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An improved SEED clustering model for wireless sensor networks

Kablosuz sensör ağları için geliştirilmiş SEED kümeleme modeli

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An Improved SEED Clustering Model for Wireless Sensor Networks

Highlights

- *This study presents a clustering method for Wireless Sensor Networks.*
- *The study interests on heterogeneous clustered topology network.*
- *The study differs from the SEED method in terms of the cluster formation and data gathering method.*
- *This study includes extensive performance simulations.*
- *The results of the simulations show the advantages of the proposed method.*

Graphical Abstract

This study presents a method of clustering the nodes distributed on the wireless sensor network according to the proposed advanced sleep-awake energy efficient distributed (SEED) method and collecting the data in the network by selected Cluster Heads (CHs) and delivering it to a certain base station (BS).

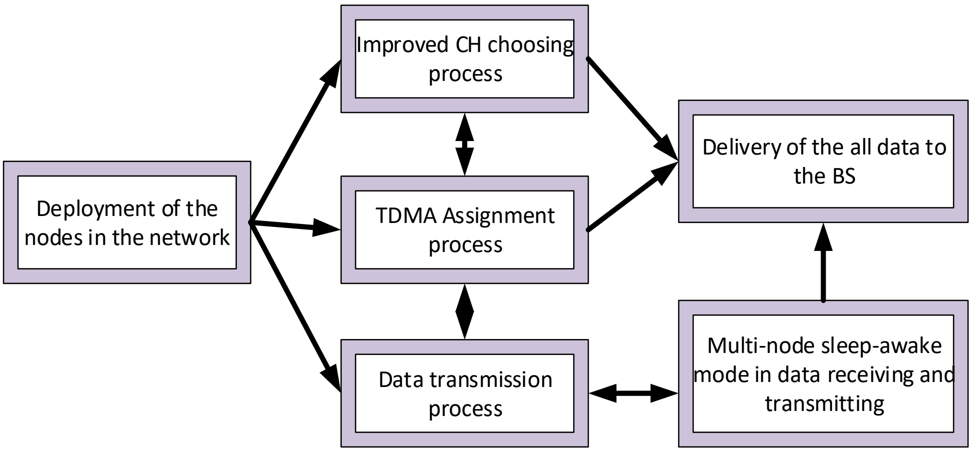

Figure. The graphical abstract of the proposed study

Aim

It is aimed to present a clustering method for Wireless Sensor Networks (EN).

Design & Methodology

The study designs a heterogeneous clustered topology network (EN).

Originality

The study differs from the SEED method in terms of the cluster formation and data gathering method (EN

Findings

With this method, energy consumption is reduced and network life is elongated by choosing the optimum CHs.

Conclusion

The results of the simulations show the advantages of the proposed method (EN).

Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

An Improved SEED Clustering Model for Wireless Sensor Networks

Araştırma Makalesi / Research Article

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ABSTRACT

It is important to develop clustering methods to collect data efficiently in wireless sensor networks (WSNs). Among the clustering methods in the literature, the most popular on behalf of balanced energy depletion and increasing the life of the network is heterogeneous clustering consisting of nodes with different characteristics. In this study, Sleep-awake Energy Efficient Distributed (SEED) clustering method that is a heterogeneous clustering, has been improved. In this sense, the mechanism of the SEED has been developed on behalf of the data sending-receiving, and energy consumption. According to the proposed method, the nodes in the WSN perceive the data in specified time periods and do not transmit and receive data by staying asleep at certain times. The most important difference of the proposed algorithm from the SEED method is that the remaining energy of the nodes and the network average energy are added to the threshold value in the cluster head (CH) selection. Moreover, cluster formation and CH selection enables more effective method than SEED algorithm by providing cluster members to communicate with CHs, and then the data transmission process is also included in the method process. Thus, energy consumption is reduced and network life is elongated by choosing the optimum CHs. The proposed method has been compared with both the SEED algorithm and other heterogeneous clustering methods existing in the literature in the simulation environment. The results of the simulations show the advantages of the recommended method.

Keywords: Wireless sensor networks, energy efficiency, data gathering, heterogeneous clusterin.

Kablosuz Sensör Ağları için Geliştirilmiş SEED Kümeleme Modeli

ÖZ

Kablosuz Sensör ağlarında (KSA) verimli bir şekilde veri toplamak için kümeleme yöntemleri geliştirmek önemlidir. Literatürdeki kümeleme yöntemleri arasında, dengeli enerji tüketimi ve ağın ömrünün uzatılması adına en popüler olanı, farklı özelliklere sahip düğümlerden oluşan heterojen kümelemedir. Bu çalışmada, heterojen bir kümeleme olan Uyku-Uyanık Enerji Verimli Dağıtılmış (Sleep-awake Energy Efficient Distributed, SEED) kümeleme yöntemi geliştirilmiştir. Bu anlamda, SEED mekanizması veri gönderme-alma ve enerji tüketimi adına geliştirilmiştir. Önerilen yönteme göre, KSA'daki düğümler verileri belirli zaman aralıklarında algılar ve belirli zamanlarda uyuyarak veri iletmez ve almaz. Önerilen algoritmanın SEED yönteminden en önemli farkı, düğümlerin kalan enerjisinin ve ağ ortalama enerjisinin, küme başı (KB) seçimindeki eşik değerine eklenmiş olmasıdır. Ayrıca, küme oluşumu ve KB seçimi, küme üyelerinin KB'lerle iletişim kurmasını sağlayarak SEED algoritmasından daha etkili bir yöntem sağlar ve daha sonra veri iletim süreci de yöntem sürecine dahil edilir. Böylece, optimum KB'ler seçilerek enerji tüketimi azaltılır ve ağ ömrü uzatılır. Önerilen yöntem hem SEED algoritması hem de simülasyon ortamında literatürde bulunan diğer heterojen kümeleme yöntemleri ile karşılaştırılmıştır. Simülasyonların sonuçları önerilen yöntemin avantajlarını göstermektedir.

Anahtar Kelimeler: Kablosuz sensör ağları, enerji verimliliği, veri toplama, heterojen kümeleme.

1. INTRODUCTION

Wireless sensor networks (WSNs) comprise of sensor nodes integrated with different physical components such as microprocessor unit, flash memory, and transmission and reception circuit. WSNs have been designed for decades for intelligence transportation systems (ITSs), military surveillance, health monitoring, smart networks, and many real applications. The sensor nodes detect the analog data and relay the data to either other nodes or deliver to collector nodes or a sink node.

The functioning of the sensor nodes with similar characteristics or in close proximity may seem necessary for energy efficient data collection in WSNs. This coordinated structure is called as clustering [1,2].

1.1. Motivation and Problem Statement

A cluster head (CH) selected by various criteria is contained in the cluster and other nodes are associated with CHs as member nodes. The member nodes send their collected environmental data to the CHs. All CHs formed in the WSN deliver the data obtained from both themselves and the member nodes to the base station (BS). The CHs that are in the coverage area of the BS deliver data to the BS directly. The other CHs transmit all data to the BS through multi-hop routes. In energy-efficient WSNs, CHs are often chosen from nodes with higher energy and the CHs follow the network path passing the multi-hopping path through the closest CHs

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[3]. WSNs consisting of nodes with different properties, and energy levels are called heterogeneous networks, and other types of the networks are called homogeneous networks. Figure 1 illustrates the heterogeneous network model as an example. In Figure 1, it is observed that there is a three-level heterogeneous network. Red nodes are most likely to be CH after gray nodes. However, the CHs close to the BS lose their energy more quickly, and they receive and transmit more packets [4,5]. That is called as the energy hole issue. Energy efficient heterogeneous clustered WSNs are designed to overcome this issue [4].

The main purpose here is to consume all the energy of the network in a fair and balanced way throughout the life of the network.

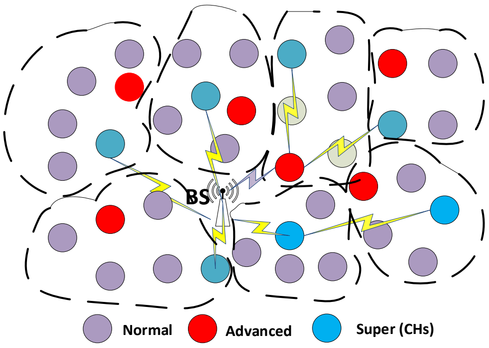


Figure 1. A sample of the heterogeneous network model.

1.2. Overview of the Proposed Methodology

In the proposed study, a method is presented to overcome the shortcomings of the sleep-awake energy efficient distributed (SEED) protocol, to improve the cluster formation during the network life and to provide more accurate data delivery. In the proposed method, unlike the SEED method, the remaining energy of the nodes and the average of the network energy are considered in the calculation of the threshold. Once the randomly selected value is less than the CH selection threshold value, the node for that round is chosen as a CH. Moreover, the energy consumed by the CHs is reduced and the network life is increased. With the proposed algorithm, multiple nodes remain awake in a cluster and possible faults in data acquisition are avoided. In this way, the total packets number transmitted to the BS increases considerably. Figure 2 represents a flow diagram of the present study.

The proposed improved SEED protocol was compared with EDEEC, CEEC and SEED on behalf of alive nodes in the network, packet delivery ratio, packets transmitted to the BS, and average number of CHs.

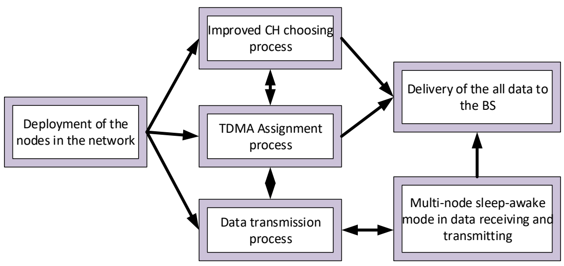


Figure 2. The flow diagram of the present study

2. RELATED WORKS

Increasing the lifetime of the WSNs and delivering the data to the target address with less loss ensures a high level of energy efficiency. Improved homogeneous clustering in the literature such as Low-Energy Adaptive Clustering Hierarchy (LEACH) [6] and Power Efficient Gathering in Sensor Information Systems (PEGASIS) [7] algorithms are available. In these algorithms, the CHs are usually randomly selected and the CH is not re-selected for each round of the network. This problem leads the network energy to be depleted rapidly and the network life to be shortened. For all these reasons, researchers have proposed many heterogeneous clustering methods. In [8], the authors proposed the Stable Election Protocol (SEP), a two-level heterogeneous clustering algorithm. This algorithm aims to rise the interval time before the first node death, which is called the stability time. The SEP is depending on the weighted selection possibilities of each node relative to the remaining energy in each node. It performs the selection of the CH according to these possibilities. In [9], Younis and Fahmy presented the Hybrid Energy-Efficient Distributed Clustering (HEED) algorithm. According to this algorithm, the CHs are periodically chosen based on a secondary parameter, such as the remaining energy of the nodes, their neighbors or the degree of the node. The HEED creates a low message load and performs fairly even CH distribution across the network. In [10], Dis-tributed Energy Efficient Clustering (DEEC) is presented to solve the challenges of multiple levels heteroge-neous networks. It increases the network stability in contrast to the SEP. The DEEC is a distributed clustering algorithm that enables the nodes to compute themselves as the CH depend on their initial energy, remaining energy, and per cluster choosing possibilities. In [11], Saini and Sharma proposed the DEEC-derived EDEEC (Enhanced DEEC) protocol for three node types to improve network life and stability. This protocol increases the energy level of the network. In [12], a method has been introduced named Central Energy Efficiency Clustering (CEEC), which is three levels of heterogeneous WSNs. In [13], a new LEACH based routing algorithm is proposed for energy saving and fair expenditure. Selecting the CHs equally from the cluster reflects that this algorithm is more efficient than the LEACH algorithm. In parallel with this study, an improved LEACH protocol derived from the LEACH algorithm is presented in [14]. In [15], an energy efficient developed algorithm with a mobile sink node is presented, and compared to mod-LEACH and PEGASIS in terms of performance. In [16], the authors proposed a bio-inspired approach cluster model for WSNs, inspired by the chemical interaction of bacteria. In [17], a new energy efficient clustering method is proposed for single-pass heterogeneous WSNs. In [18], a new routing method named sleep-awake energy balanced distributed (SEED) clustering algorithm has been proposed, and the SEED divides the network detection area into three energy fields, since the CHs communicate with the BS directly. When a randomly selected value between 0 and 1 is less than the CH selection threshold, the node for that round is chosen as a CH. SEED is a new energy efficient routing algorithm has been proposed for cluster based WSNs. Sub-clustering in SEED is performed to decrease the redundant data transmissions towards the BS. As a result, SEED model uses sleep-awake awareness to save the available power.

The rest of the article can be summarized as follows. Section 3 investigates the proposed method thoroughly. Simulation setup and parameters are given in section 4. The simulation findings and evaluations are presented in section 5. Section 6 briefly concludes and discusses the results.

3. PROPOSED METHOD

In this section, the recommended SEED based algorithm is introduced. In the network, a diverse number of clusters are formed, with distributed sensor nodes organized according to the proposed method. In order to consume energy resources less and eliminate the redundancy data, the two highest energy nodes remain awake and perceive the data in each cluster. The data obtained is transmitted to the CH. Because all sensor nodes often detect similar or identical data, the other sensor nodes in the cluster remain in sleep mode to conserve battery resources. This method has been adopted to reduce energy depletion from measurements and increase network life. The proposed method consists of setup, cluster choosing, TDMA assignment, and data transmission processes, similar to the SEED method.

3.1. Setup Process

In the setup of the WSN, each sensor node transmits the alert message to its neighbors, including $node\_ID$, application type, neighbor number, and position. In this sense, all sensor nodes record this message information in their routing tables [18].

3.2. Cluster Head Choosing Process

When the setup process finishes, each node i announces itself as a CH candidate for that round. When a determined number between 0 and 1 randomly is lower than the threshold $T(S_i)$, the node i is assigned as a CH for the current round. Note that, only one CH functions within each cluster. To ensure balanced energy depletion across all sensor nodes in the proposed method, the CHs are chosen according to the remaining and average energy. Unlike SEED method, threshold value is determined according to Equation (1) in the proposed model. The SEED method determines the desired selection probability in different possibilities for each type of node. However, with the proposed algorithm, the probability of being the CH is determined only according to the probability value p_i. $E_r(i)$ and E_{av} are the remaining energy of the node i, and the network average energy in round r, respectively. E_{av} is calculated by all nodes for each round, and all CHs are informed about this energy by message.

$$T(S_i) = \begin{cases} \frac{p_i}{1-p_i\left(mod\left(r,\frac{1}{p_i}\right)\right)} \frac{E_r(i)}{E_{av}} for\ each\ node\ i \in G \end{cases} \quad (1)$$

where G includes the sensor nodes that had not been CHs in the past rounds. The energy depleted of a cluster is calculated as given in Equation (2).

$$E_{ch} = AE_{elec}\left(\frac{N_{nml}+N_{ad}+N_{sup}}{k} - 1\right) + Ae_{amp}d^4(BS) + Ae_{fs}d^2(CH) \quad (2)$$

Because N is the total nodes number in the network, the number of normal, advanced, and super nodes in the network are N_{nml}, N_{ad} and N_{sup}, respectively. ($N = N_{nml} + N_{advcd} + N_{sup}$). A is the packet size in the network. E_{elec} refers to the energy consumption of the sensor per bit to operate the transmitter or receiver electronically; e_{fs} and e_{amp} indicate radio amplifier types for free space and multipath, respectively. The mean distance between CH and BS, and the mean distance between members of clusters are expressed as $d(BS)$ and $d(CH)$, respectively [18].

After the CH selection, for each non-cluster node, it is decided which CH to assign for this round. These nodes are named as cluster members. The energy depletion of the cluster member node in the cluster formation process is given in Equation (3).

$$E_{ch(mem)} = AE_{elec} + Ae_{fs}d^2(CH) \quad (3)$$

Therefore, the total energy consumed in the clustering process is found as in Equation (4).

$$E_{CH} = k(E_{ch} + E_{ch(mem)}\left(\frac{N_{nml}+N_{ad}+N_{sup}}{k} - 1\right)) \quad (4)$$

where, k is the number of the CHs in the network.

3.3. TDMA Assignment Process

After the cluster members join themselves with a CH, the CH assigns a Time Division Multiple Access (TDMA) slot to the members. In the assigned time period, the cluster members only communicate with the assigned CH, and transmit the data they have obtained. The energy depleted of a CH for TDMA slot assignment is given in Equation (5).

$$E_{tdma(ch)} = AE_{elec} + Ae_{fs}d^2(mem) \quad (5)$$

where $d(mem)$ refers to the distance between the members of the clusters and the CH in the assigned time period. The energy depleted of a cluster member to receive the TDMA slot is calculated as in Equation (6).

$$E_{tdma(mem)} = AE_{elec} \quad (6)$$

In the initialization process (TDMA), taking into account all clusters of the network, the total energy consumed by each CH and its members is given as in Equation (7).

$$E_{TDMA} = k(E_{tdma(ch)} + E_{tdma(mem)}\left(\frac{N_{nml}+N_{ad}+N_{sup}}{k} - 1\right)) \quad (7)$$

3.4. Data Transmission Process

The data transmission process begins after the CHs are selected, and the TDMA program is set. After TDMA slots are detected, the nodes wait for the assigned time intervals. When the time slots start, they deliver their data to the assigned CHs. The energy depleted by the cluster member node during the transmission of a data packet is calculated as in Equation (8) [18].

$$E_{dt(mem)} = AE_{elec} + e_{fs}d^2(CH) \quad (8)$$

The energy depleted by a CH to receive, collect, and send a data packet is calculated according to Equation (9).

$$E_{dt(ch)} = AE_{elec} + AE_{da} + Ae_{amp}d^4(BS) \quad (9)$$

where E_{da} is the necessary for data aggregation energy. The total energy depleted by all nodes in all clusters to transmit and receive a data packet is calculated according to Equation (10) [18].

$$E_{DT} = k(E_{dt(ch)} + E_{dt(mem)}\left(\frac{N_{nml}+N_{ad}+N_{sup}}{k} - 1\right)) \quad (10)$$

Finally, after calculating the energy depleted at each stage of a round, the energy depleted by all nodes E_{Round} is found according to Equation (11).

$$E_{Round} = E_{CH} + E_{TDMA} + E_{DT} \quad (11)$$

The pseudo code of the presented method is written in Algorithm 1. The CH selection (in the 11-19 lines), and alive and dead nodes determination (in the 8-10 lines) in the network, are given in the algorithm 1.

Algorithm 1. The proposed algorithm

1: Calculate the alive nodes of the network
2: **for** r=1:1: R
3: Calculate the E_{round} according to Equation (11) using Table 1
4: Calculate the total energy according to all types of the nodes
5: Substract the depleted energy (E_{round}) of a cluster from the total energy
6: Calculate E_{avg} and E_r at current round
7: **if** each $E_i(r)$ <=0 **then**
8: deadNode++;
9: aliveNode--;
10: **end**
11: **if** ($E_i(r) > 0$) **then**
12: **if** (node ∈ G) **then**
13. Calculate the $T(S_i)$ according to Equation (1)
14: Value← Generate a random value between (0,1)
15: **if** (Value $< T(S_i)$ **then**
16: CH^r ← node i // node i assign as a CH for round r
17: **else**
18: Cluster member^r← node i// node i assigns as a cluster member for round r
19: **end**
20: **end**
21: **end**
22:**end for**

4. SIMULATION SETUP AND PARAMETERS

In this study, the energy-efficient clustering method has been proposed by improving the SEED method for three levels of heterogeneous WSNs. The proposed method has been compared with EDEEC, CEEC, and SEED protocols. Performance analysis have been done by various simulations using MATLAB R2019a programming. While creating the WSN, 100 nodes have been deployed randomly in a 100 × 100 m^2 and 250 × 250 m^2 network area with a centered BS in the (0,0) location. From these nodes, the initial energy of normal nodes is E_0, and the coefficients a and b determine how many times the advanced and super nodes have from normal nodes, recpectively. The coefficients are set at 1.25 and 1.5, respectively. The purpose of these scenarios is to measure the impact of network size on performance. It is supposed that all of the nodes are positioned fix, and there is not any loss of energy because of distortion between the nodes signals. In all simulations, the parameters in Table 1 are used in order to ensure the condition of the simulations are the same. As an example, in the scenarios, 100 nodes and heterogeneous clustered network structure formed according to the proposed model in the 100 × 100 m^2 and 250 × 250 m^2 network area is represented in Figure 3 and 4, respectively.

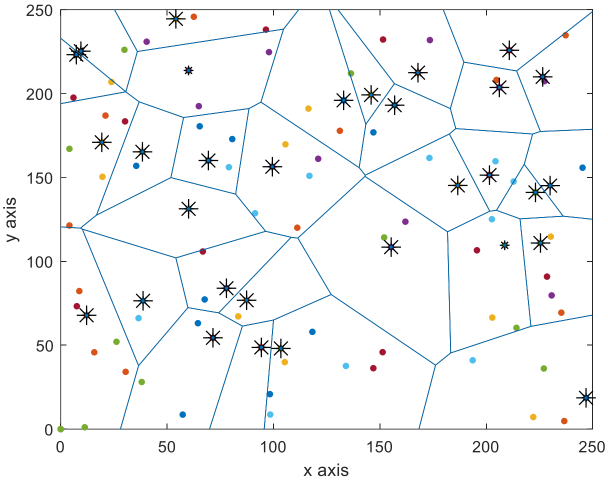
Each cluster contains a CH node, which is depicted as a star, shown in the Figure 3 (a). The CH node is generally selected from the advanced or super nodes. During the lifetime of the network, the CH node can also be selected from normal nodes. Because the energy levels of all nodes are near to one another, the energy is consumed balanced way. The other node points also represent the normal nodes. As the number of rounds increases, the energy of the nodes decrease, and are shown with different colors with Figure 3 (a) and (b).

Table 1. The parameters of the simulations.

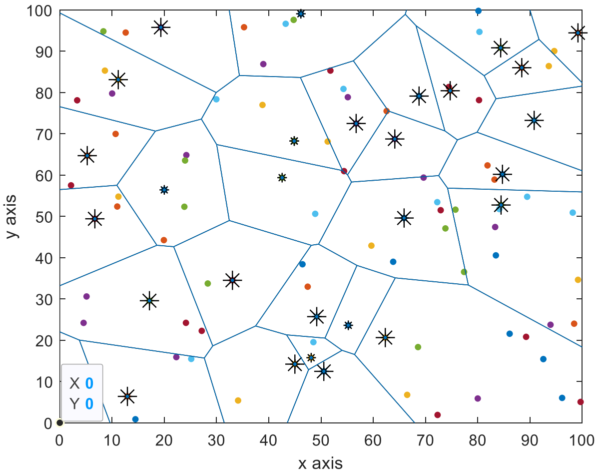
Parameters	**Symbol**	**Value**
Energy depletion of the amplifier (Short distance)	e_{fs}	10nJ/bit/m^2
Energy depletion of the amplifier (Long distance)	e_{amp}	0.0013pJ/bit/m^4
Energy depletion of the node's electronic circuit to transmit or receive the signal	E_{elec}	40nJ/bit
Data aggregation energy	E_{da}	4nJ/bit/signal
Possibility of desired CH	p_i	0.2
Number of rounds	R	5200
Data amount	A	500 (bytes)
The size of network		100*100m^2 250*250 m^2
Position of the base station		(0,0)
Total nodes number	N	100
Normal nodes number	N_{nml}	N*50/100
Advanced nodes number	N_{ad}	N*30/100
Super nodes number	N_{sup}	N*20/100
Node deployment		Random
Initial energy of the normal nodes	E_0	0.5J

5. SIMULATON RESULTS

The results of the simulations are evaluated in this section. The quality performance metrics used to simulate all methods are alive nodes in the network, packet delivery ratio, the number of packets transmitted to the BS, and the average number of CHs.



a)



b)

Figure 3. The heterogeneous network structure in the proposed model with network size: a) $100 \times 100\ m^2$ b) $250 \times 250\ m^2$.

5.1. Evaluation of the Alive Nodes in the Network

The purpose of the alive nodes metric is to measure the number of nodes that have not run out of their energy as the number of rounds increases in the network. When the nodes deplete of their energy, the number of alive nodes decreases. In this study, the effect of the alive nodes in the network has been carried out as two different simulations for the networks with a network area of $100 \times 100\ m^2$ and $250 \times 250\ m^2$. The simulation results are given in Figure 4 and 5, respectively. As observed in Figure 4, the longest network life is obtained when the proposed method is run over 5000 rounds. In other words, 100 nodes in the network completely lost their energy after 5000 rounds. The point to be known here is that the life of the network is number of rounds. In other words, the larger the number of rounds, the longer the life of the network. EDEEC, CEEC, SEED, and the proposed method, when executed, the first node die in rounds 1741, 1988, 1997 and 2475, respectively. In this sense, the proposed method has performed best among the compared algorithms. From Figure 4, compared to CEEC and SEED algorithms, although the first node died earlier, the last node measurement yielded the longest network life result, with the recommended algorithm above 4980 rounds. When the simulation results in Figure 4 and 5 are compared, it is understood that the network life reduces when the network size increases. Table 2 and 3 present the comparison results of the algorithms on behalf of the network life performance, with network size of 100x100m² and 250x250m², respectively.

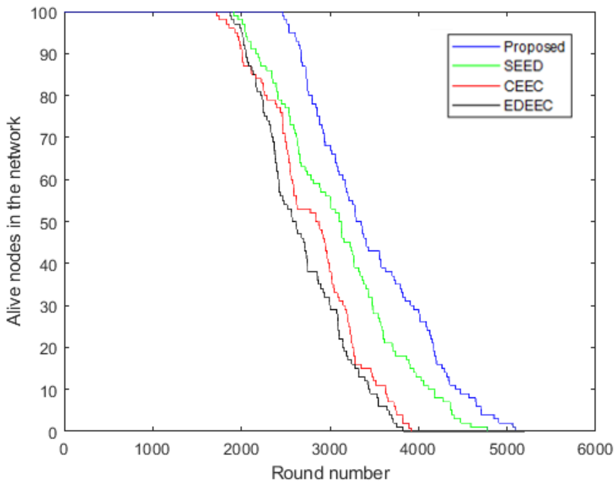


Figure 4. The number of alive nodes in the network with network size $100\text{x}100m^2$.

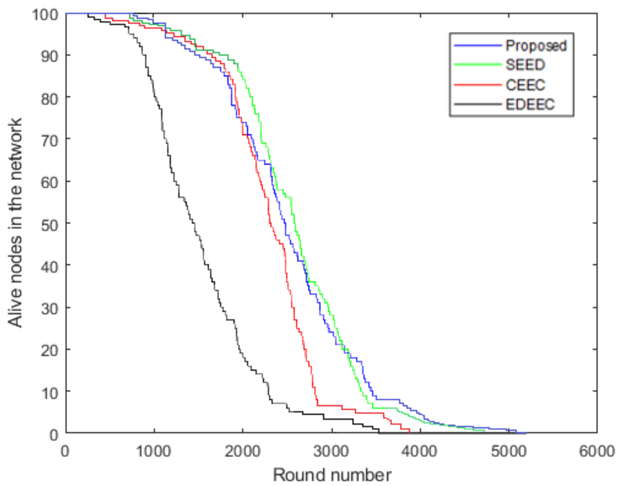


Figure 5. The number of alive nodes in the network with network size $250\text{x}250m^2$.

5.2. Evaluation of the Packet Delivery Ratio (PDR)

We define the packet delivery ratio (PDR) term as the ratio of the number of data packets transmitted over the network to the number of data packets generated. This ratio is a measure of how much of the generated data is delivered. The proposed algorithm by the PDR metric for nodes ranging from 100 to 500 is subjected to performance criterion by other algorithms. Figure 6 shows the PDR of the algorithms according to the number of nodes with network size of $100 \times 100\ m^2$. As seen in Figure 6, as the number of nodes increases due to packet collision and traffic intensity, the PDR reduces in all of the algorithms. However, with the proposed algorithm, a PDR of almost 99.85% is obtained in the network having 100-nodes. However, the other algorithms that are EDEEC, CEEC and SEED give the highest PDR, respectively. Expecially, EDEEC gave a PDR of less than 87% in the network having 500-nodes. However, in the proposed algorithm, due to the improvement of the SEED, the data packets are delivered to the destination accurately. Therefore, the proposed methodology yields the best PDR among all algorithms. Figure 7 shows the PDR of the algorithms according to the number of nodes with network size of $250 \times 250\ m^2$. Comparing Figure 6 and Figure 7, it should be noted that when the network size increases, the data delivery decreases as the distance between nodes increases.

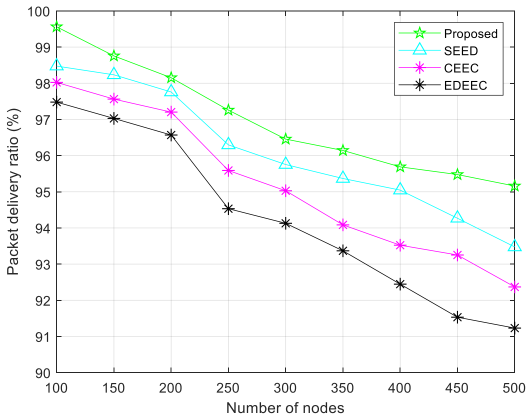


Figure 6. The packet delivery ratio (PDR) versus number of nodes with network size 100x100m^2.

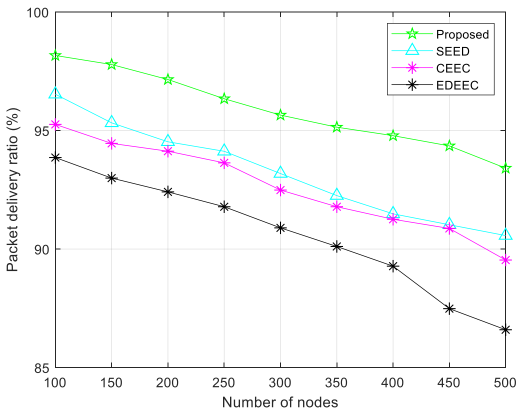


Figure 7. The packet delivery ratio (PDR) versus number of nodes with network size 250x250m^2.

5.3. Evaluation of the Number of Packets Transmitted to the BS

The total number of packets transmitted to the BS is taken into account with this performance metric. Figure 8 and 9 represent the total number of packets transmitted to the BS by number of rounds. As seen in Figure 8, when the proposed method, SEED, CEEC and EDEEC methods are executed, the number of packets transmitted to the BS is approximately 18x10^4, 7.8x10^4, 4.3x10^4 and 2.5 x10^4, respectively. In this sense, the best packet delivery has provided by the proposed method. As can be understood from Figure 9, when the proposed method, SEED, CEEC and EDEEC methods are run, the number of packets transmitted to the BS is approximately 12.3x10^4, 6.3x10^4, 3.8x10^4 and 2.3 x10^4, respectively. Comparing Figure 8 and 9, packet delivery decreases for all protocols as the network size increases.

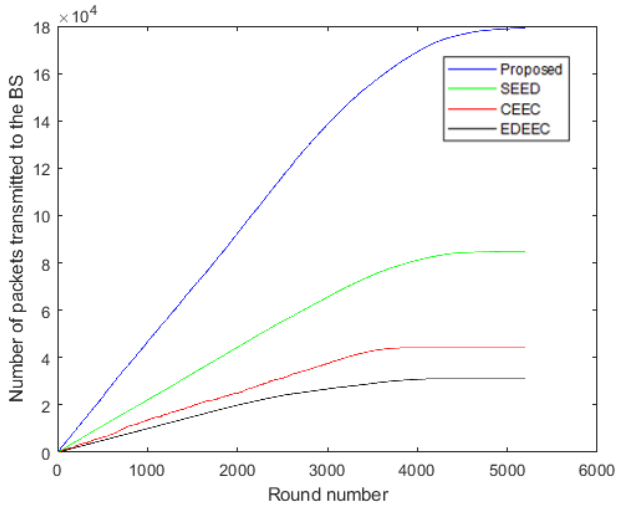


Figure 8. The number of packets transmitted to the BS with network size 100x100m^2.

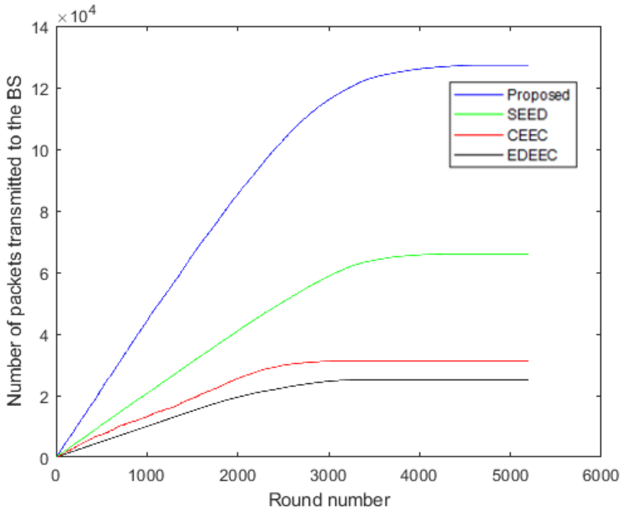


Figure 9. The number of packets transmitted to the BS with network size 250x250m^2.

5.4. Evaluation of the Average Number of the CHs

It is aimed to measure the average number of CHs with this performance metric. In this study, based on the average number of CHs, since 10 simulations are performed for each scenario, Figure 10 and 11 represent the average CHs number by rounds number. From Figure 10, it is clear that the number of CHs ranges from about 18 to 20 until 2500 rounds. In other words, in the network with a network size of 100 × 100 m^2 , the network with the highest CHs number and the network life for the longest rounds is formed by the proposed method. From Figure 11, it is clear that the number of CHs ranges from 16 to 18 until 2000 rounds. In other words, in the network with a network size of 250 × 250 m^2, the network with the highest CHs number, and the network life for the longest rounds is formed by the proposed method. However, when comparing Figure 10 and 11, the average size of CHs decreases for all methods as the network size increases. It should be noted that when the number of CHs in the network decreases, the data loss decreases as the distance between nodes increases.

Table 2. The comparison results of the methods (100x100m^2).

Algorithms	The round where the first node died	The round where the all nodes died
EDEEC	1741	3945
CEEC	1988	3961
SEED	1997	4831
Proposed	2475	5072

Table 3. The comparison results of the methods (250x250m^2).

Algorithms	The round where the first node died	The round where the all nodes died
EDEEC	237	3512
CEEC	434	3946
SEED	757	4803
Proposed	771	5102

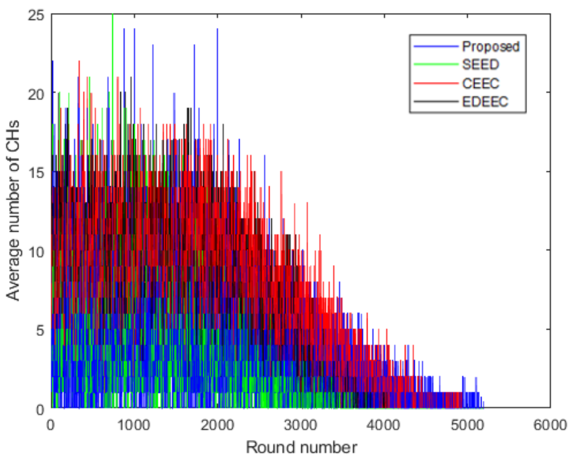


Figure 10. The average number of CHs with network size 100x100m^2.

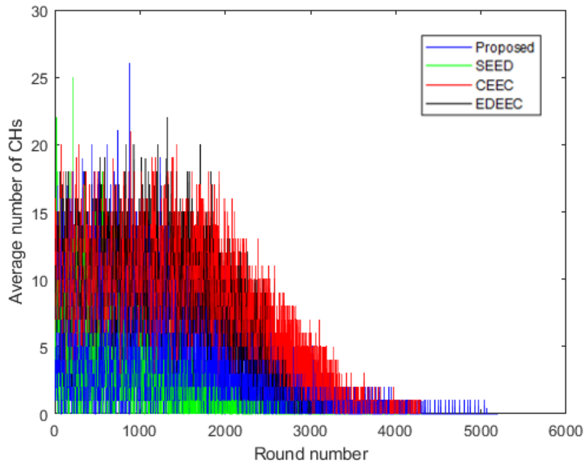


Figure 11. The average number of CHs with network size 250x250m^2.

6. CONCLUSION

In this study, the SEED protocol, a heterogeneous clustering algorithm for WSNs, has been improved. The proposed method differs from the SEED protocol in terms of network distribution structure, CH select ion, and the number of nodes remaining in sleep-awake mode within the cluster. In the present algorithm, the optimum number of CHs is formed by selecting the adaptive CHs in the network. In the network model of the proposed algorithm, unlike the SEED method, there are different number of nodes in each cluster with different energy levels, and the nodes waiting for data acquisition are selected from high energy nodes. In this way, since the energy depleted by the CH and member nodes for data transmission and reception decreases, the network life and the total packets number transmitted to the BS increase. It is understood from the results of the simulations that the present algorithm is better than not only the SEED algorithm but also the existing EDEEC and CEEC algorithms. However, due to the fact that CHs spend more time transmitting their acquired data to the BS, multi-hop route trail becomes difficult, we will try to develop methods that mobile nodes can collect data by traveling around the CHs, in future.

DECLARATION OF ETHICAL STANDARDS

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AUTHORS' CONTRIBUTIONS

Sercan YALÇIN: Performed the experiments and analyzed the results.

Ebubekir ERDEM: Wrote the manuscript.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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