Wireless Personal Communications (2022) 122:2235–2251
https://doi.org/10.1007/s11277-021-08990-3

A New Energy-Aware Cluster Head Selection Algorithm for Wireless Sensor Networks

Muhammed Tay[1] · Arafat Senturk[2]

Accepted: 8 August 2021 / Published online: 28 August 2021

Abstract
Wireless Sensor Networks (WSN) always need energy due to the areas they are used. The use of sensors is quite wide, and in some of the places, it is very difficult or impossible to restore the energy of the sensors such as in war areas or in wildlife. Therefore, they need to use their existing energy most efficiently. For WSN, the role of clustering is crucial in terms of using less energy. Selecting the most appropriate sensor node as cluster head (CH) according to the criteria determined within the clustered sensors reduces the energy consumption. In this study, a new clustering algorithm is proposed for WSNs to reduce energy consumption and thus prolong the life of the WSNs. The Cluster Centered Cluster Head Selection Algorithm (C3HA), which is developed in line with this objective, gives a new perspective to the selection of CH while creating a more efficient WSN than the popular clustering algorithms LEACH, and PEGASIS. This developed algorithm is compared with popular algorithms and proved to be more efficient in terms of fast and accurate CH selection.

Keywords Wireless sensor networks · Clustering · Energy efficiency · Cluster head

1 Introduction

Wireless Sensor Networks (WSN) consist of nodes with a small size, limited battery life, limited communication distance, and working area [1, 2]. Most of the energy in sensors is consumed while collecting data from the environment. Efficient use of energy is important for sensors where data communication is made much more than normal sensors. Some protocols and algorithms have been developed to regulate the consumed energy within the framework of certain criteria [3, 4].

WSNs have a wide range of uses that allow thousands of sensor nodes appear in the same network. The sensors must use their energies efficiently under some conditions such

✉ Arafat Senturk
arafatsenturk@duzce.edu.tr

Muhammed Tay
muhammettay@duzce.edu.tr

1 Science Institute, Duzce University, Duzce, Turkey

2 Deparment of Computer Engineering, Engineering Faculty, Duzce University, Duzce, Turkey

as the impossibility of energy renewal or its difficulty [5]. From this perspective, the clustering of sensors plays an important role in reducing energy consumption [6]. This important role of clustering in reducing energy consumption is based on choosing the correct cluster head (CH). CH selection is the most important factor of clustering and it contributes positively to energy saving depending on the distance of packets sent. Besides, the problem that can occur in any cluster should not affect the entire network, making it possible to use the network more effectively [7]. In the literature, cluster-based protocols are classified as homogeneous and heterogeneous. In a homogeneous network, all network elements have the same characteristics (storage, data processing, battery life, detection, and communication). On the other hand, heterogeneous network elements may have different characteristics like battery capacity [8–10].

In clustered WSNs, the base station (sink) and the CH must be placed in the correct location for a proper communication [8]. Positional differences facilitate an extended network lifetime and data transfer on the network in an efficient way. Determining the proper positions of the sensors in the network is still an up-to-date topic and has paved the way for the development of many algorithms in the literature. In general, these studies focus on optimization techniques ([5, 12, 13]). According to these studies' CH selected randomly and CHs can be near to each other. Because of this issue the energy consumption increases. In these clustering algorithms selected CH can be far away from the cluster. If that happens the energy consumption of the CH will increase. On the other hand, for chain-based clustering data collision can reduce the efficiency of the network.

In this study, an energy-efficient CH selection method was proposed. An algorithm is proposed for homogeneous networks. To reduce energy consumption, we select sensors near to the cluster center first with a mean distance threshold. The proposed CH selection algorithm uses energy-efficient clustering methods. The algorithm was compared in terms of lifecycle and the efficiency of the proposed algorithm was proved. The developed algorithm aims to reduce the energy consumption in WSNs through determining the CHs accurately to consume less energy during data transfer. The idea behind the algorithm can be implemented to these algorithms and it will reduce the energy consumption.

The contributions of C3HA, which aims to reduce the amount of energy consumed in WSNs and decides on the selection of the most appropriate cluster head, are as follows:

- A new and energy-efficient clustering algorithm was proposed.
- The proposed algorithm causes less energy consumption when compared to LEACH and PEGASIS.
- The algorithm does not require advanced sensor nodes for communication. All the nodes in the simulations are ordinary sensors.
- Since the method selects CH near to the center of the clusters, the energy expenditures during packet transfer from nodes to BS were minimized.
- The developed C3HA is double times more efficient than popular algorithms in terms of the number of packets sent.
- In the simulations performed, with the 0.5 joule initial energy for each node, the lifecycle of the wireless network was approximately 400 rounds higher than the closest algorithm (RaCH), and also it is the best in terms of FND (First Node Death) and HND (Half Node Death).

The reminder of the paper is organized as follow. Section 2 define the problem. Section 3 discusses the related works. Section 4 presents the energy and network model used to evaluate our proposed work presented. In Sect. 5 The proposed alg. is presented. The simulation results as well as a performance evaluation are discussed in Sect. 6 Finally, the paper is concluded in Sect. 7 with recommendations.

2 Problem Definition

WSNs are required to transmit the data they have received from the environment to the recipient via Sink. When the energy consumption of the sensors is taken into consideration, it is seen that they spend the most energy during data transfer. The energy consumption in the data transfer is directly related to the distance between the sender and receiver and the size of the data [10].

In the clustering, the sensors are generally divided into two categories as normal sensors and cluster head sensors. Normal sensors need to send the data to their CH while CH must send it to the sink or to the next CH. Determination of the CHs plays an important role in data transfer and this issue has enabled the development of many algorithms in the literature. These algorithms will be discussed in the rest of the study.

The location information of each sensor is very important for the clustering of WSNs. Let's assume that $S = a_1, a_2, \dots a_n$ is a set of sensors placed randomly on the surface area and the sensors (including CHs) are constant. Clustering algorithms need to decide which of these sensors should be included in which cluster and which sensor will be CH in which cluster. CHs collect data from NS (normal sensors) within the cluster, so they consume more energy than NS. To overcome this problem, determination of CHs correctly and changing CH according to certain statistical calculations are vital.

Considering the position of CH in the cluster, the proposed method is based on the idea that CH must be located near to the center of the cluster. So, NS send the data to a shorter distance and thus contribute to energy saving. To solve the CH problem, each cluster is divided into two separate clusters. These two clusters are defined as Cluster Centered (CC) and Out of Cluster Center (OCC). The selections of CC and OCC are explained in detail in Sect. 5.

3 Related Work

Clustering, which is an important issue to reduce the energy consumption of WSNs, has been examined in the literature under three algorithms as homogeneous, heterogeneous, and chain rule. In this section, we briefly explained the most popular algorithms.

One of the most striking of these studies is the LEACH (Low Energy Adaptive Clustering Hierarchy) protocol developed by Heinzelman et al. [13]. This algorithm has a homogeneous network structure. The LEACH protocol is based on the principle of clustered sensors and the presence of a CH in each cluster. CH selection is based on a statistical calculation as given by Heinzelman et al. [13]:

$$T_n = \begin{cases} \frac{p}{1 - p \times (r \bmod \frac{1}{p})} & \textit{if } n \epsilon G, \\ 0 & \textit{otherwise} \end{cases} \tag{1}$$

According to formula 1, the probability that p is CH, r is the current loop, and G is the set of non-CH sensors with the probability 1/p.

The LEACH-C [14] (LEACH-Centralized) protocol, which was developed based on the LEACH protocol, is superior to the LEACH protocol in terms of cluster and sensor selection. The LEACH-C protocol allows the selection of two-layer CH. In this way, the use of a central control algorithm is effective in creating a better clustering and unnecessary energy usage is prevented. Within the context of LEACH-C protocol, all nodes in a clustered sensor network send their current position and amount of energy to sink and this data is used for the determination of a threshold. Sensors with a value lower than this threshold cannot be selected as CH. The identification number (ID)s of the CHs that are determined by the central control algorithm are sent to all sensors and the IDs of the sensors that match with the sent ID become CH, the other sensors go into sleep mode within Time Division Multiple Access (TDMA) [14, 15].

The Mod-LEACH [16] distinguishes two level of power amplification depending on intra-cluster or inter-clusters transmission. It minimizes the energy transmission for the inter-clusters and CH to sink transmissions. But the CH selection mechanism does not consider the case if the CH is near to each other.

The EECPK-means [17] used K-Means algorithm to identify clusters and used for homogeneous networks. According to this algorithm, threshold value is determined for CH selection. For every round, if the value of a node is greater than that threshold, then this node can be CH. While the FND (First Node Death) is high in this algorithm, the network lifetime is decreased.

Ngangbam [18] developed a new algorithm to increase the lifetime based on LEACH algorithm. To reduce the energy consumption, the author proposed CH selection criteria based on the distance to BS.

The RaCH [19] algorithm was proposed for homogeneous WSN. For CH selection the virtual circular areas were identified. The circles start from BS and goes to the end of the network. The region is divided into quarters. The distance between BS and the circles plays an important role to identify quarters. In each quarter, the CH is selected according to some computation.

There are also algorithms related to chain rule approach. PEGASIS (Power-Efficient Gathering Sensor Information System), H-PEGASIS and Multi Chain PEGASIS algorithms are popular algorithms in this topic.

The PEGASIS [20] protocol is different from other protocols since it is index-based. This difference is because of chain rule method. Thanks to the developed algorithm, all sensors in the network connection to each other and communicate with Sink over this connection. A route is determined by identifying the nearest neighbor of all sensors in the network. It has proved to be more efficient compared to LEACH [20]. Requests from the other nodes to the LN (Leading Node) are forwarded to sink. Using PEGASIS in a network of multiple sensors will result in delays in data transfer. In this respect, some additional arrangements have been made to avoid delay. Using multiple LAs in the network is one of them. Networks with multiple chains and multiple LNs instead of a single chain network have somewhat reduced latency [21, 22].

H-PEGASIS [21], protocol has been developed to prevent delays in the PEGASIS protocol [23, 24]. In this protocol, simultaneous data transfer is proposed to avoid data collision. To avoid data collision and possible signal interference, CDMA signal coding and spatially separated sensors are offered [24]. A chain-based sensor using CDMA acts as a tree structure and reaches the sink starting from the data layers to be transmitted. Thanks to this structure, data is transmitted simultaneously while latency is reduced [23].

According to the RaCH algorithm proposed by Kardi and Zagrouba [19] the chain creation starts from the farthest node and goes through sensor nodes placed randomly in the field for forming multiple clusters. Each sensor finds the nearest node, not included in the chain and connects with it. Hence each node act as parent for the next node in the chain and as child for the previous one so that sensors communicate with its close neighbors and only one node is selected as chain leader used to transmit packets to the sink. Chain chooses the primary chain leader based on a weight Q assigned to each sensor.

The Gateway-Based Energy-Aware Multi-hop Routing Protocol (M-GEAR) is different from the other algorithms. It uses a special rechargeable node, called gateway node, placed at the center of the sensing area and used to collect and aggregate data from CHs and close nodes, and send them to the BS in order to ensure an energy efficient routing [25]. But to implement the algorithm the gateway node was added but in some cases, it is hard to replace the gateway node if its died. And it also needs extra cost.

To reduce energy consumption, we proposed the C3HA algorithm that is explained in detail in Sect. 5. According to the algorithm for each round, we select CHs in some locations near to the center of the cluster. That selection reduces energy thanks to the distance between CHs and sensors. One of the differences of our method and the existing studies is that for each round we select the best CH which is located at the center of each subclass. Besides, our approach uses simple sensors, not multi-functional devices, and provides a cheap and easy implementation.

4 Energy and Network Model

4.1 Energy Model

In data communication to estimate the energy consumption, we have free space propagation model in communication. There are two calculations for energy consumption based on the distance. Threshold distance is calculated by the formula given in Eq. (2). $'E'_{mp}$ refers to the energy expense in multipath propagation and it is equal to 10×10^{-12} $'E'_{fs}$ refers to free space energy component and equals to 0.0013×10^{-12}. Therefore, the threshold value for the distance is about $\cong 87.7$ [6]. If the distance is less than the threshold, then Eq. (3) is used for the calculation of energy consumption. Otherwise, multipath propagation model (Multipath fading) will be used as given in Eq. (4).

To calculate energy expenses in data communication, we are using some of the energy attributes used by Purkar and Deshpande [6]. $'E'_{elec}$ refers to the energy component of radio electronics and $'E'_{DA}$ is the data aggregation energy required by radio electronics in communication circuit.

The $'d'_0$ is threshold distance,

$$d_0 = \sqrt{\frac{E_{fs}}{E_{mp}}} \tag{2}$$

Energy consumption with free space communicating model, is calculated as,

$$E_{TX}(L, d) = L.E_{elec} + L.E_{fs}.d^2;\ if \quad d \le d_0 \tag{3}$$

where $'E'_{TX}$ Energy expenses in sending data packet of length L. With multipath propagating mechanism, energy expense is calculated as,

$$E_{TX}(L,d) = L.E_{elec} + L.E_{fs}.d^4; if \quad d > d_0 \tag{4}$$

For receiving the data packets, $'E'_{RX}$ refers to the energy expenses at receiving terminal.

$$E_{RX}(L,d) = L.E_{elec} + L.E_{DA} \tag{5}$$

4.2 Network Model

This section presents the details of the proposed algorithm based on certain assumptions. Our assumptions are;

- Wireless sensor nodes are deployed randomly in a square area.
- The position of sink (BS) is changed in every simulation.
- Placed sensors are insensitive to location, able to sense and aggregate the data.
- Sensors have same energy in the field.
- Sensors always have data to transfer, and they are firstly clustered according to the k-means algorithm.
- Each cluster is divided into two clusters which is explained in Sect. 5.

The model has the following features:

- A stationary Sink
- Random distribution of nodes
- Wireless communication medium
- Static position of nodes
- CH probability is set to p = 0.1
- The depletion of the battery leads to the death of the sensor

To build the model, the Matlab programming environment has been exploited. The location of the stationary BS was defined at the center or any other position of the area and the position of the BS did not change until the end of the simulation. The nodes in the area are randomly distributed and the location of the nodes stored by the BS. the number of CHs was determined as 10% of the number of all nodes. That is, if 100 nodes exist in the area, then there will be 10 CHs. In the simulation, if node energy depletes, then that node dies, and it is removed from the simulation.

5 Proposed Cluster Centered–Cluster Head Selection Algorithm (C3HA)

The C3HA was proposed as a new clustering method for WSNs. C3HA was designed for clustered sensors. K-means algorithm was exploited to determine the clusters of the network. The proposed C3HA is a new CH selection (CHS) algorithm developed to extend the network lifetime and to use their energy more efficiently. This algorithm, unlike the algorithms in the literature, requires two-fold clustering. That is, first the network is clustered based on k-means, and then a special subset of the nodes in a cluster is determined for each cluster. This special subset is called as CC (Cluster Centered) and the nodes in CC have a priority during CH selection. The set of nodes out of CC, i.e. the complement of CC is called as OCC (Out of Cluster Centered) and the nodes in this set can only be CH once all the nodes in CC are dead. The details of the determination process of CC and OCC will be explained below.

With the new approach introduced by C3HA, the efficiency of CH selection will be improved by increasing the importance of the central nodes.

Let us mathematically explain the proposed method. First let us define the notations to better explain the below equations:

k: number of clusters

C_k: Center of the kth cluster

(x_c^k, y_c^k): Location of the center of the kth cluster

(x_i^k, y_i^k): Location of the ith sensor of the kth cluster

n_k: total number of sensors in kth cluster

d_i^k: distance between the ith node of cluster k and the kth cluster center

r_k: mean distance to kth cluster center, which is the radius for CC_k

CC_k : Cluster-centered nodes for the kth cluster

OCC_k: Out of Cluster-centered nodes for the kth cluster

U_k: kth universal set that is equal to kth cluster defined by K-Means

Now we can define the calculations:

$$C_k = \frac{1}{n_i} \sum_{j=1}^{n_i} x_i \tag{6}$$

$$d_i^k = \sqrt{(x_i^k - x_c^k)^2 + y_i^k - y_c^k)^2}. \tag{7}$$

$$r_k = \frac{1}{n} \sum_{i=1}^{n_k} d_i \tag{8}$$

$$CC_k = (x_i, y_i) \ \in \cup_k | \ d_i \leq r_k \tag{9}$$

$$OCC_k = CC_k' = (x_i, y_i) \ \in \cup_k | \ (x_i, y_i) \notin CC_k \tag{10}$$

The CC boundary is a circular area with radius r_k that is equal to the average Euclidean distance of all the sensors to the kth cluster center as given in Eq. (9). OCC_k is the complement of the set CC_k. It includes the set of sensors of the kth cluster not in CC_k as given in Eq. (10).

5.1 Simulation Setup

In the simulations, we established clusters with the probability of 0.1 which means that the number of clusters will be 10% of the number of nodes. For a network with 100 nodes, there will be 10 clusters. Although, for simplicity we assumed the probability as 0.05, which means there will be 5 clusters in the figures of this paper. Randomly distributed 100 nodes (in Fig. 1a) [13, 26, 27] were clustered into five clusters according to the probability of $p = 0.05$ by K-Means algorithm which determines the center of each cluster as shown in Fig. 1b. After that the mean distance (r_k) of each cluster was determined Fig. 1c, d the CC and OCC clusters were identified.

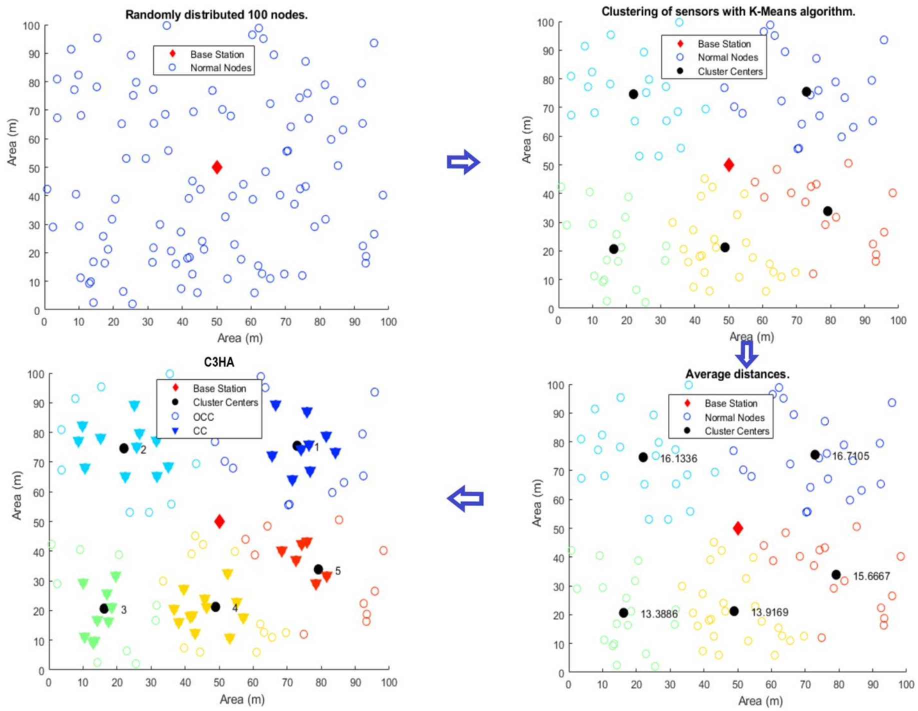

Fig. 1 Workflow of C3HA. **a** Random distributed 100 nodes in area of surface, **b** Distribution of 5 cluster after the K-means algorithm is implemented and the number of clusters determined by probability "p", **c** The mean Distance of 5 clusters according to the center of each clusters, **d** After C3HA, the distribution of Cluster Center and Out of Cluster Center

After identifying the sensors in CC and OCC for each cluster, the priority is given to the sensors to being CH in the central cluster. CH is selected from the set of sensors in CC until all the nodes die in this set. Once all the nodes in CC dies, then CH is selected among the nodes in OCC. The reason of giving priority to the sensors in the central cluster is to reduce total energy consumption through sending sensed data to a receiver in a shorter distance. With this method, it is ensured that the CH which takes packets from the sensors will be near to the cluster center and it is estimated that the energy consumed by the sensors depending on the distance can be reduced (Fig. 2).

6 Performance Analysis

The most important performance criterion in WSNs is energy consumption. WSNs require energy and bandwidth to transmit data. In the energy consumption calculation, the number of packets sent, the distance between the nodes and the number of clusters are the effective factors [13, 26, 27].

The analysis and comparison of the performance of the C3HA was performed in setup and steady stages. According to the stages the CH selected and all nodes in each cluster

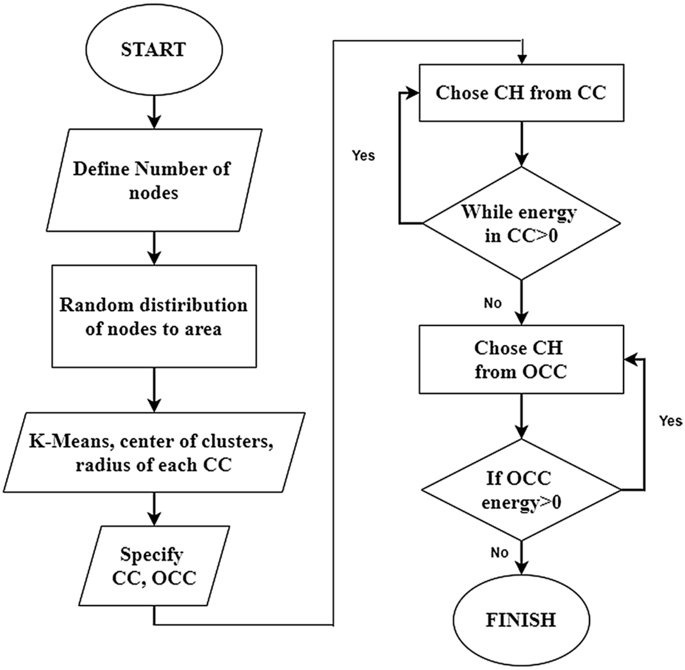

Fig. 2 Flow diagram of proposed algorithm

send their data after that in steady stage CHs send data to the BS. All sensors in the field were kept equal (homogeneous).

The performance of the C3HA proposed in this study was evaluated in terms of the following criteria [6, 28];

- The number of life cycles: In the simulations performed, the life cycle number is based on determining the number of surviving sensors after each data transmission. The variables used for comparison are the number of sensors.
- Energy consumption: In the simulations performed, energy consumption was evaluated according to three variables. These variables are the distance between the sensors, the number of sensors and the number of clusters.
- The number of packets sent: In the simulations performed, the number of packets sent to sink depends on two variables: intra-cluster data transmission and inter-cluster data transmission. To determine the number of packets, the packet size was determined as 4000 bits per cycle for each transmission.

The performance evaluation environment consists of a wireless network with the homogenous nodes. A random placement model is used for the placement of the sensor nodes. In most of the studies in the literature, the sensors are placed randomly [16, 17]. Therefore, to make the comparison properly, we placed the sensors randomly.

In the literature, for the duration of the simulation, all the sensors continue data transmission until their energies are decreased to a level that is not enough for transmitting the data. The total number of sensors used in the simulation varies from 100 to 400. All sensors used in the comparison have equal initial energy.

Table 1 Environment parameters for the simulations sim1, sim2 [6, 26]

Definition	Symbol	Sim1	Sim2
Network size	MXM	100X100	400X400
Node number	N	100	400
Initial energy of normal nodes	E_0	1 J	0.5 J
Initial energy of advanced nodes	p_{Adv}	0	0
Probability	P	0.1	0.1
Packet size	K	4000 bit	4000 bit
Number of CH	No	P*n	P*n
Sink position	(Sink, Sink)	(50, 50)	(400, 200)
Energy spent on transmission and reception for each bit	E_{elec}	50 nJ/bit	50 nJ/bit
Cost of trans. amp./short distance	E_{fs}	$10nJ/bit/m^2$	$10nJ/bit/m^2$
Cost of trans. amp./long distance	E_{amp}	$0.0013pJ/bit/m^4$	$0.0013pJ/bit/m^4$
Data aggregation energy	E_{DA}	5 nJ/bit/Signal	5 nJ/bit/Signal
Threshold distance	d_0	87.7 m	87.7 m

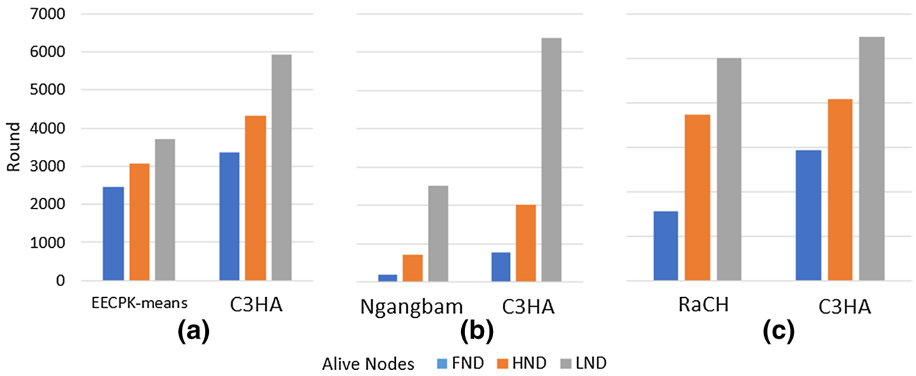

Fig. 3 Comparison of C3HA and the latest CH selection algorithms EEPK-means (**a**), Ngangbam's (**b**) and RaCH (**c**). C3HA algorithm simulated based on parameters of each algorithm

C3HA was simulated according to the parameters shown in Table 1 in a WSN with normal sensors. According to Fig. 3, FND, HND (Half Node Dead), and LND (Last Node Dead) values of the existing CH selection methods are shown. So the first three graphics give the result of the proposed algorithm vs the latest algorithms: EECPK-means, RaCH, and Ngangbam et al.'s [17–19].

From Figs. 4, 5, 6, 7, 8, 9, 10 and 11 show the results of simulation according to the Table 1. As a result of the comparison, it is seen that the life cycle or the number of surviving sensors of the proposed algorithm is higher than the other algorithms. CC-CHA is 14,68% more efficient than other algorithms on the average.

The amount of packet sent to Sink is important for network performance. Figures 7 and 11 shows that the proposed algorithm sends double times packets in this comparison based on the network life of the LEACH and PEGASIS algorithms.

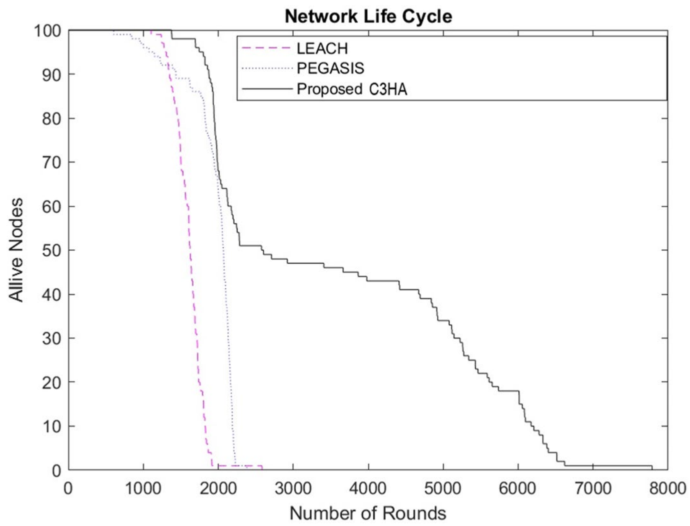

Fig. 4 Alive nodes vs rounds according to the sim1

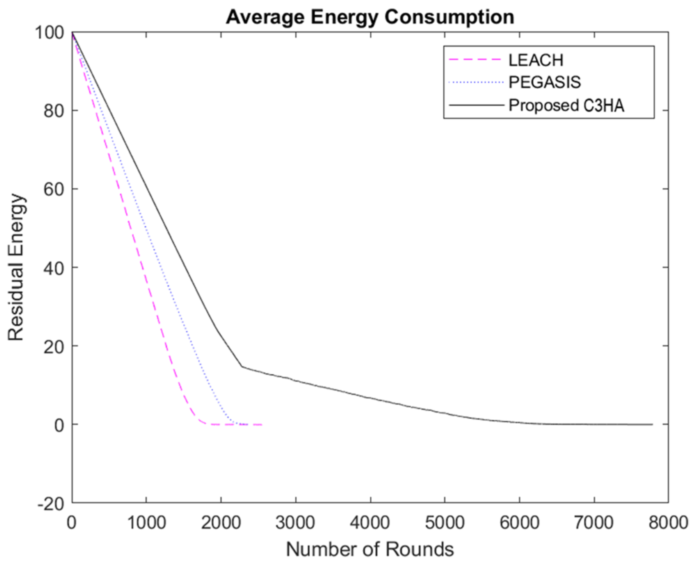

Fig. 5 Residual energy vs rounds according to the sim1

CC-CHA is compared with the popular algorithms LEACH and PEGASIS, and also the latest algorithms EECPK-means, RaCH and Ngangbam et al.'s [17–19]. The results show that the proposed algorithm is more efficient in terms of the consumed energy.

Figure 3 shows the FND, HND, and LND values of the algorithms according to rounds. The proposed algorithm provides the best values among the existing approaches. In each comparison, the initial adjustments of the compared methods were adopted, and the results

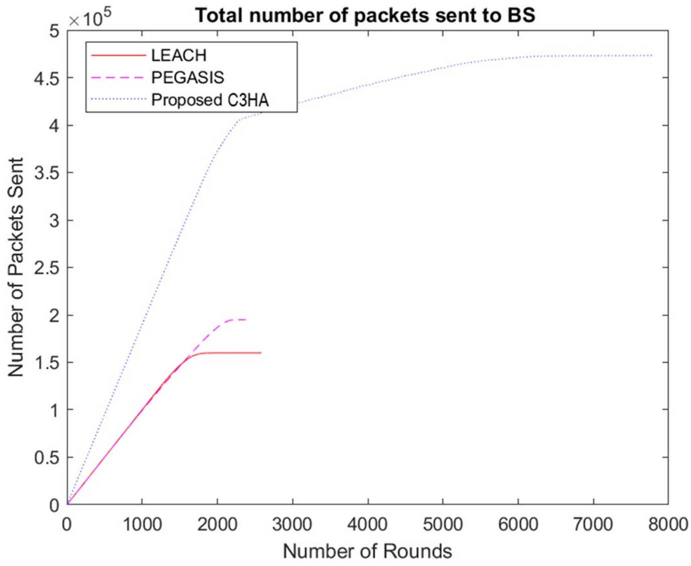

Fig. 6 Number of packets sent vs rounds according to the sim1

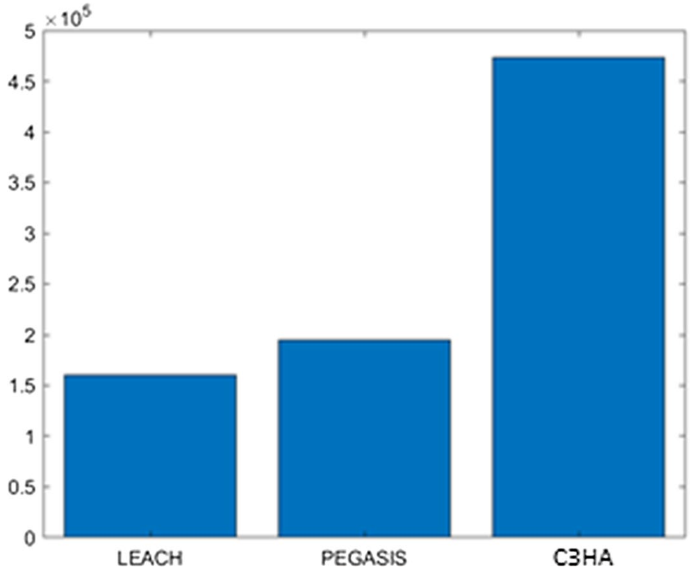

Fig. 7 Total packets sent according to the sim1

were taken so. The differences in FND, HND, and LND values in each comparison are because of these initial adjustments. For example, the initial energies of the nodes, network size, the number of nodes, etc. were set differently in different algorithms. Therefore, we used the parameters of the algorithms during comparison for proper evaluation.

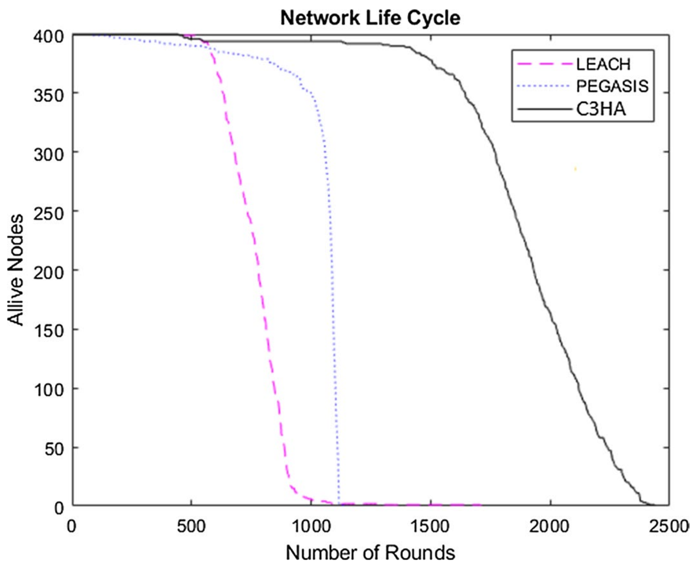

Fig. 8 Alive nodes vs rounds according to the sim2

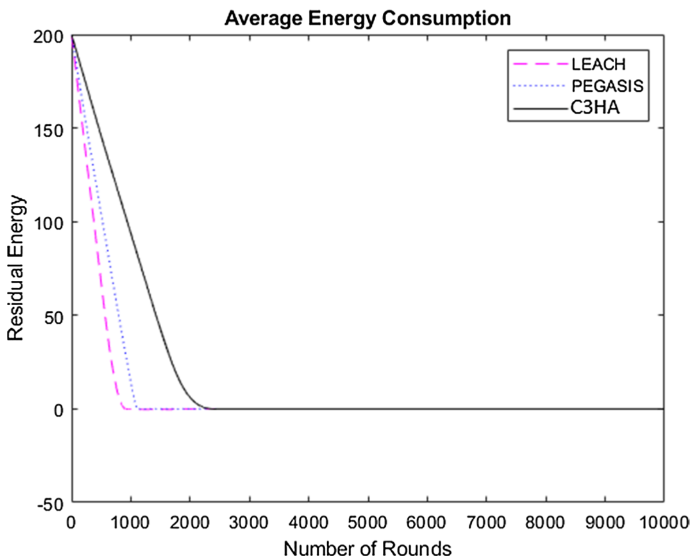

Fig. 9 Residual energy vs rounds according to the sim2

According to the simulation 1, the Fig. 4 show that choosing CHs from CC extends the network lifetime. With the Figs. 5, 6 and 7, C3HA leaves more energy in the network and send more packets than other algorithms.

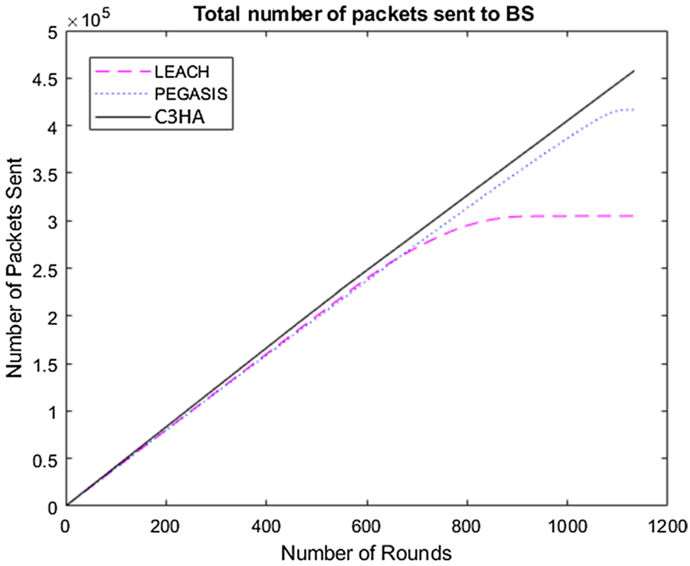

Fig. 10 Number of packets sent vs rounds according to the sim2

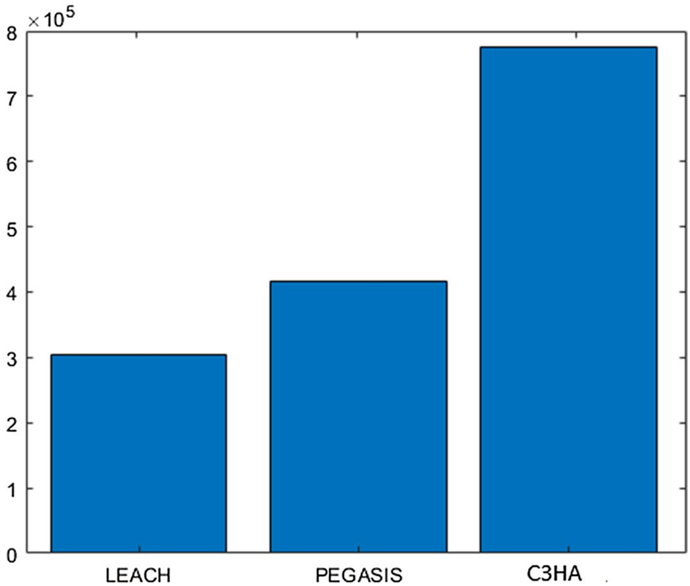

Fig. 11 Total packets sent according to the sim2

The results of the simulation 2 also show the efficiency of the proposed algorithm in terms of residual energy, number of alive nodes, and the number of packets sent. Both simulations support the effectiveness of the proposed algorithm.

7 Conclusion

In this study, a more effective method was proposed and compared with the existing popular CH selection methods used for WSNs. Compared to other algorithms, the residual energy of C3HA is considerably more than the others. The performances of the leading clustering algorithms were evaluated and compared. The results show that in the proposed algorithm 14.68% more nodes alive in the network on average. The number of packets sent is 187.5% more than LEACH, a very popular clustering method, i.e. about twice packets can be sent by the proposed algorithm. The residual energy of the proposed method is about 20% more than LEACH and PEGASIS. According to the different simulation results, the efficiency of the proposed algorithm was shown.

Based on the simulation results of the proposed algorithm, the following future studies can be considered:

- The effect of selecting cluster heads 75% from CC and 25% OCC can be evaluated.
- The sleep/awake states of the nodes can be evaluated according to the distance between the nodes. Because in a random distribution of the nodes, some nodes may overlap, and making one of the nodes sleep can be logical.
- The performed simulations can easily be applied to real cases and the real efficiency can be measured.
- An exception handling procedure can be implemented in case of the radius of CC includes few or no sensors.
- Machine-learning algorithms can be used for faster CH selection.

References

1. Akyildiz, I., Su, W., Sankarasubramaniam, Y., & Cayirci, E. (2002). Wireless sensor networks: A survey. *Computer Networks, 38*(4), 393–422.
2. Stankovic, J. A., & He, T. (2012). Energy management in sensor networks. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 370*(1958), 52–67.
3. Othman, M. F., & Shazali, K. (2012). Wireless sensor network applications: A study in environment monitoring system. *Procedia Engineering, 41*, 1204–1210. https://doi.org/10.1016/j.proeng.2012.07.302
4. Gopi, P. (2014). Multipath routing in wireless sensor networks: A survey and analysis. *IOSR Journal of Computer Engineering, 16*(4), 27–34.
5. Sheikhpour, R., Jabbehdari, S., & Khadem-zadeh, A. (2011). Comparison of energy efficient clustering protocols in heterogeneous wireless sensor networks. *Science and Technology, 36*(January), 27–40.
6. Purkar, S. V., & Deshpande, R. S. (2020). Clustering algorithm for deployment of independent heterogeneous wireless sensor network. *Wireless Personal Communications*. https://doi.org/10.1007/s11277-020-07103-w.
7. Selmic, R., Phoha, V., & Serwadda, A. (2016). Wireless sensor networks: Security, coverage, and localization, vol. 65
8. Qing, L., Zhu, Q., & Wang, M. (2006). Design of a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks. *Computer Communications, 29*(12), 2230–2237.
9. Kumar, A., & Singh, D. (2016). Importance of energy in wireless sensor networks: A survey. *An International Journal of Engineering Sciences, 17,* 500–505.
10. Singh, S. P., & Sharma, S. C. (2015). A survey on cluster based routing protocols in wireless sensor networks. *Procedia Computer Science, 45*(C), 687–695.
11. Chakrabarti, A., Sabharwal, A., & Aazhang, B. (2004). Multi-hop communication is order-optimal for homogeneous sensor networks. *Third International Symposium on Information Processing in Sensor Networks, IPSN, 2004*, 178–185.

12. Ephremides, A. (1981). The architectural organization of a mobile radio network via a distributed algorithm. *IEEE Transaction on Communication, 29*(11), 1694–1701. https://doi.org/10.1109/TCOM.1981.1094909.
13. Heinzelman, W., Chandrakasan, A., & Balakrishnan, H. (2000) . Energy-efficient communication protocol for wireless microsensor networks. In: Proceedings of the 33rd Annual Hawaii International Conference on System Sciences vol. 1(c), 10
14. Shi, S., Liu, X., & Gu, X. (2012). An energy-efficiency Optimized LEACH-C for wireless sensor networks. In: Proceedings of the 2012 7th International ICST Conference on Communications and Networking in China, CHINACOM 2012, pp. 487–492
15. Biazi, A., Marcon, C., Shubeita, F., Poehls, L., Webber, T., & Vargas, F. (2016) . A dynamic TDMA based sleep scheduling to minimize WSN energy consumption. In: ICNSC 2016: 13th IEEE International Conference on Networking, Sensing and Control. pp. 1–6. IEEE
16. Mahmood, D., Javaid, N., Mahmood, S., Qureshi, S., Memon, A.M., & Zaman, T. (2013). MODLEACH: A variant of LEACH for WSNs. In: Proceedings of the 2013 8th International Conference on Broadband, Wireless Computing, Communication and Applications, BWCCA 2013, pp. 158–163
17. Ray, A., & De, D. (2016). Energy efficient clustering protocol based on K-means (EECPK-means)-midpoint algorithm for enhanced network lifetime in wireless sensor network. *IET Wireless Sensor Systems, 6*(6), 181–191.
18. Ngangbam, R., Hossain, A., & Shukla, A. (2020). Improved low energy adaptive clustering hierarchy and its optimum cluster head selection. *International Journal of Electronics, 107*(3), 390–402. https://doi.org/10.1080/00207217.2019.1661023
19. Kardi, A., & Zagrouba, R. (2020). RaCH: A new radial cluster head selection algorithm for wireless sensor networks. *Wireless Personal Communications, 113,* 2127–2140.
20. Raghavendra, S. L. C. (2002). PEGASIS: Power-efficient gathering in sensor information systems. *IEEE Aerospace Conference Proceedings, 3,* 1125–30.
21. Linping, W., Zhen, C., Wu, B., & Zufeng, W. (2010). Improved algorithm of PEGASIS protocol introducing double cluster heads in wireless sensor network. In: Proceedings of the 2010 International Conference on Computer, Mechatronics, Control and Electronic Engineering, CMCE 2010 1, pp. 148–151
22. Jafri, M. R., Javaid, N., Javaid, A., & Khan, Z. A. (2013). Maximizing the lifetime of multi-chain PEGASIS using sink mobility. *World Applied Sciences Journal, 21*(9), 1283–1289.
23. Rana, H., Vhatkar, S., & Atique, M. (2014). Comparative study of PEGASIS protocols in wireless sensor network. *IOSR Journal of Computer Engineering, 16*(5), 25–30.
24. Guo, L., Wang, W., Cui, J., & Gao, L. (2010) . A cluster-based algorithm for energy-efficient routing in wireless sensor networks. *Proceedings of the 2010 International Forum on Information Technology and Applications, IFITA 2010* 2(2), 101–103
25. Nadeem, Q., Rasheed, M.B., Javaid, N., Khan, Z.A., Maqsood, Y., & Din, A. (2013) . M-GEAR: Gateway-based energy-aware multi-hop routing protocol for WSNs. In: Proceedings of the 2013 8th International Conference on Broadband, Wireless Computing, Communication and Applications, BWCCA 2013, pp. 164–169
26. Islam, M. M., Matin, M. A., & Mondol, T. K. (2012). Extended stable election protocol (SEP) for three level hierarchical clustered heterogeneous WSN. *IET Conference Publications, 2012,* 1–4.
27. Elbhiri, B., Rachid, S., El Fkihi, S., & Aboutajdine, D. (2010). Developed Distributed Energy-Efficient Clustering (DDEEC) for heterogeneous wireless sensor networks. In: Proceedings of the 2010 5th International Symposium on I/V Communications and Mobile Networks, ISIVC 2010, pp. 1–4
28. Mohamed, F. A., Hassan, E. S., Dessouky, M. I., & Elsafrawey, A. S. (2020). Performance enhancement routing protocols for heterogeneous WSNs. *International Journal of Communication Systems, 33*(4), 1–18.

Muhammet Tay received the B.S. Degree in Computer Engineering from Istanbul Aydin University, Istanbul, in 2016, and the M.S. Degree in Computer Engineering from the Duzce University, Duzce, in 2019. He is currently a Ph.D. candidate in the Department of Computer Engineering at Duzce University, Duzce. His current research interests include energy conservation, IoT, 5G, clustering and network security in wireless sensor networks.

Arafat Senturk received the B.S. Degree in Computer Engineering from Atilim University, Ankara, in 2009, the M.S. Degree in Electrical-Electronic Engineering from the Duzce University, Duzce, in 2012, Ph.D. degree from Duzce University, Electrical and Computer Engineering Department, Duzce, 2017, and has been working as a associate professor at Duzce University since 2011. His current research interests include clustering, IoT, Energy Consumption, Multimedia in wireless sensor networks.