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Inflated Multi-Layered Energy-Efficient Clustering Method for Ad Hoc Distributed Wireless Sensor Networks

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ABSTRACT

This study introduces a inflated multi-layered clustering protocol for ad hoc wireless sensor networks (WSNs), where the size of clusters is variable. So that the closer clusters to the base station (BS) have a smaller size than farther ones. Moreover, in each cluster, using some intelligent fuzzy rules and in a decentralized way, a novel sub tree strategy is determined. In this way, some parent nodes are chosen that are responsible for collecting and aggregating data from their adjacent or dinary nodes and sending them to its cluster head, directly or via other parent nodes, which substantially decreases intra-cluster communication energy costs. Furthermore, these two compatible techniques can fairly mitigate the hot spot problem resulting from multi-hop communication with the BS. The simulation results demonstrate that the proposed protocol outperforms two energy-efficient protocols named DSBCA and LEACH in terms of functional network longevity for both small-scale and large-scale sensor networks.

1. Introduction

Wireless sensor networks (WSNs) are application specific networks composed of small nodes, which can sense the environment, collect the data, do aggregation and every single node can communicate with each other wirelessly via radio link [1, 2]. Today's fast technology improvements in low-power and wireless communication have provided a good condition for WSNs in real-world applications and distributed sensor applications have increased significantly such as wild life and ocean life monitoring, supervising the vibration of structures, automatic warning, supervising the agricultural applications and target tracking [3, 4].Nodes have limitations in memory, process and energy; therefore it is difficult to design WSNs. Among the above-mentioned limitations, energy is the most important one because when the sensors are installed their batteries cannot be replaced or charged. Thus, energy considerations are the most prominent factors in WSNs routing. One of the most famous routing algorithms for WSNs is clustering-based hierarchical routing [5–7]. In this method, all nodes are divided into groups called clusters based on specific methods. In each cluster, one node is selected as a cluster head (CH) and other nodes are considered as normal nodes. Different parameters are taken into account while selecting a CH in various methods. In the major part of clustering algorithms, the main goal is to achieve uniform energy distribution to increase network lifetime. In this type of routing, sensor nodes play different roles and they may have different energy consumption according to their role. This group of methods is the best class of routing algorithms for WSNs [8–10]. A CH is able to manage and schedule intra-cluster activities, and as a result nodes may change their state to low-power sleep mode and reduce energy consumption.

Moreover, the nodes might be utilized in a Round-robin order and a specific time could be determined for data transmission and receive. Thus, retransmitting is avoided and data redundancy in target region is decreased and medium access collision is also avoided [11, 12]. Nodes alternatively transmit their data to CH. The CH collects the data, compresses it and transmits the compressed data to the base station (BS).Transmission to the BS might be done directly or in a multi-hop process and with the incorporation of other CHs. Since CHs transmit their data over longer distance, the energy consumption rate is higher in CHs. A simple approach to balance energy consumption is to reselect the CHs periodically. In this case, the role of CH is changed. The structure between normal nodes, CHs and BS might be repeated as much as it is required [13–15].In this paper, a multi-layered clustering algorithm is proposed where cluster sizes are variable. The size of clusters increases as the Distance from the BS increases. As a result in the vicinity of the BS cluster sizes are smaller than clusters, which are far from the BS.As a matter of fact, a multi-layered structure is formed where cluster sizes increase while getting farther from the BS. In each cluster, a novel structure called sub-tree topology is utilized to balance energy consumption in the whole network. In each cluster, one or more nodes (depending on size of cluster) are selected using fuzzy logic, which is called the parent. They are responsible for collecting and the compression of data from their neighboring normal nodes, which are called child nodes (CNs) .The rest of this paper, is as follows: Section 2 reviews the related works. The details of the proposed protocol are expressed in Section3 and Section 4 contributes the simulation results and evaluating the performance of the proposed protocol. Finally, Section 5 concludes this paper.

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2. Related works

There are many protocols in the literature dealing with the clustering issues in WSNs and most of them tried to improve energy efficiency and network lifetime. One of the most popular distributed clustering protocols in WSNs is the low energy adaptive clustering hierarchy(LEACH) algorithm [16]. The clustering operation is repeated periodically and each round has several steps. Each round starts with initial setting step; then, the round enters a steady-state step, where data are transmitted to the BS. First off, each node decides whether it should become a CH in the current round or not. This decision depends on the recommended percentage for a number ofCHs and must be determined in advance. Another factor affecting this decision is the number of times when the node has been selected as a CH. Node n generates a random number between 0 and 1 to make a decision. If the generated number is less than a threshold value T(n), the node will consider itself as a CH. T(n) is calculated via

$$T(n) = \begin{cases} \frac{p}{1-P(r \bmod \frac{1}{p}} & if\ n \in G \\ 0, & \end{cases} \quad (1)$$

In (1), P is the desired percent of CHs, G is the set of nodes, which have not been CHs in the last 1/p rounds and r denotes the number of rounds. Subsequently, each node, which becomes a CH in the current round transmits a message to other nodes. The normal nodes should turn on their receivers. They detect the closest CH with respect to thepower of the received signal. They join the cluster by sending a joint message and so the clusters are formed. Then, each CH informs its members about the data transmission timing plan. The nodes may transmit their data in an allocated time span and CHs directly transmit this data to the BS. The major Short coming of the LEACH algorithm is that the CHs might not be selected properly from the distribution and energy respective. So far many algorithms based on the LEACH protocol and for improving the performance of WSN has been designed [17,18].The LEACH-G protocol is based on the LEACH protocol that attempts to optimize the cluster numbers in the LEACH algorithm for better node distribution, prevent the overuse of energy and fast energy releasing to decrease the consumption energy effectively and consequently increasing the network lifetime [19].Another algorithm is Hybrid Energy Efficient Distributed (HEED)clustering algorithm, which is different from the LEACH algorithm in CH selection. In this method, a selected CH only informs its neighbors while in LEACH all nodes are informed. The CH selection is based on two parameters: communication cost and residual energy. The communication cost is a function of various factors such as the cluster size, transmitted power changing level, node degree and inverse of node degree. It has several advantages. first, contrary to the LEACH algorithm CHs have a suitable distribution in this algorithm. Furthermore, as residual energy and communication costs are both involved, the energy consumption is not considered to be uniform for all nodes. Moreover, it uses multi-hop communication to connect the BS [20].Energy efficient clustering scheme (EECS) [21] protocol is one of the other distributed protocols. It tries to address LEACH shortages. Each node generates a random number and compares it with threshold valueT. If the random number is less than T, the node makes itself a candidate for being a CH. Afterwards, all candidates try to introduce themselves in broadcast radius of candidate nodes(R-COMPTE) radius using Carrier Sense Multiple Access (CSMA) protocol and they include their residual energy in this message. Each candidate node listens to messages of other nodes in its radius before introducing itself. If its energy is higher than all other introduced nodes in that radius, it introduces itself as a candidate. When it introduces itself, it listens again and if it is still the best choice from an energy point of view it considers itself as a CH. Normal nodes consider distance to the BS as well as distance to the CH in order to select their CH. The data are transmitted from a CH to the BS in a single-hop manner. This protocol proves that according to the CH selection algorithm there would be only one CH in R-COMPETE radius. The main drawback of EECS protocol is its data overload. Infect the large number of CH candidates which are selected based on T threshold is near to N*T (N is the number of nodes).The Energy Balanced Distributed Clustering (EBDC) is a clustering distributed algorithm based on the virtual grid. Each cluster is divided into some squares. In this algorithm, to select the CH, the residual energy and the history of sending packets are used. This protocol leads to balance energy consumption of the nodes and increasing the lifetime of the network [22]. In [23], a distributed clustering protocol is proposed for increasing the communication steps and the network lifetime. In this protocol, first every CH candidate informs the neighboring nodes and k-step nodes by a message. Then each node that receives this message, if it is not a CH, links to the nearest CH candidate. After a certain time, if a node finds that it is not a CH and does not have any link to the CH candidates, it is a compulsive CH. In [24], Wei et al. introduce a distributed clustering protocol to address the hot spot problem; the cluster sizes are adjusted considering the hop distance to the BS properly. In addition to increasing the lifetime, decreasing the load volume at the hot spot area and avoiding fast releasing of nodes energy at this area is achieved. The other clustering protocols for addressing the hot spot problem using clusters with variable size have been introduced in[25, 26].Energy efficient unequal clustering (EEUC) [27] is a clustering protocol with a non-uniform size of clusters, where CHs use a multi-hop scheme for data transmission to the BS. The main problem of multi-hop protocols is the hotspot issue. It means that CHs, which are closer to the BS must endure a higher traffic load. Consequently, their energy will deplete sooner and network lifetime decreases. To address this issue clustering methods with a different cluster size are proposed such as EEUC. In this method clusters, which are closer to the BS have a smaller size. Thus, intra-cluster energy consumption of these clusters decreases. Therefore the CHs are able to provide the energy needed for inter-cluster communications. Using this technique increases network life time. The protocol proposed by Gupta et al. [28] exploits fuzzy logic to determine CHs. In each round the node, which has the highest? Opportunity to be a CH is selected as the CH. To calculate the Chance of each node, three fuzzy variables including node energy, node centrality and number of neighbors are utilized. In this method, the BS determines the CHs. Thus, it initially collects data regarding all nodes and then selects the CHs. The main drawback of this method is that in each round only one of the CHs is selected while more are needed to balance energy consumption and increase network lifetime. In 2008, Myoung Kim et al. [29] proposed an algorithm called cluster head election mechanism using fuzzy logic (CHEF) using fuzzy logic. The only difference between CHEF and previous algorithm is that more than one CH is selected.

The chance of each node is derived from two fuzzy sets, node energy and distance. First, a random number is generated for each node. If the number is less than a specific probability function, the chance of being a CH is calculated for that node. Finally, nodes with higher chances are selected as CHs. In 2013, Liao et al. [30] presented a self-organization distributed clustering algorithm called distributed self-organization balanced clustering algorithm (DSBCA). It uses a multi-layered structure. The size of clusters in each level is different from the size of clusters in other layers. Nonetheless, the size of clusters inside a layer is the same. The size of clusters close to the BS is smaller than further away clusters. Fig. 1 demonstrates the structure of this algorithm in uniform distributions. This algorithm consists of three phases including CH selection, cluster formation and cycle phase. In CH selection phase, a few nodes are randomly selected. Calculating connection density and distance from the BS they are selected as temporary CHs and transmit a message to their neighbors. Among these nodes, the CH with larger weight is selected as a CH. The Weight is Determined based on residual energy, connection density and time of selection. In the cluster formation phase CHs, high receive joint messages from normal nodes accept or reject them as their members considering their size threshold. Finally, in cycle phase CHs collect data from their members and transmit data to the BS using a multi-hop scheme. In large networks, last layers, which include large clusters increase the distance passed by data and intra-cluster communication which increases energy consumption.

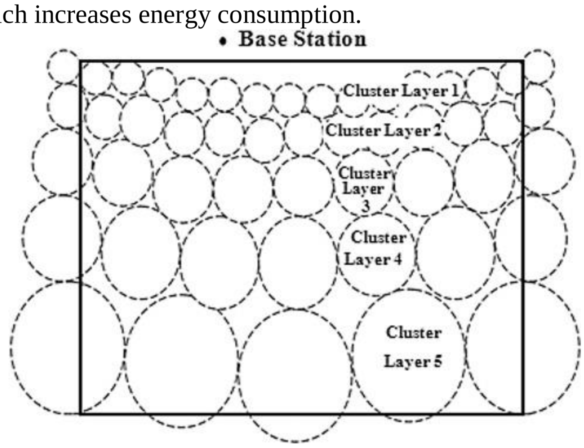


Fig. 1. DSBCA clustering in uniform distribution.

3. Proposed protocols

The proposed protocol is a distributed and decentralized clustering protocol. It acquires an appropriate structure in order to achieve energy efficiency in both intra- and inter-cluster communications. Moreover, it overcomes the energy-hole problem significantly which, in turn, increases network lifetime. In this protocol, cluster size increases while getting farther from the BS. Actually, a layered structure is formed where clusters close to the BS are smaller than those which are farther from it. In this protocol, to select high-energy level nodes and proper distribution as CHs three criteria are considered including residual energy, number of neighboring nodes in neighborhood radius of the CH,which is demonstrated by Ndeg and distance to the neighboring nodes. In this protocol, in each cluster a sub-tree topology is used. As a matter of fact, each CH selects its parent nodes among volunteer parent nodes in its cluster according to residual energy and the number of volunteer parent nodes in the parent radius. The selection is performed using fuzzy logic. Furthermore, the number of selected nodes depends on R size such that the larger the size of Cluster, it is highly probable that more parent nodes are selected. Parent nodes are tasked with collecting and aggregating data from their CNs. It leads to balanced distribution of energy consumption in the whole network. Besides, it decreases intra-cluster tasks so that the CH saves more energy. Therefore the proper amount of energy could be dedicated to inter-cluster communication. Parent nodes transmit aggregated data to CH either directly or via other parent nodes in the same cluster. Afterwards, CHs transmit the received data to the BS in a single-hop or multi-hop manner depending on their distance to the BS. Fig. 2 shows the multi-layered structure of network protocol. Following, some assumptions and the radio model of the proposed protocol and the Formation steps are expressed.

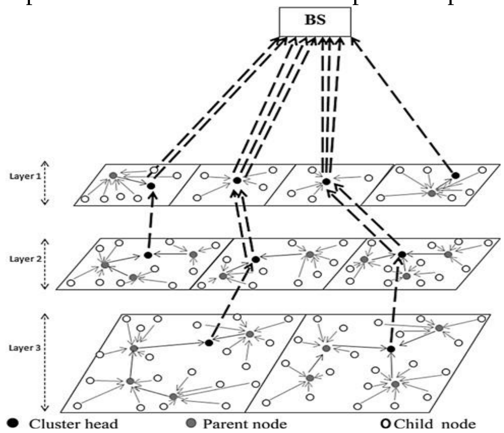


Fig. 2. Multi-layered structure of network.

3.1 Model assumptions

The considered assumptions for the proposed protocol are described as follows:

(1) All nodes are distributed randomly and uniformly in a square area as M×M× (M2).

(2) The BS is located stable and far from the network without any energy, processing and memory constraints.

(3) All nodes are the same in terms of resources, processing, communication, the initial energy and so on.

(4) All nodes are stable after deployment and sense the environment and do have data to send.

(5) The nodes are considered as dead nodes when their energy is over.

(6) Every round consists of a complete cycle for selecting the CH and parent nodes, the formation progress and data phase.

(7) Nodes do not know their location and BS location, and they are not equipped with a global positioning system.

(8) Every sender node considering its distance to receiver can adjust its sending power level.

(9) Every node can estimate its distance to sender considering the Receiving signal power.

3.2 Energy consumption model

The radio model is same as model given in [11]. For smaller distances than threshold distance d0, the free space channel model is used, otherwise the multipath fading channel model is considered. When a node sends a k-bit package to d distance, the energy consumption is computed as follows

$$Es = \begin{cases} k * (Eelec + Efs * d2); d < d0 \\ k * (elec + Emp * d4); \quad d \geq d0 \end{cases} \qquad (2)$$

In (2), Eelec is the required energy to activate the electronic circuits and depends on digital coding modulation, filtering technique, spreading of the signal and amplifier energy, EMp*d4 energy term, which depends on the distance between sender and receiver and acceptable bit-error rate, Efs and EMp are required energies to send a bit in free space and multipath, respectively, d is the distance between sender and receiver and d0 is the threshold distance that is computed with the following equation

$d = \sqrt{Efs/Emp}$ (3)

When nodes receive a k-bit package, the consumption energy is computed with the following equation

$ER = k * Eelec$ (4)

In addition, energy for data aggregation by parent nodes and/or CH is computed with the following equation

$Eagg = EDA * k * n$ (5)

In (5), n is the number of messages and EDA is the required energy to Aggregate a bit.

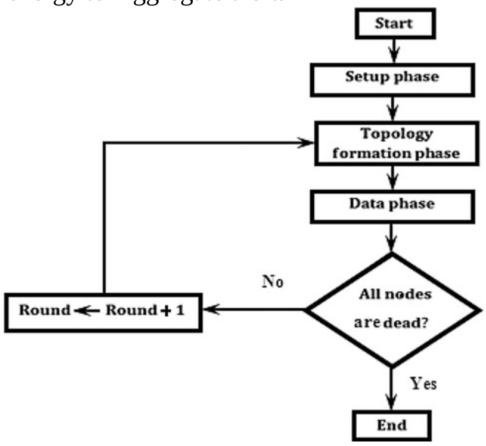


Fig. 3. Overall steps of the proposed protocol.

3.3 Protocol phases

This protocol is composed of three phases: setup, topology formation and data phase. In the first phase, each node obtains primary

Fig. 2 Multi-layered structure of network information according to power of received signal, whereas in the second phase CHs and parent nodes are selected and clusters are formed. Additionally, the inter- and intra-cluster communications manner is specified in this phase. In the steady-state phase, data sensed by nodes is transmitted to the BS using a single-/multi-hop approach after collection and aggregation. Fig. 3 depicts the overall steps of the proposed protocol. Following, the details of every phase is described. All message types that are used in this paper

3.3.1 Topology formation phase:

In this phase protocol topology is formed. This phase consists of four sub-phases including CH selection, parent selection, intra-clusterCommunication and inter-cluster communication which areexplained as follows:

CH selection sub-phase: In this sub-phase, CHs are determined by the steps of which are depicted in Table 3. Lines 1–2 were specifiedin the setup phase for each node. In lines 3–8, each node generates arandom number between zero and one. If the generated number isless than the normalized FM-value of the node, the node willconsider itself as a CH candidate. In lines 9–18, each node which has considered itself as CH candidate waits for its time slot whenit can introduce itself as CH candidate via head-volunteer-MSG.Till then it listens to all messages of this type which are transmitted by other candidates. If among candidates a candidate j is found such that its residual energy ECHVj is higher than candidate i and simultaneously one or two of them has Rsize larger than the distance between them, dij candidate i leaves the competition and will not send its head-volunteer-MSG. In contrast, if one or both of the above-mentioned conditions are not met candidate i will send its head-volunteer-MSG.

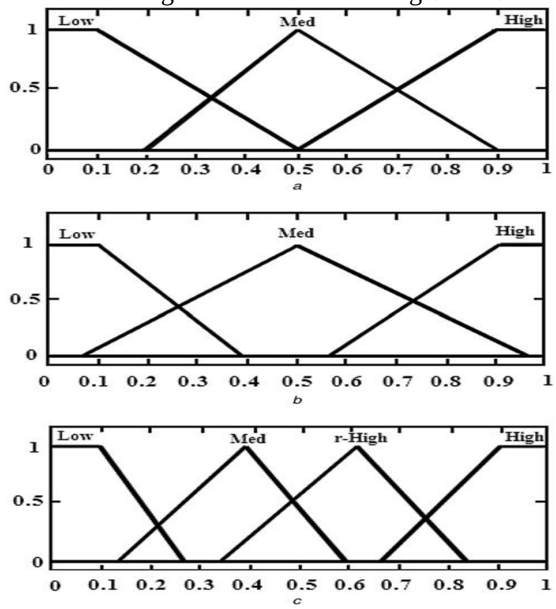
In lines 19–26 the CH candidate node, which has introduced itself as a candidate CH via head-volunteer-MSG and listens to all messages of this type as it was doing before. If there is not any other node, which satisfies the aforementioned criteria, the candidate node considers itself as a CH; otherwise, it withdraws its claim for being CH. Then, CHs announce their selection as CH by transmitting a head-MSG including ID and spreading code. Afterwards, other nodes select the closest CH as their corresponding one according to receivedsignal powers. protocol is 1088. The results revealed that the proposed method has improved network lifetime 48 and 12% compared with LEACH and DSBCA, respectively. Fig. 7c illustrates network energy consumption in each turn for all protocols. As shown in Fig. 7c, sudden changes of energy consumption in the proposed protocol are less than LEACH and DSBCA. It verifies that the proposed protocol distributes energy consumption uniformly across the network. Figs. 7d and e demonstrates residual energy at the end of each turn and the residual energy percentage after first node death. According to Fig. 7d at the end of each turn, network residual energy for the proposed protocol is more than residual energy related to LEACH and DSBCA protocols. It demonstrates improvement in energy efficiency and decrease of energy consumption. As depicted in Fig. 7e when the first node dies in LEACH, DSBCA and the proposed protocol, respectively, 21, 8 and 1.8% of total energy remains, respectively. It shows that energy distribution in the proposed protocol is better than two others. As a matter of fact, the shorter the time span between first node death and last node death, the more uniform is the energy Consumption of all nodes.

Parent selection sub-phase: In the proposed protocol, first off,each non-CH node generates a random number and compares it with Nthreshold-PVN (which is the same for all nodes and is considered as a protocol parameter). With respect to the generated number, the node selects whether it could be a parent volunteer or not. Then each parent candidate node transmits a parent-volunteer-MSG including its own ID and its CH's ID to inform other nodes. Each parent volunteer node (PVN) counts PVNs in its RPN radius considering the received power of parent-volunteer-MSG and comparing its CH to the CH of each message. The number of these neighbors is denoted by NPVN-radius. Subsequently, each parent candidate transmits a PVN-energy-MSG which consists of its ID, its CH's ID, its residual energy and NPVN-radius value to its CH. Receiving this information, each CH utilizes the following fuzzy logic algorithm and normalized inputs of residual energy and NPVN-radius to priorities its parent candidates. Then, some of the parent candidate nodes with low priority are eliminated using (11). Each CH transmits parent-ID-MSG and inform its parent nodes about the ID of all parent nodes considering its distance to the furthest PVN. Each parent node, then, broadcasts a parent-MSG including its ID and its CH's ID to announce its position as parent

$NPN_{final} = n\,PVN * delete - rate$

In (11), delete-rate is a protocol parameter, NPVN is the number of PVNs and NPN-final is the final number of parent nodes in each cluster. The input parameters of fuzzy logic in this method are residual energy and number of neighbors. The variable language for these inputs is as follows

residual energy : (low; med; high) NPVN-radius : (low; med; high) In the fuzzy model, one of the most common fuzzy inference techniques is exploited called the Mamdani method [31, 32]. The output values are achieved using centroid defuzzification. Membership functions and its linguistic states are given in Table 4 and Figs. 4a–c.



Intra-cluster communications formation sub-phase: In this sub-phase, a sub-tree topology is formed in each cluster. The steps of this sub-phase are illustrated in Table 5 algorithm and are explicated in the following paragraphs. According to lines 1–2 if a CH does not have any parent node, each node considers a CH as its next hop. In lines 3–4, each CN selects the closest parent node. Then, it transmits a join-child-MSG message including its own ID and its parent ID to the corresponding CH. In lines 5–17, parent node i determines its next hop, which might be either another parent node in the cluster or its CH. According to lines 7–8, first the parent node i selects parent node j which is the closest parent node among those parent nodes which are closer to the CH than node i.In lines 9–15, if the distance of the parent node i to its CH d(PNi, CH) is less than the distance between nodes i and j dPNi , PNj, the CH would be the next hop of parent node i;other wise, j would be its next hop. Now each parent node informs its CH about its next hop using a join-parent-MSG which includes its own ID and the ID of its next hop. Each CH transmits a schedule-MSG message to each node so that it could inform them about the time slot number of each node for time division multiple access data transmission.

Inter-cluster communications formation sub-phase:

In this sub-phase, the data path from CH to BS is determined. The steps are presented in Table 6. Nodes whose distance from BS are less than relay-radius form, the first layer and are called send direct(SD) nodes. The nodes inside other layers are called multi-hops end (MHS) nodes. According to lines 1–10 if CH i CHi is MHS, it transmits its own aggregated data and the data received from other CHs (which are even further from the BS) to the CH which is closer to the BS. As a result, data reaches to BS step-by-step. In lines 3–5, first, the cluster head j CHj is selected among the CHs which are closer to the BS than CH i. CHj must be the closest CH to i and it would be chosen as the next hop. Otherwise in lines 6–8, if there is a SD CH in the first layer, CH i chooses a CH among those SD ones such that the sum of energy consumption in i and the selected CH is minimized. The optimal CH is called CH optimal.

4. Simulation result

In this section, the performance of the proposed clustering algorithm is compared with famous clustering algorithms; LEACH [16] and DSBCA [30]. Network lifetime is considered as the main factor of energy and the superiority of our proposed algorithm is demonstrated. Moreover, to achieve precise evaluation and results, simulations are performed in both large- and small-scale networks. In this way, the scalability of the proposed method is assessed as well. Additionally, four main parameters are considered to evaluate the protocols more efficiently. These main parameters include network lifetime, residual energy at the end of each turn, network energy consumption and residual energy percentage after first node death. It is worthy to note that the ad hoc model is chosen for the network as node arrangement and their location is completely random in the square area. Thus, each simulation is iterated in 50 different arrangements and the results are averaged

4.1 Effect of relay-radius on network lifetime

As demonstrated by Fig. 6 when relay-radius increases network lifetime increases first. After it reaches a maximum value it will Decrease considerably. Actually at the first step with small Relay-radius, all CHs would be MHS type and use a multi-hop Communication. In other words, the proposed protocol in this case behaves such as protocol where its inter-cluster communication for transmitting data to BS is completely performed in a multi-hop manner. In this condition, adjusting relay-radius in an appropriate value the network lifetime reaches to its maximum; however, extra increase in relay-radius causes almost all nodes to be SD type, which uses direct communication to transmit data to the BS. It rapidly depletes the energy of CHs located further from the BS.

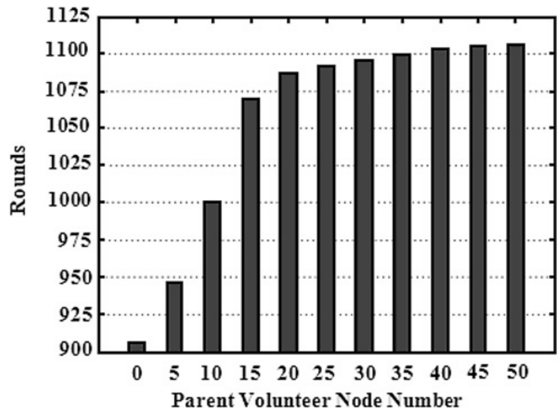


Fig. 5. Effect of parent volunteer number on network lifetime.

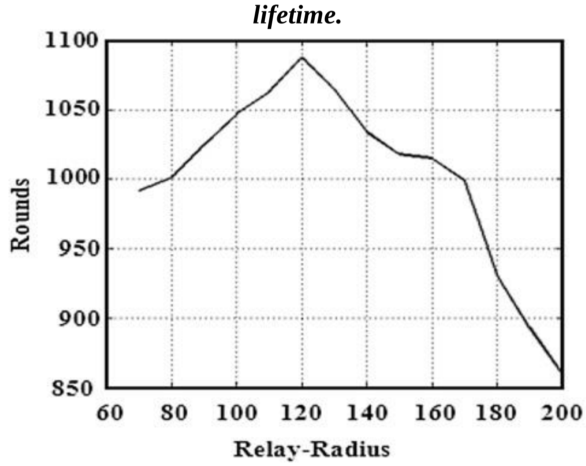


Fig. 6. Effect of relay-radius on network lifetime.

4.2 Evaluating the performance of the proposed protocol in small-scale networks

In this section, the proposed protocol is compared with LEACH and DSBCA in small networks.

The most prominent evaluation factor is network lifetime which has various definitions.In most cases, first node death criterion is considered. The second and third criteria are last node death and average node death, respectively. In the simulation, the values of the proposed protocol in small scale for relay-radius, Rmin, NPVN and NCHVN are 120 m, 25 m, 20 and 9, respectively. As demonstrated by Figs. 7a and b network lifetime in LEACH protocol is 733, in DSBCA is 963 and in the proposed protocol is 1088. The results revealed that the proposed method has improved network lifetime 48 and 12% compared with LEACH and DSBCA, respectively. Fig. 7c illustrates network energy consumption

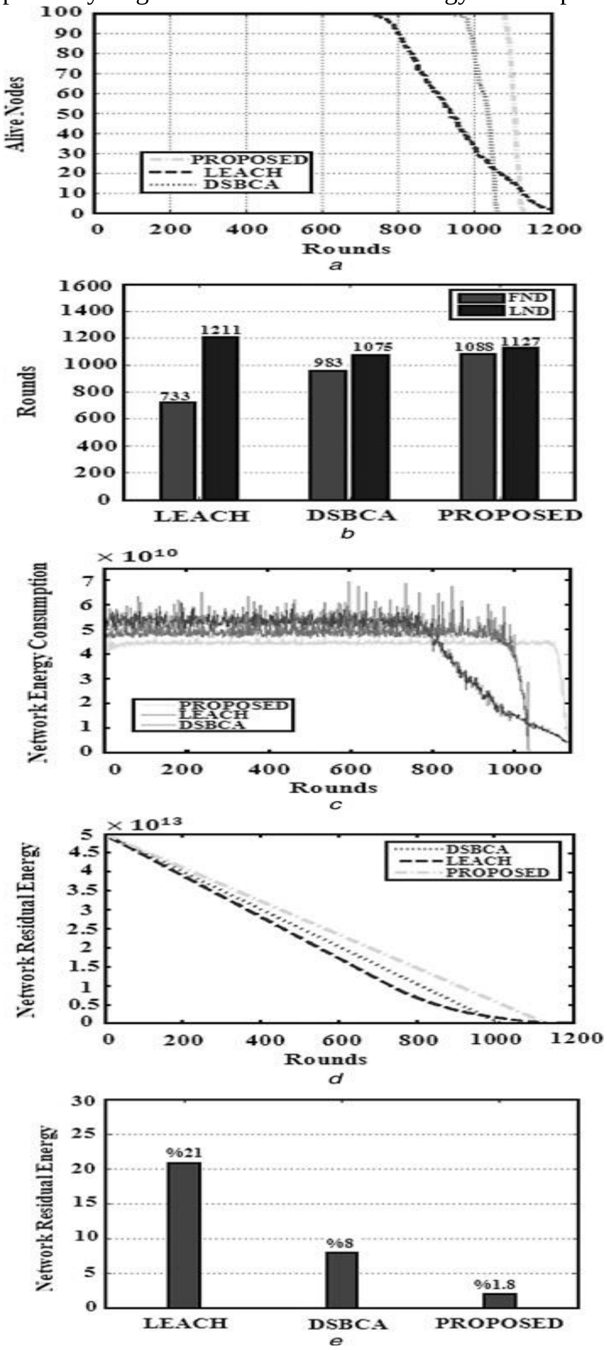


Fig. 7. Evaluating the performance of the proposed protocol in small-scale networks.

a Lifetime evaluation of protocols for scene 1

b Number of rounds against first node dead (FND) and last node dead (LND) for scene 1

c Network energy consumption in each round for scene 1

d Total remaining energy of network for scene 1

e Network residual energy against FND for scene 1

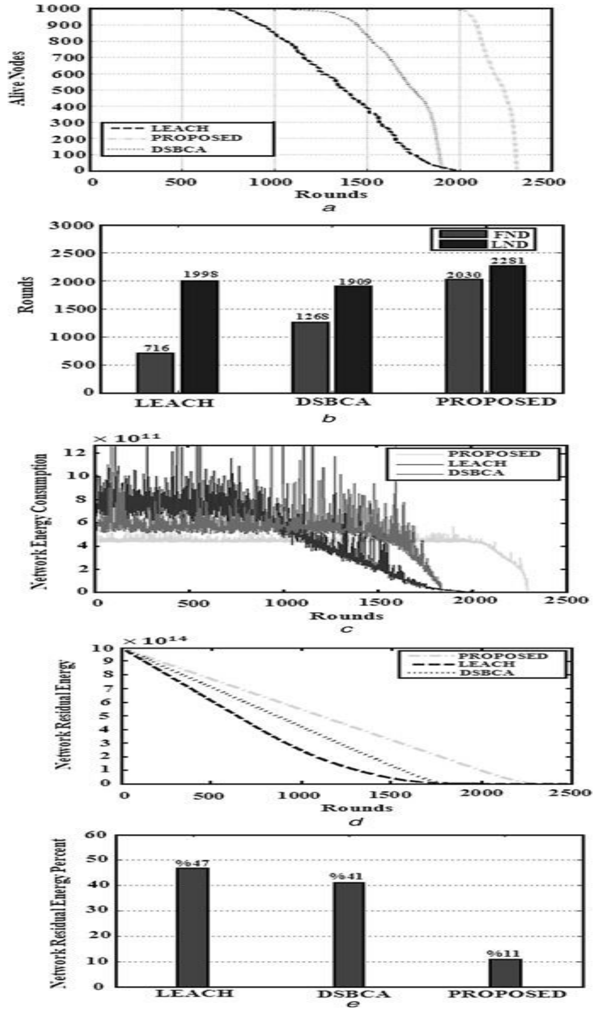


Fig. 8. Evaluating the performance of the proposed protocol in large-scale networks.

a Lifetime evaluation for scene 2

b Rounds against FND and LND for scene 2

c Network energy consumption in each round for scene 2

d Total remaining energy of network of protocols for scene 2

e Network energy residual per cent while FND for scene 2

4.3 Evaluating the proposed protocol in large-scale Networks

One of the most important characteristics of routing protocols is Scalability. Scalability is the important factor to evaluate protocols in WSN. It means they must have a structure to perform properly in every scale. In this section, the mentioned protocols are evaluated in a large-scale network in order to assess their scalability. It must be noted that sub-tree topology shows itself better in a larger scale, because in a larger scale the size of clusters is bigger and this topology in each cluster arrangement does have better structure and lead to increasing the network lifetime compared with the other clustering protocol. The simulation parameters of the proposed protocol for relay-radius, Rmin, NPVN and NCHVN are assumed to be 245 m, 30 m, 70 and 60, respectively. As can be seen in Figs. 8a and b network lifetime in LEACH, DSBCA and the proposed protocol are 716, 1268 and 2030, respectively. Therefore the proposed protocol obtains 238 and 160% improvement in comparison with LEACH and DSBCA, respectively. Furthermore, the instability period which is the time interval between the first node dead and the last node dead is improved by the proposed protocol; less values of this parameter demonstrate better distribution, network coverage and balancing after finishing the first node energy.

Obviously, the scalability of the proposed method is confirmed. Fig. 8c represents the network energy consumption in each round for all protocols. As shown, the value of suddenly changing energy and network energy consumption in the proposed protocol compared with LEACH and DSBCA is lower and this proves that the proposed protocol performs uniformly throughout the network in terms of energy consumption. Residual energy of the network at the end of each turn and residual energy percentage after first node death are depicted in Figs. 8d and e. As shown by Fig. 8d, the overall residual energy when the first node dies is called load balancing compared with LEACH and DSBCA protocols and is improved by the proposed protocol. According to Fig. 8e, residual energy percentage after first node death is 47, 41 and 11% for LEACH,DSBCA and proposed protocols, respectively. Smaller value for the proposed protocol reveals that it provides better load balancing across the network.

5. Conclusions

In this paper, a multi-layered distributed clustering protocol for Ad-hoc networking with variable clustering size and also a novel intra-cluster communication scheme has been proposed for the sake of energy efficiency. As the result demonstrated, the proposed protocol increased the network life cycle dramatically by 48 and12% in small-scale networks and 283 and 160% in the large-scale Network in comparison with LEACH and DSBCA protocols, respectively. Furthermore, the proposed protocol offers a much better distribution of the nodes resulting in significantly improved balanced energy consumption throughout the network and decreased risks of an instability period. Our results show the overall residual energy of network for the proposed protocol is 1.8% after the first node is dead, whereas it is 21 and 8% for LEACH and DSBCA, respectively, indicating improved load balancing conditions as a result of almost better distribution in CHs. These values are 11, 47, and 41% for the large-scale scenario.

6. References

1.Mainwaring, A., Culler, D., Polastre, J., Szewczyk, R., Anderson, J.: ‘Wireless sensor networks for habitat monitoring’. Proc. ACM Workshop on Wireless Sensor Networks and Applications, 2002, pp. 88–97

2.Fard, M.V., Mazinani, S.M., Hoseini, S.A.: ‘Introducing a novel fault tolerant routing protocol in wireless sensor networks using fuzzy logic’.J. Int. J. Compute. Sci. Inf. Tech., 2013, 5, (5), pp. 171–176

3.Bagci, H., Yazici, A.: ‘An energy aware fuzzy unequal clustering algorithm for wireless sensor networks’. Proc. IEEE Int. Conf. Fuzzy Syst., 2010, pp. 1–8

4.Watteyne, T., Molinaro, A., Richichi, M.G., Dohler, M.: ‘From MANET to IETF ROLL standardization: a paradigm shift in WSN routing protocols’, IEEE Commun. Surv. Tutor., 2011, 13, (4), pp. 688–707

5.Al-Karaki, J.N., Kamal, A.E.: ‘Routing techniques in wireless sensor networks: a survey’, IEEE Wirel. Commun., 2004, 11, (6), pp. 6–28

6.Heinzelman,W.B., Chandrakasan, A.P., Balakrishnan, H.: ‘An application-specific protocol architecture for wireless microsensor networks’, IEEE Trans. Wirel. Commun., 2002, 1, (4), pp. 660–670

7.Kaur, T., Baek, J.: ‘A strategic deployment and cluster-header selection for wireless sensor networks’, IEEE Trans. Consum. Electron., 2009, 55, (4), pp. 1890–1897

8.Choe, J., Xu, J.: ‘Energy balancing LEACH for wireless sensor networks’, Int. J. Intell. Inf. Process., 2012, 3, (2), pp. 56–65

9.Chen, H., Zhang, C., Zong, X., Wang, C.: ‘LEACH-G: an optimal cluster-heads selection algorithm based on LEACH’, J. Softw., 2013, 8, (10), pp. 2660–2667

10.Younis, O., Fahmy, S.: ‘HEED: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks’, IEEE Trans. Mob. Comput., 2004, 3, (4), pp. 366–379

11.Zhang, Y., Yang, L.Y., Chen, J.: ‘RFID and sensor networks’ (Auerbuch Pub, CRC Press, Boca Raton, FL, USA, 2010)

12.Tarhani, M., Kavian, Y.S., Siavoshi, S.: ‘SEECH: scalable energy efficient clustering hierarchy protocol in wireless sensor networks’, IEEE Sens. J., 2014, 14, (11), pp. 3944–3954

13.Misra, S., Woungang, I., Misra, S.C.: ‘Guide to wireless sensor networks’ (Springer, London, 2009)

14.Dahani, D.P., Singh, Y.P., Ho, C.K.: ‘Topology-controlled adaptive clustering for uniformity and increased lifetime in wireless sensor networks’, IEEE Wirel. Sens. Syst., 2012, 2, (4), pp. 318–327

15.Zairi, S., Zouari, B., Niel, E., Dumitrrescu, E.: ‘Nodes self-scheduling approach for maximise wireless sensor network lifetime based on remaining energy’, IEEE Wirel. Sens. Syst., 2012, 2, (1), pp. 52–62

16.Atzori, L., Iera, A., Morabito, G.: ‘The internet of things: a survey’, Comput. Netw., 2010, 54, (15), pp. 2787–2805

17.Rasouli, H., Kavian, Y.S., Rashvand, H.F.: ‘ADCA: adaptive duty cycle algorithm for energy efficient IEEE 802.15.4 beacon-enabled wireless sensor networks’, IEEE Sens. J., 2014, 14, (11), pp. 3893–3902

18.Lee, J.S., Cheng, W.-L.: ‘Fuzzy-logic-based clustering approach for wireless sensor networks using energy predication’, IEEE Sens. J., 2012, 12, (9), pp. 2891–2897

19.Mahani, A., Kargar, A., Kavian, Y.S., Rashvand, H.F.: ‘Non-uniform distribution of multi-hop sensor networks: performance improvement and energy hole mitigation’, IEEE Wirel. Sens. Syst., 2012, 2, (4), pp. 302–308

20.Kumar, D.: ‘Performance analysis of energy efficient clustering protocols for maximising lifetime of wireless sensor networks’, IEEE Wirel. Sens. Syst., 2014, 4, (1), pp. 9–16

21.Ye, M., Li, C., Chen, G., Wu, J.: ‘an energy efficient clustering scheme in wireless sensor networks’, Ad Hoc Sensor Netw., 2006, 3, pp. 99–119

22.Zhang, M.: ‘Energy-balanced distributed clustering algorithm in wireless sensor networks’, J. Softw. (1796217X), 2013, 8, (8), pp. 2008–2014

23.Bandyopadhyay, S., Coyle, E.J.: ‘An energy efficient hierarchical clustering algorithm for wireless sensor networks’, IEEE Comput. Commun. Soc., 2003, 3, pp. 1713–1723

24.Wei, D., Jin, Y., Vural, S., Moessner, K., Tafazolli, R.: ‘An energy-efficient clustering solution for wireless sensor networks’, IEEE Trans. Wirel. Commun., 2011, 10, (11), pp. 3973–3983

25.Akyildiz, I.F., Su, W., Sankarasubramaniam, Y., Cayirci, E.: ‘A survey on sensor networks’, IEEE Commun. Mag., 2002, 40, (8), pp. 102–114

26.Chen, G., Li, C., Ye, M., Wu, J.: ‘An unequal cluster-based routing protocol in wireless sensor networks’, Wirel. Netw., 2009, 15, (2), pp. 193–207

27.Li, C., Ye, M., Chen, G., Wu, J.: 'An energy-efficient unequal clustering mechanism for wireless sensor networks'. IEEE Int. Conf. Mobile Ad-hoc and Sensor Systems, 2005, pp. 604–611

28.Gupta, I., Riordan, D., Sampalli, S.: 'Cluster-head election using fuzzy logic for wireless sensor networks'. Proc. IEEE Communication Networks and Services Research Conf., 2005, pp. 255–260

29.Myoung Kim, J., Park, S., Han, Y., Chung, T.: 'CHEF: cluster head election mechanism using fuzzy logic in wireless sensor networks'. Proc. IEEE ICACT, 2009, vol. 1, pp. 654–659

30.Liao, Y., Qi, H., Li, W.: 'Load-balanced clustering algorithm with distributed self-organization for wireless sensor networks', IEEE Sens. J., 2013, 13, (5), pp. 1498–1506

31.AlShawi, I.S., Yan, L., Pan,W., Luo, B.: 'Lifetime enhancement in wireless sensor networks using fuzzy approach and A-star algorithm', IEEE Sens. J., 2012, 12, (10), pp. 3010–3018

32.Iyer, S.K., Manjunath, D., Sundaresan, R.: 'In-network computation in random wireless networks: a PAC approach to constant refresh rates with lower energy costs', IEEE Trans. Mob. Comput., 2011, 10, (1), pp. 146–155