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Reducing Energy Consumption in Wireless Sensor Networks Using a Routing Protocol Based on Multi-level Clustering and Genetic Algorithm

Amin Rezaeipanah[1,*], Hamed Nazari[2], MohammadJavad Abdollahi[3]

[1] *Department of Computer Engineering, University of Rahjuyan Danesh Borazjan, Bushehr, Iran*
[2] *Department of Computer Engineering, Urmia University, Urmia, Iran*
[3] *Department of Computer Engineering, University of Lian Bushehr, Bushehr, Iran*

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Abstract

Wireless sensor networks (WSN) consist of a large number of sensor nodes with finite and limited energy levels distributed throughout a finite area. The energy of the nodes is mostly consumed to send information to a central station. Extending the network lifetime through decreasing the energy consumption of the nodes has always obtained attention, due to the energy limitations in WSNs. In this paper, a multi-level genetic based clustering algorithm is proposed to extend the lifetime of these types of networks. The proposed multi-level clustering algorithm divides the geographical area into three levels according to the radio range and the clustering of the nodes in each level is performed independently. Technically, Cluster Heads (CH) consumes more energy than other nodes to transmit data. So, the proposed algorithm aims to extend the network lifetime by reducing the number of CHs. Finally, a better energy consumption balance between the nodes is realized by altering the CHs in each routing round. The results of the experiments show the superiority of the proposed algorithm in terms of and the network lifetime over other analogous protocols.

Index Terms: Wireless Sensor Networks, Multi-level Clustering, Routing Protocol, Network Lifetime, Genetic Algorithm.

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* Corresponding author
E-mail address: amin.rezaeipanah@gmail.com, st_h.nazari@urmia.ac.ir, it1393@yahoo.com

1. Introduction

Wireless Sensor Networks (WSN) is one of the prevailing environmental data gathering tools that extensive researches have been dedicated to. Despite increasing advancements in these networks, sensor nodes enormous in number and extremely small in size still supply their energy utilizing low-energy batteries. Actually, it is approximately impossible to recharge or replace the sensor nodes due to deploying this category of networks in harsh and inaccessible environments. So, one of the most important issues in wireless sensor networks is the optimal energy management problem [1].

Since the performance of wireless sensor networks is highly dependent on the network lifetime, the protocols provided in WSNs should consider extending the network lifetime. Accordingly, the time from the network starting until the complete energy depletion of the first node defines the lifetime of the network [2]. To extend network lifetime, two factors such as reducing the energy consumption and properly distributing the energy between sensor nodes should be considered. Indeed, all sensor nodes transmit or receive data from a fixed database, namely Base Station (BS).

One of the most important issues in these networks is reducing the energy consumption to develop and improve routing protocols that consequently leads to extend the network lifetime [3]. Hierarchical routing protocols (a.k.a. cluster-based routing protocols) are new approaches to reduce energy consumption and extend the network lifetime and scalability. In this type of protocols, the nodes in the cluster are organized in such a way that high-energy nodes (those are potentially CHs) could be considered to process and transmit data while the nodes with lower energy levels are used to perform measurements over the target environment [4]. In fact, data in the nodes of each cluster is sent to the BS only by the CH nodes. Fig. 1 schematically illustrates data transferring in the WSN using clustering techniques [26].

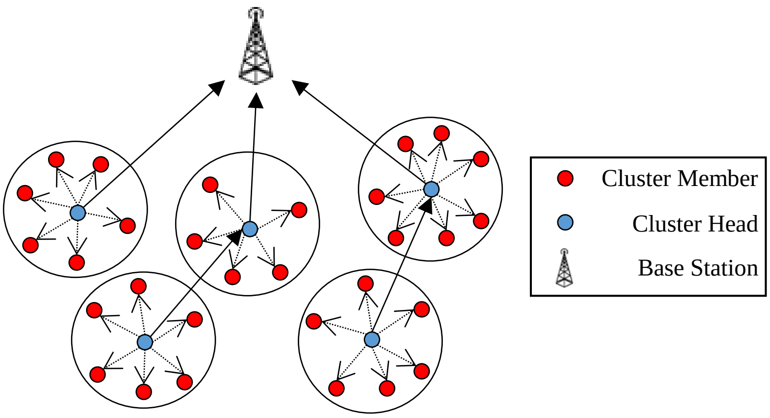


Fig. 1. Data transferring to the BS using clustering techniques

There are many issues in WSNs which have to be considered, such as coverage, lifetime, energy efficiency and security. Among these concerns, lifetime and energy efficiency are the most crucial issues and they are related to the nodes' battery usage. Energy-efficient routing and clustering protocols are used to transfer sensed data through networks nodes to the base station in the network. In this case, besides routing problem, increasing the network lifetime is another important issue. Lifetime of sensors constrains the amount of utility provided by the network. It has a close relationship with the energy efficiency of the WSN. In such way, some advanced nodes can transfer the network information via multi-hop communications to BS. In hierarchical routing protocols, the concept of clustering is used as basic concept to develop various protocols. In the clustering approach, some specific nodes are chosen as Cluster Head (CH) to transfer the network data to the sink node.

Therefore, selecting some nodes as CH nodes in the deployed network is considered as one of the main targets of these research works, besides considering the lifetime issue.

As mentioned before, the key important challenge of WSNs traced back to the limited energy resources of sensor nodes. Therefore, the energy available at each node should be considered as the highest priority in developing the clustering protocols [5]. In this research, a multi-level clustering algorithm is presented which performs the clustering of the sensor nodes according to their level (distance) from to the BS [6]. Designing of a clustering protocol that decreases the consumption of energy of the network is a key issue that needs to be solved. Clustering is a technique that is developed to decrease the consumption of the energy. Nowadays, more researchers are trying to increase the network lifetime by the development of heuristic and meta-heuristic based clustering algorithms. Due to the uncertainty in the variable number and the strong constraints of the clustering problem in WSNs, it is appropriate to design clustering algorithm with meta-heuristics. In this study, a combination of multi-level clustering and genetic algorithm is suggested.

In the remainder of this paper, we state literature review in Section 2. Section 2 presents research assumptions. In Section 4 the proposed clustering algorithm and in Section 5 the energy consumption model is discussed. This section is dedicated to elaborate on the pattern of the energy consumption of each node in the routing process. The results of evaluating the proposed method are presented in Section 6 and finally the conclusions are presented in Section 7.

2. Literature Review

In recent years, a lot of researches has been dedicated to improving the energy consumption based on the clustering algorithms. Meanwhile, the two LEACH and HEED protocols have played a key role in the emergence of many new algorithms. In 2000, an algorithm known as LEACH was proposed by Hillzaman et al. that found a special place among routing protocols in sensor networks [7]. HEED was proposed by Eunice and Fahmi and uses the combination of the remaining energy of the nodes and the communication costs as a criterion for selecting CH nodes [8].

Nehra et al. proposed an energy-efficient ad-hoc routing algorithm for wireless sensor networks [9]. This algorithm attempts to reduce the energy consumption through reducing the number of data forwarding hops (i.e. intermediate sensor nodes). Multi-objective routing in WSNs has been proposed with the aim of extending network lifetime using Genetic Algorithm (GA) [10]. In [11] Xrong et al. attempt to present a cluster-based routing method in WSNs using a hybrid GA and ants colony to distribute energy consumption across the whole network. Moh'd Alia presented the dynamic mobility of mobile stations in wireless sensor networks using a cluster-based harmonic search algorithm. In [12]. The location of the BS has been considered mobile to reduce the distance for communication.

Yao et al. proposed an improved genetic algorithm to resolve the problem of producing invalid genotypes which consequently led to the improvement of the routing in wireless networks [13]. Dasaratan and Kumar presented a dynamic routing for MANETs with the aim of Quality of Service improvement [14]. As a matter of fact, centralized networks are not efficient and reliable enough in encountering unpredictable events. Therefore, MANETs are better alternatives. Boyer et al. developed a combination of LEACH and c-means to reduce the energy consumption challenge. In [15], the c-means algorithm is applied to determine the optimal number and location of CHs. In an analogous study, Barzegari and Mossadry proposed a c-means clustering method by generating symmetric clusters [16]. This method improved the random process of selecting CHs and reduced the overall communication distance between clusters by generating symmetric clusters. Kaoshik proposed combining Fuzzy c-means (FCM) and neural network clustering methods to create a wireless sensor network with optimal energy consumption [17]. Indeed, FCM algorithm is applied to form the Clusters in order to create clusters with equal size.

In another study, Khan et al. presented two improved versions of the well-known DEEC algorithm, namely H-DEEC and MH-DEEC [18]. Rezaeipanah et al, suggested a method while routing is being performed an online clustering approach has been developed for updating the sensors’ clustering, if it is required. The proposed clustering is carried out based on three objectives including reducing the distance between nodes within a cluster, reducing the distance between the cluster head (CH) candidate nodes and the sink node, and online appropriate energy distribution of the nodes in each cluster for each routing round [19]. Lamine, introduced an energy-aware clustering (EAC) algorithm in which the CHs are selected based on the remaining energy of the nodes [20]. Ducrocq et al. developed the Battery-Level Aware Clustering (BLAC) algorithm, which uses a combination of energy levels and the criteria such as density and degree of the nodes in the CHs selection process [21].

3. Research Assumptions

In this paper, the BS is responsible for performing clustering of nodes, assigning certain roles to the nodes, and determining the data transmission path. The BS is usually assumed different from sensor nodes so that has no limitations on energy and processing resources. The maximum radio range has been assumed equal for all the sensor nodes distributed across the network. The radio range indicates the distance that each node is able to transmit the data in the form of electromagnetic waves [26].

The BS node assign the CH role to a sensor node based on the priorities of each cluster as well as the routing protocol policies. The CH is in charge of collecting information from the cluster nodes, eliminating redundant data, combining and forwarding data in the form of a single packet. Accordingly, all of the calculations are performed within the BS. Hence, the BS node has sufficient knowledge of the energy level and location of the nodes. The BS constructs a Time Division Multiple Access (TDMA) table and forwards toward all CH nodes. In fact, TDMA is used for scheduling data transmission at sensor nodes so as to enables sensor nodes to turn off their radio antenna and store their energy until reaching their transmitting time slot [26].

4. Proposed Clustering Algorithm

Hierarchical routing protocols, also known as clustering-based routing protocols, are a new approach to reducing energy consumption that can improve network longevity and scalability. In the proposed method to reduce energy consumption, first the network topology is determined. In the first step, the proposed method identifies the network topology. The network topology is randomly generated in a geographic environment. Secondly, the sensor nodes are clustered according to their geographical location relative to the BS. The rationale idea of this study is to cluster nodes according to the topology structure means that perform clustering in a multi-level manner based on GA. The purpose of clustering is to reduce the data transmission distance and consequently extend the network lifetime. In the third step, the proposed method benefits from a fuzzy logic based routing algorithm for transmitting packets to extend the network lifetime [22]. During network transfers, the energy of the eclipses decreases and ultimately prolongs the life of the network. The LEACH protocol rotates the ellipses between all nodes. This balances the energy consumption between the cluster nodes. Finally, the CHs are updated in the fourth step. At this stage, the sensor nodes of a cluster are awake (i.e. turn their antenna on) and start transmitting information according to the TDMA scheduling.

4.1 Network topology and setup

The topology of WSNs is shaped by distributing a number of nodes in a geographically finite environment. Initially, the energy of all the nodes is equal and measured in terms of Joules (J). The energy vector of nodes is defined by the following Eq. (1).

$$E_{node} = \left[e_{1,} \quad \ldots, \quad e_i, \quad \ldots, \quad e_n \right] \tag{1}$$

Where, e_i represents the remaining energy of node i. The nodes in the network have predefined locations. Here, the locations of the nodes are considered random and with a uniform distribution. Given the fixed location of the BS and the availability of the location information of the other nodes, the BS with the help of the Euclidean distance is able to determine the distance between each pair of nodes. The D_{node} matrix contains the distances between all the nodes by Eq. (2).

$$D_{node} = \begin{bmatrix} d_{1,1} & \dots & d_{1,j} & \dots & d_{1,n} & d_{1,n+1} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ d_{i,1} & \dots & d_{i,j} & \dots & d_{i,n} & d_{i,n+1} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ d_{n,1} & \dots & d_{n,j} & \dots & d_{n,n} & d_{n,n+1} \\ d_{n+1,1} & \dots & d_{n+1,j} & \dots & d_{n+1,n} & d_{n+1,n+1} \end{bmatrix} \quad (2)$$

Where, D_{node} is a symmetric matrix and $d_{i,j}$ is the distance between two nodes i and j. Given the existence of n nodes in the network, the index $n+1$ indicates the BS.

Theorem 1: The distance of each node to itself equals zero. So, $if\ i = j$ then $d_{i,j} = 0$.

Theorem 2: Nodes have a maximum sensing radius. So, $if\ d_{i,j} > sense$ then $d_{i,j} = 0$.

4.2 Multi-level Genetic-based Clustering Algorithm

Basically, the genetic based clustering algorithms construct clusters with different shapes. The shape of the clusters plays an important role in the energy consumption and redundant data transmission. For example, in Fig. 2 the nodes of the network are divided into two clusters A and B. In cluster A, the nodes appear to be horizontally aligned relative to the BS. In consequence, this form of clusters suffer from redundant transmissions to forward information to the BS so that some of the nodes of the cluster A forward their data to a farther location. That way, the sensing information irrationally traverses longer paths to reach the BS. However, the nodes in cluster B are almost vertically aligned relative to the BS. Although there are still exist redundant transmissions in this cluster, the amount is lower.

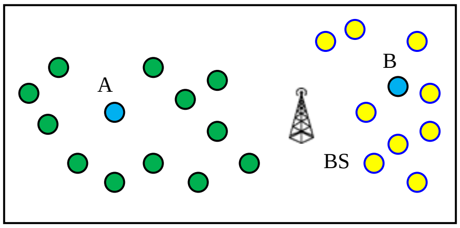


Fig. 2. Schema of clustering in a wireless sensor network

In this paper, the purpose is to minimize the redundant transmissions by considering the sensor nodes in multiple levels according to their distance from the BS. Here, the network is classified to a series of circular levels surrounding the BS as the centroid. Fig. 3 shows a sample of the network layout in three levels.

Next, the nodes of each level form different clusters. The purpose of clustering is to reduce the overall communication distance between the sensors and ultimately extend the network lifetime. According to the accomplished classification, all the nodes in the first level are in the radio range of the BS. Therefore, in order to avoid redundant transmission, these nodes directly forward their information to the BS. In fact, the first level nodes form a cluster with only one CH, i.e. the CH node. Subsequently, the clustering in the second and third level nodes is accomplished by the GA.

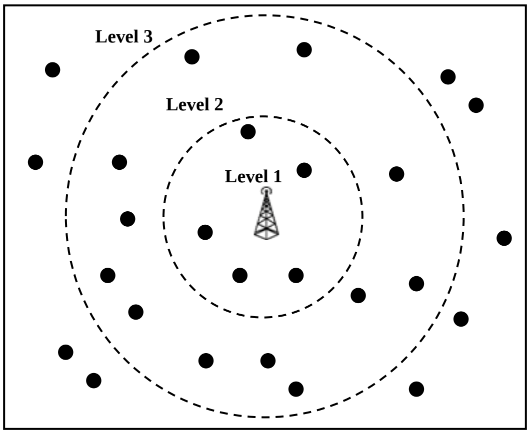


Fig. 3. Multi-level classification of the nodes in a wireless sensor network

A. *Representation of Solutions and Constructing Initial Population*

The encoding used in this study is an L-length array which L denotes the number of nodes in a level. The value of each element identifies the clusters number in which the designated node is located. A greedy approach is applied to construct the initial population. In this approach, the nodes in the cluster are randomly listed, then the cluster of each node is specified. If the current node has not been assigned to a cluster yet, the current node and all its neighbors (neighbors without clusters) would be assigned to a new cluster.

B. *Multi-level Clustering*

The greedy algorithm randomly places the sensor nodes into clusters. Nevertheless, there are two challenges: first, the number of optimal clusters is unknown, and the second challenge which has not been clearly addressed in prior researches, is the radio range of the sensor nodes in a cluster. With respect to necessity of determining a CH in each cluster for gathering the sensing information from cluster members, the CH node should be in the radio range of all the cluster members. In addition, we have modified the GA in order to automatically find the number of clusters and form clusters with at least n CH candidate node. Hence, two abovementioned challenges are addressed.

The method is that the nodes in second and third levels are clustered individually with k clusters. Where $k = 1, \ldots, N^s$ and N^s identifies the number of the nodes in each level. After performing each clustering, the validity of the performed clustering with k clusters is assessed. If the performed clustering yield the clusters with at least n candidate nodes in each cluster, then clustering with k clusters is considered as the fixed clustering of the network. Otherwise, clustering would be performed with more clusters ($k = k + 1$). In this research, the clustering is performed using FCM algorithm in each round. As mentioned before, the CH candidate nodes in each cluster are the nodes that are available (in the radio range) to other cluster members. It worth's to mention, it is impossible to determine a constant number as the minimum n candidate node from each cluster because of the variability of the clusters members. So, the $\text{cov}\,erRate$ parameter is used to identify the percentage of the potential nodes of a cluster to be a CH candidate. Proposed clustering pseudo-code is illustrated in Algorithm 1.

```
Flat Clustering Algorithm
Nodes that are in radius of the sensor base station, Terms are as a cluster.
k = 1;
while true;
    Clustering N' remaining nodes using fuzzy c-means algorithm with k cluster.
    For c = all clusters produced
        Cover_c = Calculate the number of nodes in the cluster_c candidate.
        if Cover_c >= coverRate × N'
            return ( k );
        end if
    end for
    k = k + 1;
    if k = N'
        return ('Clustering is not possible');
    end if
end while
```

Algorithm 1: Pseudo-Code of the Proposed Multi-level Clustering Algorithm

C. Fitness of Solutions

The evaluation metric for a solution is minimizing the energy consumption and extending network lifetime. Therefore, the solutions which reduce the overall communication distances are more valuable. The sum of the distances between nodes in all clusters is the criterion of calculating the fitness of a solution. At first, the nodes in each cluster are identified. Then, the node with the least sum of distances (CH) is determined by iterating the process for all the nodes in a particular cluster. Indeed, the smallest distance represents the best candidate for being CH. Therefore, the total distance between nodes along with the distance to the BS is considered as the fitness of that cluster. Mainly, the minimizing objectives consist of the energy consumed to forward the message from the cluster to the BS and the distance between the nodes. Lower energy consumption and shorter transmission distances lead to increase the fitness of each genotype.

D. Selection and mutation operator

The selection operator of the proposed GA is based on the Roulette Wheel method. Here, the evolution of the population is conducted through a mutation operator. The mutation operator with the mutation rate M_r is assigned to each bit of the solution. Subsequently, a new cluster number randomly assigned to the node. Then, the fitness of the solution is calculated with the conducted mutation and in case the solution improved, it is replaced.

E. Updating cluster heads

During the transmission, when the remaining energy of a node is totally depleted, the node would become disable and unable to transmit data. Therefore, the CH nodes are updated in order to cope with this problem based on the LEACH protocol. In LEACH protocol, the CH nodes are frequently changed in a rotating manner to prevent exhausting the energy of the CH node. Accordingly, the energy consumption would be balanced amongst all the nodes and thus extend the network lifetime. Here, the distance to the BS is also considered to select new CH in rotating the CH role among the nodes. Therefore, only the nodes are potential to be selected as CH that are in the list of the CH candidate nodes. N_p^k represents the list of candidate nodes for k-th cluster. In N_p^k list only those nodes are allowed to be CH which have one of the following two conditions.

1. If the amount of the remaining energy of the node is higher than the average of the energy of all the cluster nodes.
2. At least 30% of their initial energy has remained.

The cluster randomly assigns the CH among the cluster members, in case there is no CH candidate node in a cluster. If N_p^k assumed subset of N_p^k which have one of the two abovementioned conditions, the CH of the k-th cluster is assigned through the following Eq. (3).

$$N_{CH}^k = arg \min_{i \in N_{p'}^k} \left\{ \sum_{j=1}^{|N_{p'}^k|} d_{i,j} + d_{i,N+1} \right\} \tag{3}$$

Where, $d_{i,j}$ is the Euclidean distance between the nodes i and j, $d_{i,N+1}$ is Euclidean distance from i to the BS and $\arg \min_{I 賤 N_{p'}^k} \{.\}$ represents the index of the member of $N_{p'}^k$ with the minimum value. Accordingly, N_{CH}^k denotes the node that minimizes the sum of inter-clusters transmissions distance and also has the least distance to the BS.

Theorem 3: It is not possible to update the CHs in each routing round due to its high computational overhead. Therefore, only if the minimum energy among the participating nodes in the routing were lower than the average of all the nodes in the network, the CH would be updated.

5. Energy Consumption Pattern

The energy consumption in each routing round is calculated regarding the packet transmission path. The ordinary nodes forward their sensing data to the CH node of that cluster. The CH nodes combine the received data applying certain techniques and eliminate redundant information. In the data combination, the information packets are merged in the middle nodes. Thus, the number of transmitted packets across the network would be remarkably reduced and consumes lower energy [23]. After combining the data, the information encapsulate in a packet and forward to the BS. At this stage, the energy consumed due to the packet transmission along the path would be subtracted from the remaining energy of the participating nodes in the path.

The proposed model incorporate radio model discussed according to [24] for energy consumed by sensor nodes in transmission of data, in which a free space model is used, when the distance is less than a threshold value d_0; otherwise, multi-path model is used. Energy consumed by the sensor node radio to transmit an l-bit data over a distance d is given as follows. The following Eq. (4) and Eq. (5) describe the sending E_{tx} and receiving E_{rx} nodes energy consumption.

$$E_{tx} = \begin{cases} E_{elec} \times l + \varepsilon_{fs} \times l \times d^2, d > d_0 \\ E_{elec} \times l + \varepsilon_{mp} \times l \times d^4, d \le d_0 \end{cases} \tag{4}$$

$$E_r = E_{elec} * l \tag{5}$$

Where, E_{elec} is the energy required to send or receive one bit data, ε_{mp} and ε_{fs} denote the energy required to amplify the transmitted signal over the given distance. Also, l is the length of the transmitted packet and d is the distance to the receiving node, d_0 is a threshold for sending a message in terms of distance and is usually calculated based on the following Eq. (6).

$$d_0 = \sqrt{\varepsilon_{fs} / \varepsilon_{mp}} \tag{6}$$

Theorem 4: E_{elec} is in nJ/bit (nano Joule). One nJ is 10^{-9} joules. Also, ε_{mp} and ε_{fs} are in pJ/bit (pico Joule) and one pJ is 10^{-12} joules.

All sent packets have fixed size l. The consumed energy in each routing round consists of the following four factors.

1. The energy consumed for turning the sensors on and collecting environmental information. In this research, the scheduling of turning on the sensor nodes (TDMA) is considered randomly. On the other side, the energy required for collecting data (CD) for all nodes is equal because of the identical structure of the sensor nodes. The following Eq. (7) shows the energy required for collecting data E_{CD}.

$$E_{CD} = \omega . |N_k| \tag{7}$$

Where, ω is a constant value which represents the energy consumption of a node for collecting data sensing the environment. Also, $|N_k|$ returns the number of the nodes in the k-th cluster.

2. The energy consumed to forward data from ordinary sensor nodes to CH. After extracting information from the environment by ordinary (non-CH) nodes, this information should be forward to the CH. In this section, the energy required to send one bit data from each ordinary node to the CH node plus the energy required to receive one bit data from the CH is calculated. Obviously, both ordinary nodes and the CH nodes are members of a single cluster (i.e. k-th cluster) by Eq. (8).

$$E_{send} = \sum_{i=1}^{|N_k|} E_{tx}\left(N_i^k, N_{CH}^k\right) + E_r\left(N_i^k\right) \tag{8}$$

Where, N_i^k indicates the node i of the k-th cluster. N_{CH}^k is the CH of the k-th cluster and $E_{tx}\left(N_i^k, N_{CH}^k\right)$ denotes the energy required to send information from node i to the CH of the k-th cluster and $E_r\left(N_i^k\right)$ denotes the required energy to receive information from node i by the CH.

3. The energy consumption in combining information by the CH. As mentioned before, the CH is in charge of combining information. So, assume E_{DA} is the amount of energy needed in terms of Joule to combine one bit data by the CH. In this phase, the overall consumed energy is calculated as follows Eq. (9).

$$E_{mixture} = |N_k| . l . E_{DA} \tag{9}$$

Where, l number of bits to each node for sending, $l.?E_{DA}$ represents the energy needed to combine the information in a CH for a node.

1. The energy consumed to forward packets from CH to BS. The energy required to send packets from the CH node to the BS is calculated according to the determined path resulting from the fuzzy routing algorithm. The energy needed to send and receive information for each pair of consecutive nodes (each hop) of the routing is taken account. Suppose i and j are two consecutive nodes, i.e. a link of the forwarding path. Therefore, the energy required sending information from the node i and the energy required to receive information from the node j is calculated. The total energy consumed in this phase is calculated according to the following Eq. (10).

$$E_{path} = \sum_{(i,j) \in path} E_{tx}\left(N_i^k, N_j^k\right) + E_r\left(N_j^k\right) \tag{10}$$

Where, l bits data sending by any ordinary node to CH of the k-th cluster, the total energy consumed during a routing round in the k-th cluster is represented as E_{total}^k and calculated by the following Eq. (11).

$$E_{total}^k = E_{\mathrm{CD}} + E_{send} + E_{mixture} + E_{path} \tag{11}$$

The Eq. (12) below shows the total energy consumed in the network during a routing round for all of the clusters.

$$E_{total} = \sum_{k=1}^{K} E_{total}^k \tag{12}$$

Where, K represents the number of clusters formed by the proposed multi-level clustering algorithm.

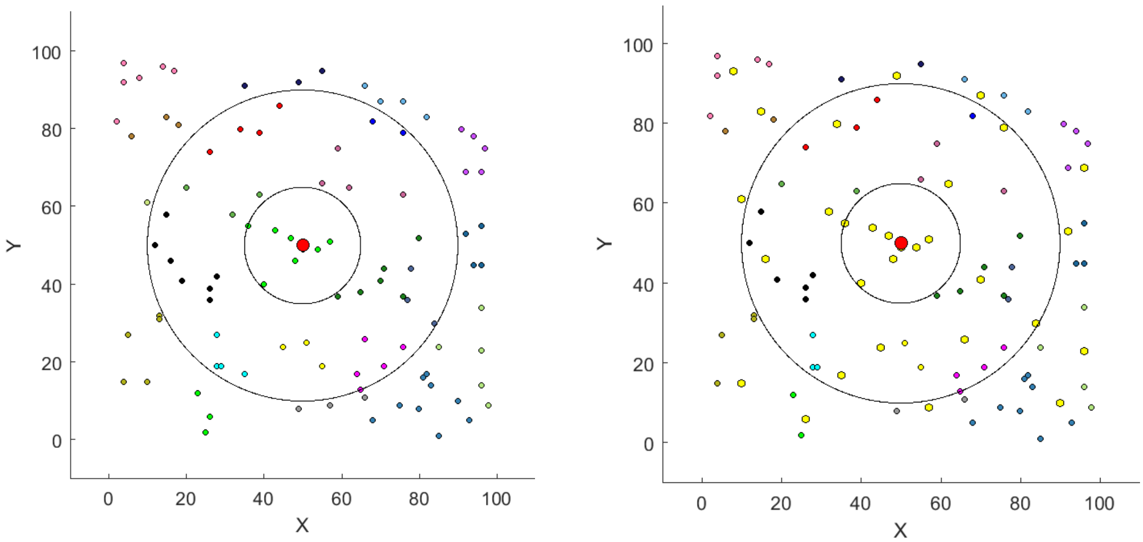
6. Experiments and Results

In this section, we investigate the simulation results of our method along with the evaluation of its performance and comparison with other similar methods. In the simulation, 100 nodes are randomly distributed in a 100×100 meters area with a non-uniform distribution. In all routing rounds, a 4000-bit length packet is transmitted from CH to the BS. The location of BS is fixed and located in the center coordinates of the geographical area. Table 1 briefly represents all the parameters and values used in the simulation.

Table 1. Values of the parameters used in the simulation

Parameter	**Value**	**Parameter**	**Value**
E_{elec}	50 n J/bit	EI	0.5 J
ε_{mp}	0.0013 pJ/bit/m^4	Surface	[15 40 50] m
ε_{fs}	10 pJ/bit/m^2	$\mathrm{cov}\,erRate$	10 %
E_{DA}	5 nJ/bit/message	Sense	15 m

Fig. 4(a) shows a layout of the network topology and the performed clustering. The CH nodes are depicted in Fig. 4(b) using yellow spots in the network topology, after selecting CHs.



a) Network topology and nodes clustering

b) Network topology after selecting CHs

Fig. 4. Multi-level clustering of the nodes based on GA

The optimal path determination is computed using a fuzzy logic based algorithm [22]. We are carried out the experiments 30 times due to the random location of the nodes and to obtain more accurate results. Accordingly, the average of 30 times of independently running the algorithm is considered. Fig. 5 illustrates the energy level of each node at the end of the routing.

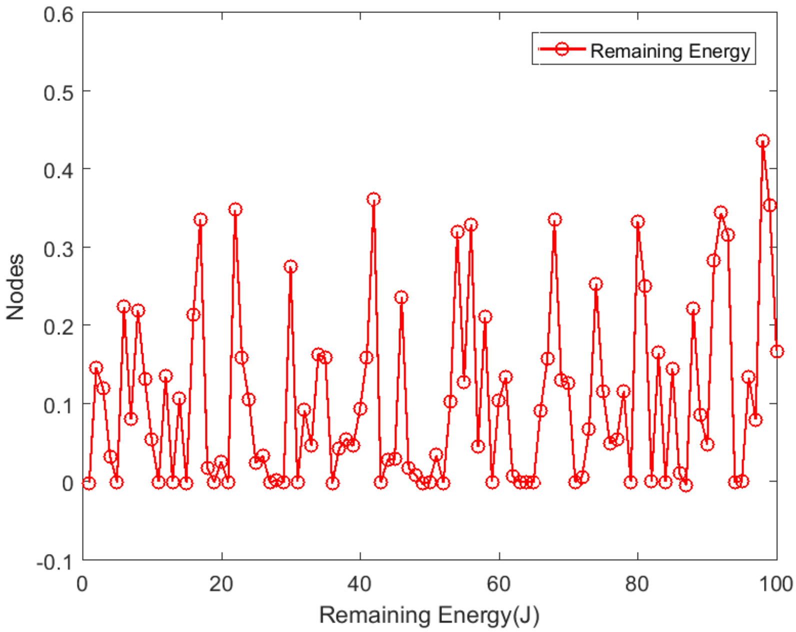


Fig. 5. The energy level of each node at the end of the routing

In this experiment, the remaining energy of 49 nodes is approximately equal to zero. It is obvious that these nodes have mostly been the CH candidate in the simulation. Only about 25% of the nodes have energy higher than 0.2 Joule that are the participating nodes in the routing. The density of the presence of the node alongside the excessive number of nodes with the remaining energy near zero indicates high performance of the proposed method in distributing the energy amongst the nodes. Table 2 shows the results of evaluating the proposed method after 5000 routing rounds.

Table 2. Results of the proposed method after 5000 rounds of routing

Criterion	**Value**	**Criterion**	**Value**
Network lifetime	3828	Total remaining energy	9.12 Jules
The number of alive nodes	51	Average remaining energy	0.09 Jules
Number of sent packets	4588	Standard deviation of remaining energy	0.13 Jules
Simulation time	50 Seconds	Number of dead nodes	49

Additionally, a comparison with a number of similar algorithms is conducted in order to evaluate the capability of the proposed algorithm. The results are compared with SEP [25], P-SEP [26], EM-SEP [27] and M-SEP [28] methods for 5000 routing rounds. In the following, the comparison results in terms of two various metrics, i.e. the number of alive nodes and the number of sent packets are presented. Fig. 6 depicts the results of evaluating out method in terms of the number of alive nodes and Fig. 7 shows the comparison results in terms of the number of sent packets metric.

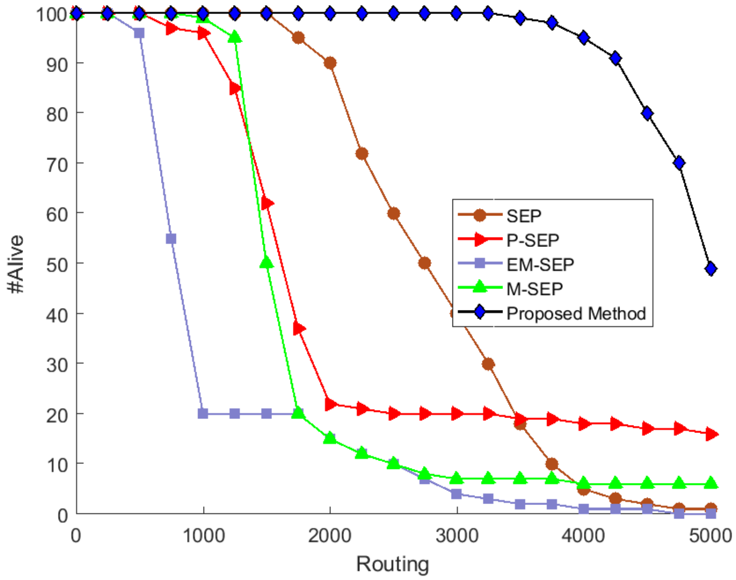


Fig. 6. Number of alive nodes relative to the number of routing rounds

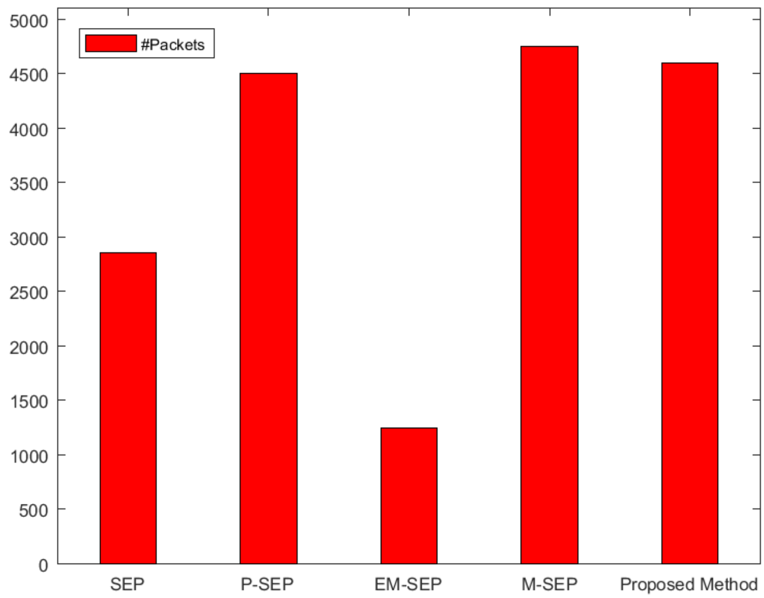


Fig. 7. Number of sent packets relative to the number of routing rounds

According to the results, the proposed method outperforms other methods from the network lifetime aspect. With scrutinizing other methods, we found that the early depleting the energy of the dead nodes is the obvious consequence of the fact that such methods have not considered the network lifetime and only concentrated on increasing the number of sent packets during the routing rounds. This is clearly evident in the number of sent packets. The number of sent packets for the P-SEP and M-SEP methods respectively is 4500 and 4750, respectively. The number of sent packets in our proposed method is 4588, which is very close to both. Despite the superiority of the M-SEP method over the proposed method from this aspect, it still outperforms considering the aggregation of two metrics.

Balancing the consumption of energy has an impact on the lifetime of the network. It is an important criterion in energy efficiency in WSNs. The residual energy directly affects the network lifetime. The proposed algorithm gives best results in prolonging the lifetime of the network than other protocols in all the scenarios as shown in Fig. 6. Generally, our proposed method is more accurate in comparison with most of the other compared methods and in other cases it also offers proper accuracy. The results show that the energy distribution amongst the nodes in the proposed multi-level clustering algorithm outperforms other algorithms.

7. Conclusions and Future Suggestions

To extend the lifetime of wireless sensor networks, researchers are always seeking ways to reduce energy consumption. In this research, the responsibility of transmitting information of each cluster is ceded to a certain node, namely cluster head. Applying the genetic algorithm for multi-level clustering leads to form vertically shaped clusters relative to the base station. As a result, the redundant transmissions of routing become minimized in wireless sensor networks. Performance of the proposed algorithm is evaluated in different network scenarios and the experimental results are compared with some well-known clustering based routing algorithms. Simulation results validate the superior performance of the proposed algorithm over the existing scheme under different network scenarios.

From the results, it can be said that the ability of the proposed algorithm to explore the positions of the CHs in an intelligent way stems from the strength of the GA algorithm in searching for the optimal location among the CHs that also minimizes the distances between the CHs and the BS. In this study, the number of network nodes is assumed to be constant, whereas the proposed protocol is capable of customizing for networks with mobile nodes. For instance, the base station could be assumed mobile and optimized the routing algorithm accordingly.

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Authors' Profiles

Amin Rezaeipanah received his B.E. in Computer Science & Engineering from Faculty of Engineering at Ferdows University, Mashhad, Iran in 2010 and M.E. in Artificial Intelligence from Shiraz University, Shiraz, Iran in 2013. He is currently a researcher and lecturer at Rahjuyan Danesh University, Borazjan, Iran. His main research interests consist of recommender systems, social network analysis, wireless sensor networks and large-scale data mining.

Hamed Nazari is graduated in M.Sc. of Computer Networking Engineering from Department of Computer Engineering at Urmia University in 2017. He received his B.E degree in Information Technology Engineering from Bushehr Islamic Azad University in 2013. He has re-affiliated with Department of Computer Engineering of Bushehr Islamic Azad University as a visiting lecturer. His research interests include but not limited to Wireless Sensor Networks, Internet of Things (IoT), Software-defined Networks (SDN).

MohammadJavad Abdollahi received his B.E. degree in computer engineering from University of Rahjuyan Danesh Borazjan, Department of Computer Engineering in 2016, and has received his M.Sc. degree in information technology engineering from of Lian Bushehr University 2018. He has taught in the areas of computer and network and his research interests include data mining, Information Security, Wireless Sensor Networks and Genetic Algorithm.

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