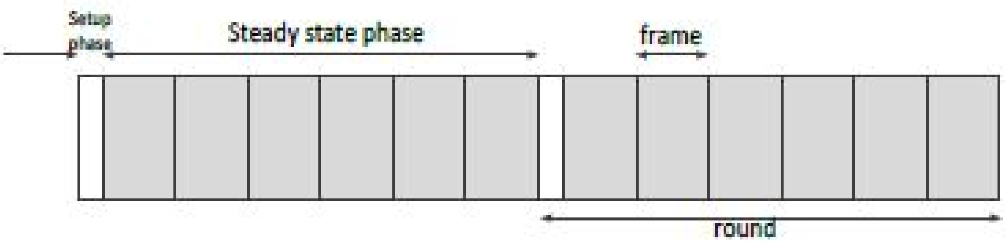

FIGURE 3. LEACH protocol operation

If this random number is less than the threshold value *T(n)*, the node becomes a cluster-head in the current round. The threshold value is calculated based on an equation that incorporates the desired percentage of nodes to become a cluster-head in the current round. The set of nodes that have not been selected as a cluster-head in the last (1/P) rounds is denoted by G. The threshold, *T(n)*, is given by :

$$T(n) = \begin{cases} \frac{P}{1-P\times(r \bmod \frac{1}{P})} & n \in G \\ 0 & otherwise \end{cases} \tag{1}$$

where P is the desired percentage of CHs, n is the round number, r is the current round and G is the set of nodes that have not yet been selected.

The elected CH nodes broadcast an advertisement message to the rest of nodes in the network to notify the others that they are the new cluster-heads. The non-cluster-head nodes reply the appropriate cluster-heads that they will be a member of the cluster. The messages receiving from the nodes included in the cluster and the number of nodes in the cluster, the cluster-head node creates a TDMA schedule in order to avoid collision during data transmission and assigns each node a time slot when it can transmit. This schedule is broadcasted to all nodes in the cluster. Each node then transmits during its own TDMA slot and goes to sleep in other nodes transmission slot.

During the steady state phase, the sensor nodes can begin sensing and transmitting data to their cluster-heads. The cluster-head node, after receiving all the data, aggregates it before sending it to the base station [1, 20]. After a certain time, the network goes back into the setup phase again and enters another round of selecting new CH. As mentioned, LEACH performs local data fusion to compress the data to be sent from the clusters to the BS, further reducing energy dissipation and enhancing system lifetime [17]. Thus, LEACH achieves energy efficiency by reducing the total number of data messages to be transmitted and by the introduction of a small number of dedicated CH nodes for data collection, fusion, and transmission. However, LEACH does not take into account of the distance and the residual energy of the nodes to be elected as CH node. Thus, there are chances that energy consumption in the network is not distributed in uniform manner. LEACH-C proposed in [14] uses a central control algorithm to produce better clusters by dispersing the cluster head nodes throughout the network. Thus, LEACH-C uses a centralized clustering algorithm and the same steady-state protocol as LEACH [13]. During the setup phase, all the nodes send their position and energy information to the BS. Using these information, the BS finds a predetermined number of CHs in the network. Then, the BS selects CHs from among the nodes which have energy greater than average energy of all sensor nodes in the network. With these candidate CHs, the BS finds clusters by using the simulated annealing algorithm [12]. The remaining energy level available in each node is that approach of LEACH, which help increasing the lifetime of network. However, LEACH-C can be achieved to increase more the lifetime of network by reducing the threshold T(n), denoted in Equation (2), relative to the nodes remaining energy. Therefore, T(n) is multiplied with a factor representing the remaining energy level of a node as given following:

$$T(n)_{new} = \frac{P}{1 - P \times \left(r \bmod \frac{1}{P}\right)} \frac{E_{n\_current}}{E_0} \tag{2}$$

where $E_{n-current}$ is current energy of nodes, E_0 is the initial energy of nodes. The steady state phase of LEACH-C is similar to the steady state phase of LEACH. LEACH-C differs from LEACH only in that it uses centralized algorithm to select the CH nodes. LEACH-C has drawback in that it only takes into account of the energy in the nodes while selecting CHs. Thus, the nodes which are far away from the BS, use up more energy when they act as CH nodes. Moreover, LEACH-C requires location information of all nodes of the network. However, location information in mobile wireless networks is only available through GPS or a location-sensing technique, such as triangulation which requires additionally communication among the nodes. The discussed drawbacks in the preceding paragraphs suggest the need for new energy efficient routing approach and are the motivating factors behind of this study. The fact of the transmission distance has a great effect in energy consumption in the network is exploited through the adjusting the threshold T(n), as shown in Section 3, and a new proposed routing scheme is named as (ECHA), which means an Energy-based Cluster Head Selection Algorithm to support long-lifetime in wireless sensor networks.

3. **An energy cluster head selection algorithm (ECHA) to support long life-time in WSNs.** In this section, the assumptions should be made before the investigation for implementing of this proposed scheme as following: (1) Simple model of transmitter dissipates energy for radio hardware energy is applied. (2) All nodes in the network are homogenous, energy constrained and able to communicate with BS. (3) Location information of nodes is available. (5) Symmetric propagation channels between nodes. (6) Cluster-heads perform data compression. The energy needed for the transmission of one bit of data from node u to node v, is the same as to transmit one bit from v to u because the symmetric propagation channel. Cluster-heads collect nk-bit messages from n adjacent nodes and compress the data to cnk-bit messages which are transmitted to the BS, with 1 c as the compression coefficient [13].

A. Network model

A simple model is assumed for radio hardware energy consumption where the transmitter dissipates energy to run the radio electronics and the power amplifier, and the receiver dissipates energy to run the radio electronics. For implementing experiments in this paper is depending on the transmission range: the free space and multipath fading model have been considered, as shown in Fig. 4.

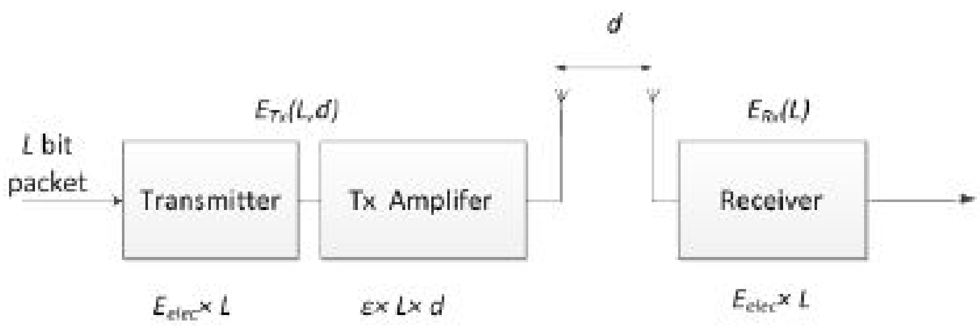

Figure 4. Transceiver energy dissipation model

If the distance d is less than or equal to a threshold d_0, the free space model (d^2 power loss) is used; otherwise, the multi path model (d^4 power loss) is used. It means that for short distance transmission, such as intra-cluster communication, the energy consumption by an amplified transmission is proportional to d^2 and for long distance transmission, such as inter-cluster communication, the energy consumption is proportional to d^4. The energy consumption models of the transmitter and receiver separated by distance d for a l bit message, respectively, are given by

$$E_{Tx(l,d)} = E_{Tx-elec}(l) + E_{Tx-amp}(l,d) = \begin{cases} lE_{elec} + l\varepsilon_{fs}d^2 & d < d_0 \\ lE_{elec} + l\varepsilon_{mp}d^4 & d \geq d_0 \end{cases} \tag{3}$$

and to receive this message, the radio expects:

$$E_{Rx}(l) = E_{Rx-elec}(l) = lE_{elec} \tag{4}$$

where E_{elec} is the energy consumed per bit to run the circuitry of the transmitter and receiver $\varepsilon_{fs} and \varepsilon_{mp}$ are the power loss of free space and multi-path models, respectively, which depend on a chosen acceptable bit-error rate. One suitable choice for the threshold transmission distance d_0 may be:

$$d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \tag{5}$$

The electronics energy, E_{elec} depends on factors such as the digital coding, modulation, filtering, and spreading of the signal whereas the distance to the receiver and the acceptable bit-error rate.

B. Optimal number of clusters

In LEACH, the cluster formation algorithm was created to ensure that the expected number of clusters per round is k, a system parameter. The optimal value of the expected number of clusters per round k in LEACH can be analytically determined by using the computation and communication energy models. Assume that there are N nodes distributed uniformly in an MxM region. If there are k clusters, there are on average N/k nodes per cluster (one cluster head and $(N/k) - 1$ non-cluster head nodes). Each cluster head dissipates energy receiving signals from the nodes, aggregating the signals, and transmitting the aggregate signal to the BS. Since the BS is far from the nodes, presumably the energy dissipation follows the multi path model (d^4 power loss). Therefore, the energy dissipated in the cluster head node during a single frame is [13],[21].

$$E_{CH} = lE_{elec}(\frac{N}{k} - 1) + lE_{DA}\frac{N}{k} + lE_{elec} + l\varepsilon_{mp}d_{toBS}^4 \tag{6}$$

where E_{CH} energy dissipated in the cluster head node during a single frame, E_{DA} energy dissipated of aggregating the signals, l is the number of bits in each data message, d_{toBS} is the distance from the cluster head node to the BS, data aggregation is assumed perfectly. Each non-cluster-head node only needs to transmit its data to the cluster head once during a frame. Presumably the distance to the cluster head is small, so the energy dissipation follows the free-space model (d^2 power loss). Thus, the energy used in each non-cluster head node is:

$$E_{non-CH} = lE_{elec} + l\varepsilon_{fs}d_{toCH}^2 \tag{7}$$

where d_{toCH} is the distance from the node to the cluster-head. The area occupied by each cluster is approximately M^2/k. In general, this is an arbitrary-shaped region with a node distribution $\rho(x,y)$. The expected squared distance from the nodes to the cluster head (assumed to be at the center of mass of the cluster) is given by

$$E_{d_{toCH}^2} = \iint (x^2 + y^2)\rho(x,y)dxdy = \iint r^2\rho(r,\theta)rdrd\theta \tag{8}$$

If this area is assumed as a circle with radius $R = (M/\sqrt{\pi k})$ and $\rho(r,\theta)$ is constant for r and θ , simplifies to

$$E_{d^2_{toCH}} = \rho \int\limits_{\theta=0}^{2\pi} \int\limits_{r=0}^{M/\sqrt{\pi k}} r^3 dr d\theta = \frac{\rho}{2\pi} \frac{M^4}{k^2} \tag{9}$$

If the density of nodes is uniform throughout the cluster area, then $\rho = (1/M^2/k)$ and

$$E\left[d^2_{toCH}\right] = \frac{1}{2\pi} \frac{M^2}{k} \tag{10}$$

Therefore, in this case

$$E_{non-CH} = lE_{elec} + l\varepsilon_{fs} \frac{1}{2\pi} \frac{M^2}{k} \tag{11}$$

The energy dissipated in a cluster during the frame is

$$E_{cluster} = E_{CH} + (\frac{N}{k} - 1)E_{non-CH} \approx E_{CH} + \frac{N}{k} E_{non-CH} \tag{12}$$

And the total energy for the frame is

$$Etotal = kE_{cluster} = l(E_{elec}N + E_{DA}.N + k\varepsilon_{mp} d^4_{toBS} + E_{elec}N + \varepsilon_{fs} \frac{1}{2\pi} \frac{M^2}{k} N) \tag{13}$$

Because the average distance from a Cluster Head to the Base Station is given by

$$d_{toBS} = \int_A \sqrt{x^2 + y^2} \frac{1}{A} dA = 0.765 \frac{M}{2} \tag{14}$$

The optimum number of clusters can be found by setting the derivative of E_{total} with respect to k to zero

$$k_{opt} = \frac{\sqrt{N}}{\sqrt{2\pi}} \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \frac{M}{d^2_{toBS}} \tag{15}$$

There are some related factors with k_{opt} within each cluster such as the number of nodes in a cluster as considering neighbor nodes n_i, the area of occupied cluster m_i and weighting probability.

$$n_i = \frac{N}{k_{opt}} \tag{16}$$

$$m_i = \sqrt{2\pi d^2_{toCH}} = \sqrt{2\pi \frac{M^2}{k_{opt}}} \tag{17}$$

So, the weighting probability should be assigned as the initial energy of each node divided by the initial energy of the normal node with m_i, the weighting probabilities for normal and advanced nodes could be given as:

$$P_{opt} = \frac{p}{1 + m_i} \tag{18}$$

In equation (2), the weighting probability (desired percentage) P is replaced by the advanced weighting probability P_opt which equation (18) is to obtain the threshold that for using to elect the CH in each round. The threshold for advanced nodes $T(S_{opt})$ is defined as given following:

$$T(S_{opt}) = \begin{cases} \frac{P_{opt}}{1 - P_{opt} \times (r \bmod \frac{1}{P_{opt}})} \times E_{ratio}, & if\ S_{opt} \in G' \\ 0 & otherwise \end{cases} \tag{19}$$

with

$$E_{ratio} = \frac{E_{current}}{E_0} \times \sqrt{n_i} \tag{20}$$

where G' is the set of normal nodes that have not become CH within the last $1/P_{nrm}$ rounds of the epoch, $T(S_{opt})$ is the threshold applied to a population of $N(1{+}m)$, E_0 is the initial energy, $E_{current}$ is the current residual energy, and n_i is the number of neighbors of the i^{th} node. The fact of the transmission distance has a great effect in energy consumption in the network is exploited through the adjusting the threshold $T(S_{opt})$, as presenting in next subsection.

C.An Energy-based Cluster Head Selection Algorithm

Determination of cluster heads as mentioned is distributed on nodes. Each node could be determined to be a cluster node according to a random number and a threshold. In this subsection, an energy-based cluster head selection algorithm is presented, also named as $ECHA$ to select cluster heads with high energy efficiency. The operation of the set-up stage is outlined in the algorithm. In each round, there is CH selection and cluster formation. The CH selection takes place in steps 1-3. Initially, all nodes set their states to "$Plain_Node$". The threshold $T(n)$, is set for the current round using equation (2). Each node generates a random number between 0 and 1. If the generated number is less than the threshold value, the node will be a CH, change its state to "$CLUSTERHEAD$" and advertise a CH message to the network. The pseudo code of this proposed algorithm is given in Table 1. The proposed equation is depicted in equation (21) by optimizing cluster with the distances between cluster member nodes and its CH, and also the distances between CHs and Base Station to be closer, the energy consumption of sensor network will be saving. For example, if the CH lies at a distant position from the majority of nodes, the communication between CH and sensor nodes, since the distances between them will be closer, the energy consumption for the communication will be high. In addition, the optimizing cluster, the number of CHs will be optimizing suitably with the number of sensor nodes [14], because the CHs energy consumption is mainly. Here a new idea to select the CH is given below

$$T(S_{opt})_{new} = \begin{cases} \frac{P_{opt}}{1-P_{opt}\times(r \bmod \frac{1}{P_{opt}})} \frac{d_{CH}}{d_{\max CH}} \frac{d_{BS}}{d_{\max BS}} \times E_{ratio}, & if\ S_{opt} \in G' \\ 0 & otherwise \end{cases} \tag{21}$$

where d_{CH} is average distances between non-CH nodes to its CH node as equation (10), d_{BS} is average distances between CHs node to BS as equation (14),$d_{\max CH}$ is maximum distance between a non CH node to its CH node, $d_{\max BS}$ is maximum distance between CHs node to BS. $T(S_{opt})$ is the threshold applied to population as equation (19). Maximum energy equal to initial energy, and Eratio is referred to equation (20). The initial of maximum distances of BS and maximum CHs to BS are calculated as in equations (22) and (23), when the deployed network with the base station is in center deployed network area Maximum distance to

$$BS = \sqrt{(BS_x)^2 + (BS_Y)^2} \tag{22}$$

where (BS_x ,BS_y) is location of Base Station. Maximum distance to

$$CH = \sqrt{(x_m)^2 + (y_m)^2} \tag{23}$$

where (x_m, y_m) is size of network area.

Note: Plai_Node means the properties of node as initial energy, location, well. Unit of E= J/bit V = volt, s = second, amplify = pJ/bit/mxm, l= bits, m = meter, A = ampere.

```
Inputs: node locations, initial energy
Outputs: cluster heads
Begin
 1.   Initialization
          Node_State ← Plain_Node
          Cluster ← Empty
          Number neighbor node  ni← No of /no round -1
 2.   Determination of Cluster-Head Threshold
          E_initial ← Maximum energy
          E_ratio ← Ec/ Maximum energy× ni
          d_maxCH ←max distance nodes and CH
          d_maxBS ← max distance BS and CH
          T ←  threshold for current round
 3.   Selection of Cluster-Head
          for each node
              temp_rand ← rand (0,1)
                if temp_rand  < T   then
                node_State ←CLUSTERHEAD
                cluster = cluster+1
                 Advertise  CH Message (ID)
              end if
          end for
End
```

FIGURE 5. The pseudo code of the proposed algorithm

4. **Simulation results.** In this section, the performance of $ECHA$ algorithm is evaluated with using MATLAB[22]. The simulation environment is set up as following. A network of 100 nodes is deployed randomly distributed in area of 100x100 m^2. The initial energy of the sensors is $E_0 = 0.5J, E_{elec} = 50nJ/bit, \varepsilon_{fs} = 10pJ/bit/m^2, \varepsilon_{mp} = 0.0013pJ/bit/m^4, P = 0.1$, message size $l = 4000bits, EDA = 5nJ/bit/message, packetheader = 25$. The channel bandwidth is set to 1 Mbps as in [23]. The simulation results are verified with several aspects such as the network's lifetime, the energy consumption and analysis with different specific values.

A. Network's lifetime

In Fig.5 compares three approaches of hierarchical routing including LEACH, LEACH-C and a new proposed ECHA in the case of BS was at center of the deployed network area, the ratio between the numbers of rounds for selecting CHs for clustering and number of the dead nodes after running in network. It can be clearly seen that number rounds of ECHA is greater than that number rounds of LEACH and LEACH-C are 35The line of ECHA (red and star dot line) reached to around 1300 rounds; it would be started of appearing the nodes died after network has been running and this line would be coming up to nearly 2000 rounds, with the number of nodes almost died. In contrast, LEACH line (blue solid line) was running at around 800 rounds, the node being died could be appeared and the longest of alive node in this line only reached 1300 rounds. LEACH-C line (green and cross line) in this case, the BS was at center of deployed area of network, the number of rounds was quite as high as the ECHA line with having appeared the dead nodes around 1300 but the node of 100th died only at 1910 rounds.

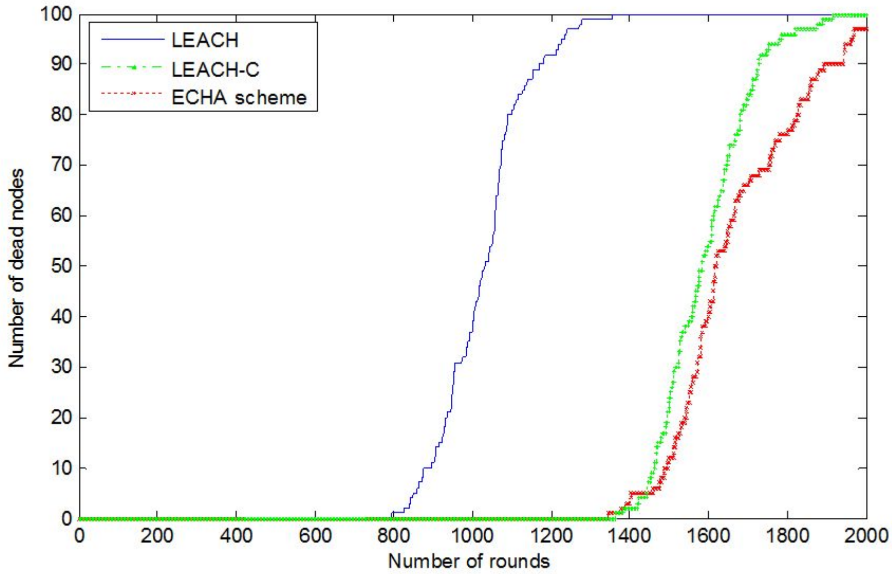

Figure 6. Comparison the lifetime of LEACH and LEACH-C with new proposed ECHA with BS was at center

It means that new scheme of ECHA perform is better than LEACH-C and LEACH, in the prolong lifetime of network about 5In addition, the new algorithm consumes energy is more efficiently adjusting. Fig.6 shows the comparison of three approaches of hierarchical routing as mentioned above LEACH, LEACH-C and ECSA, in the case of BS was not at center of deployed network area, but BS was selected randomly, the ratio between the numbers of rounds for selecting CHs for clustering and number of the dead nodes after running in network. It can be clearly seen that number rounds of ECHA is the largest proportion. In this case LEACH-C did not gain much number of rounds because of LEACH-C focuses on center. The number of rounds of ECHA line (red and star dot line) could be reached to around 1100 rounds, then it would have the appearing dead nodes after network had been running and this line would have lower slope than others have. However, the number of rounds of LEACH and LEACH-C lines (blue solid line and green and cross line respectively) were running at around 800 rounds and 1000 rounds, when the dead nodes were appeared and the longest of alive nodes in these lines only reached 1300 rounds and 1500 rounds respectively.

It means that new scheme of ECSA perform in this case is better than LEACH-C and LEACH, with prolonging the lifetime of network is about 20% to 30% in respectively.

B. The energy consumption

Fig.7 depicts the comparisons three graph lines of hierarchical routing of LEACH, LEACH-C and ECHA approaches in case BS was at center of deployed network area, the ratio between the energy consumption and number of rounds. It is noticed that the ECHA approach (red and star dot line) has a slope of energy consumption at being lower than LEACH and LEACH-C slopes; it means that the line of ECHA consumed energy less than LEACH and LEACH-C, and the number of rounds then reached nearly 2000 rounds

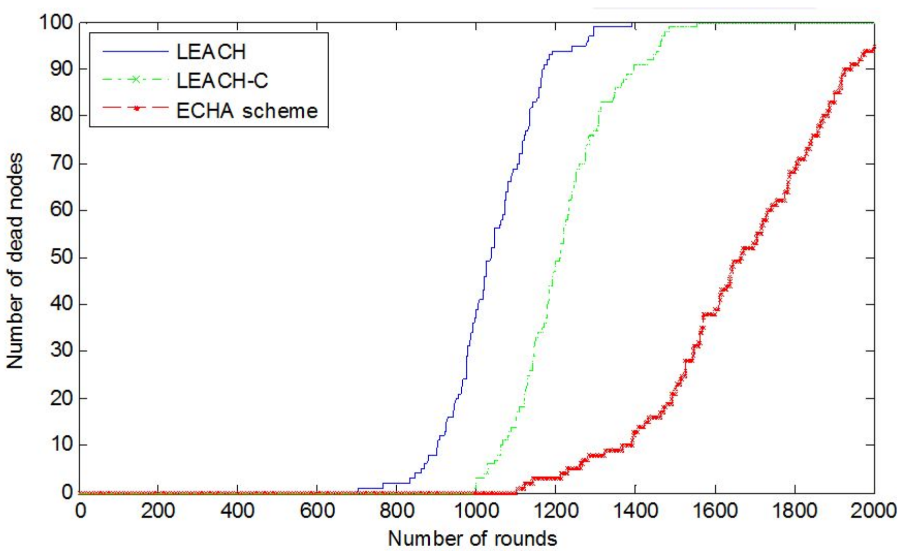

FIGURE 7. Comparison the lifetime of LEACH and LEACH-C with new proposed ECHA with BS was not at center

before becoming to saturation state, whereas, the LEACH and LEACH-C only reached 1000 and 1750 rounds respectively before coming to the state of saturation.

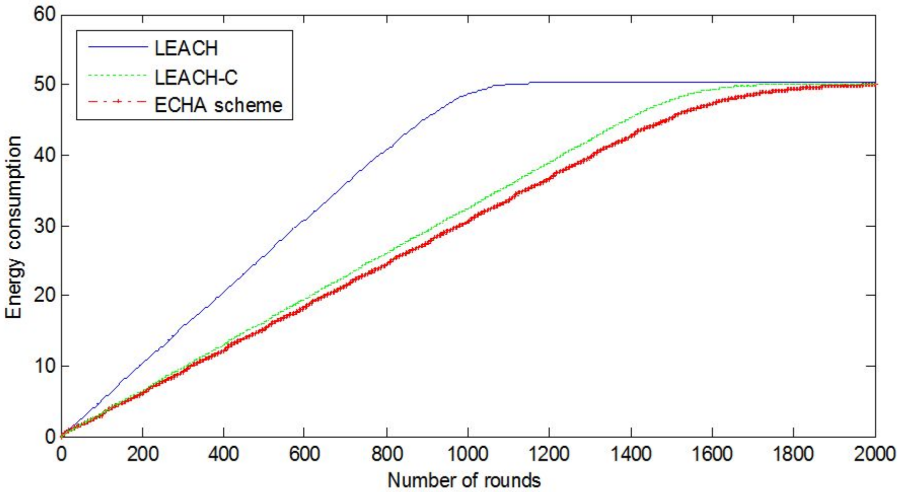

FIGURE 8. Comparison the energy consumption of three approaches LEACH, LEACH-C and ECHA in case of BS was at center

Fig.8 illustrates that the comparisons three graph lines of hierarchical routing of LEACH, LEACH-C and ECHA approaches in case BS was not at center of deployed network area, but was selected randomly, the ratio between the energy consumption and number of rounds. It is noticed that the ECHA approach (red and star dot line) has a slope of energy consumption at being lower than LEACH and LEACH-C slopes; even though the LEACH-C had long reaching but its energy consumption still was higher ECHA. The line of ECHA reached nearly 2000 rounds before becoming to saturation state, whereas, the LEACH and LEACH-C only reached 1000 and 1900 rounds respectively before coming to the state of saturation.

C. Analysis of experimental results

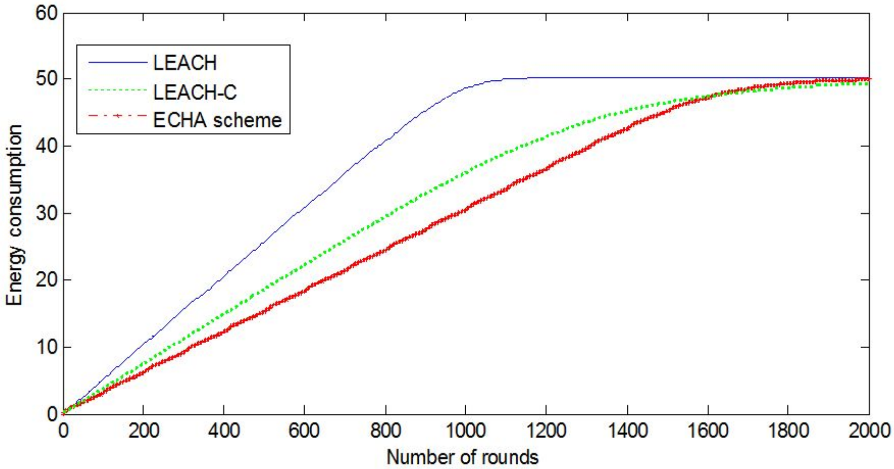

Figure 9. Comparison the energy consumption of 2 protocols

Table 1. Lifetime prolong comparison of the various nodes in density

N nodes	LEACH	LEACH-C	ECHA		
	Lifetime, (rounds)	Lifetime, (rounds)	Lifetime, (rounds)	Lifetime improvement with respective LEACH	Lifetime improvement with respective LEACH-C
100	1415	1830	1911	35.10%	4.40%
200	1428	1835	1953	36.80%	6.40%
300	1487	1839	1961	31.90%	6.60%
400	1518	1859	1943	28.00%	4.50%

The reducing of energy consumption by optimizing the distances between head nodes and other nodes and also the distances between cluster heads and base station is mentioned above. The various values for the parameters affecting the distance should be considered, such as the node density and weighting probability. The impact of these parameters to the routing algorithms in general and in particular ECHA algorithm is of great significance in applying them in practice. In this subsection, assuming performed network with that new proposed formula is adjusted in terms of recalculating the parameters N number of sensor nodes and the probability P_{opt}, the energy consumption of entire network and lifetime of network as well will make sure for the best cases to save significantly.

Table II shows the comparison of number of maximum rounds when all nodes in network died in three hierarchical routing of LEACH, LEACH-C and ECHA approaches and the percentages of the prolong lifetime of ECHA in comparison with LEACH-C and LEACH in various number of sensor nodes N. It can be clearly seen that if the density of nodes in network is increased in a cluster, the chances for nodes becomes cluster head will be higher, the maximum rounds higher. But, if the number of nodes is too high, it means the density is too thick, the effect of the interaction between the nodes is causing more energy consuming. The best case of the density of nodes in networks with N =200 results to prolong the lifetime of the sensor network accounting for the highest by 6.4% and 36.8% of ECHA scheme in compare with LEACH-C and LEACH respectively.

Table III indicates the case for the probability P_{opt} in its various values to impact the selection nodes to become cluster head. In this table, three hierarchical routing scheme of LEACH, LEACH-C and ECHA approaches were compared in various values of P_{opt} and percentages of the prolong lifetime of ECHA in comparison with LEACH and LEACH-C

TABLE 2. Lifetime prolong comparison with various of P values

Popt	LEACH	LEACH-C	ECHA		
	Lifetime (rounds)	Lifetime (rounds)	Lifetime (rounds)	Lifetime improvement with respective LEACH	Lifetime improvement with respective LEACH-C
P=0.04	1395	1612	1911	36.99%	18.55%
P=0.05	1368	1580	2000	46.20%	26.58%
P=0.06	1342	1633	1872	39.49%	14.64%
P=0.07	1374	1559	1862	35.52%	19.44%
P=0.08	1344	1662	1794	33.48%	7.94%
P=0.09	1419	1810	1872	31.92%	3.43%
P=0.1	1417	1830	1912	34.93%	4.48%

at the maximum rounds when the last nodes in network died was depicted respectively. It can be clearly seen that if the probability P_{opt} decreases, the ECHA extends sensor network lifetime significantly. But, if the probability is too small, the sensor network style will be a flat routing style, the energy consumption will be higher, network lifetime will be shorter. The best case of the probability for selection cluster heads with $P_{opt} = 0.05$, that results to prolong the lifetime of the sensor network accounting for longest 26.4% and 46.4% of ECHA scheme in compare with LEACH-C and LEACH respectively. The reasons of the new proposed ECHA scheme outperform other schemes of classical hierarchical routing protocols are to consider to the residual energy load distribution, the distances in each cluster, and the distances cluster heads to base station. As the formula for calculating the threshold for cluster head election in equation (21), in addition to the verified parameters such as the weighting probability P_{opt} and the network density of number of nodes N, there are the rational number Eratio in equation (20), the rational number d_{CH}/d_{maxCH} of average distances between normal nodes to cluster head node and maximum distance of them in each cluster, and the rational number d_{BS}/d_{maxBS} of average distances between cluster heads to the station) are evaluated as advantages following:

- *The residual energy* of the potential becoming cluster heads nodes could be distributed throughout the network balancing load evenly that makes the whole network energy consumption saving significantly. The rational number E_{ratior} parameter in equation (21) represents the fraction $E_{current}/E_o$ and the number of nodes within a cluster. The maximum value of this ratio is at initialization, the threshold for selecting CHs is to select any nodes randomly. The value of this ratio is smaller when running network, the threshold for selecting CHs is decreased, and the selection CHs is only focusing on nodes with higher residual energy. So that it could make energy distribution fairly of load balancing through whole network.
- *The rational number* of the average distances and the maximum distance between normal nodes to CH is reached maximum value when the node members of a cluster are usually distributed evenly each other to CHs. Thus, the election CHs threshold decreases, the cluster heads is selected in trend to be center of nodes in each cluster. In contrast, if the distances of normal nodes to CHs have big gap, the distributed nodes in the cluster is not optimal, the communication and energy consumption will be costly.
- *The rational number* of the average distances and the maximum distance between cluster head nodes to base station, could be greatest value when cluster head nodes are fair distributed of locations in deployment network area. The cluster head selection threshold is impacted, the trend of cluster head node locations is distributed

fairly in respective with base station. It results to make effectively in conserving energy for whole network. In general say the impacted threshold for selection CHs by three mentioned factors will make conserving energy for whole network to prolong its lifetime.

5. **Conclusion.** In this paper, an energy-based cluster head selection algorithm (ECHA) to support long-lifetime in wireless sensor networks is described as improving LEACH protocol for energy efficient routing. The new proposed ECHA scheme outperforms classical hierarchical routing protocols such as LEACH and LEACH-C by optimal selecting cluster head based on effective of the distances normal node to HC and CHs to the BS. The CHs are assigned with the duty of collecting the data from the other non-CH nodes, compressing these collecting data and transmitting the compressed data to the BS. For fair distribution of energy load in the network, ECHA uses rotation of CH roles in each round of communication and selects CHs on the basis of residual energy and distances. Also, a considerable amount of energy is conserved by determining the number of CHs dynamically depending upon the number of alive nodes in the network so as to prevent the unnecessary selection of a huge number of CHs even when a large number of nodes are dead. The simulation results show that the proposed ECHA scheme is at least more than 35% and 5% efficient in conserving energy to prolong network lifetime as compared to the classical hierarchical clustering routing protocols such as LEACH and LEACH-C respectively. Consequently, the proposed ECHA can be adapted by adjusting parameters of weighting probability and number of the effective neighbors nodes to a routing protocol for energy-sensitive WSN applications owing to its energy-efficient features and to find out the best cases for ECHA applications.

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