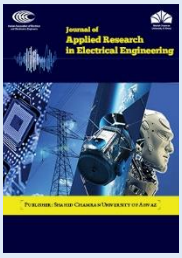
Shahid Chamran University of Ahvaz

Iranian Association of Electrical and Electronics Engineers

Journal of Applied Research in Electrical Engineering

E-ISSN: 2783-2864
P-ISSN: 2717-414X
Homepage: https://jaree.scu.ac.ir/



Research Article

A Novel Energy-Efficient Weighted Multi-Level Clustering Protocol

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Abstract: Wireless sensor networks (WSNs) consist of a large number of sensor nodes that allow users to accurately monitor a remote environment by aggregating the data from the individual nodes. These networks require robust and energy-efficient protocols that are improved reliability and lifetime of WSNs. Clustering of sensor nodes is an emerging paradigm for the energy-efficient approach to improve lifetime and the reliability of WSN by reducing energy consumption. In this paper, a new Energy-efficient weighted multi-level Clustering Protocol (EWCP) is proposed. Cluster heads (CHs) are selected based on the allotted weight to each sensor nodes. The weight includes the parameters of sensors such as density, residual energy, and distance to prolong the network's lifetime and increase its efficiency. Also, the cluster members are selected based on their distance to the selected CHs. The lifetime of EWCP is improved significantly to compare with the other protocols. This improvement is attributed to the fact that EWCP is energy-efficient in clustering protocol.

Keywords: Wireless sensor networks (WSNs), clustering of WSNs, weight-based clustering.

Article history
Received 24 December 2020; Revised 21 April 2021 Accepted 02 June 2021; Published online 29 June 2021.

How to cite this article
E. Farahmand, and A. Mahani, "A novel energy-efficient weighted multi-level clustering protocol," *J. Appl. Res. Electr. Eng.*, vol. 1, no. 1, pp. 69-78, 2022. DOI: 10.22055/jaree.2021.36169.1019

1. INTRODUCTION

In recent decades, remote sensing systems have taken into consideration in the academic and industrial community. The sensor is equipment to study the surrounding environment. They can sense the possible changes in the environment, detect events, and provide an appropriate output. Sensor nodes are the fundamental elements in Wireless Sensor Networks (WSNs) which constructed from transceiver, microcontroller and power sources [1]. The sensor nodes gather data from the environment and, the practical information can be taken from the sensors by extra process on data. Sensor network [2] include a massive number of sensors that are deployed and communicated wireless with each other. These networks consist of a huge number of nodes to aggregate and send data from an unaccessible environment to Base Station (BS) – which is called also sink.

In most application of WSNs, especially when sensor nodes are deployed in inaccessible areas, sensor nodes have a non-rechargeable and non-replaceable battery. Hence, WSNs are constrained with a limited sensor nodes' energy capacity. In order to extend the lifetime, WSNs and efficient deployment of power sources, all aspects of the network should be designed accurately. In this regards, routing protocols are crucial in WSNs [3]. Usually, routing protocols based on network structure are divided into two main groups: flat and hierarchical routing [4]. Here, the hierarchical routing protocols, also known as cluster-based routing. This technique is proved to be a smart solution to optimise energy consumption in WSNs, which can help these networks improve the lifetime and scalability of these networks.

Generally, in clustering algorithms, the nodes split into various groups called clusters. These networks consist of three pillar components: 1. Clusters, 2. Cluster Heads (CHs) and 3. Base station (BS) [5].

The clustering algorithms provide an efficient and reliable routing between sensor nodes and BS [6]. The routing of clustering technique is as follows: first, all cluster members aggregate data from the environment and send them to their assigned cluster heads based on a given routing table. Then, CHs sent the data to the other CHs or BS using the shortest route. Hence, this routing strategy provides low bandwidth usage. The communication between cluster members and assigned CH called internal communication which can be a hybrid of single- or multi-hop communication protocol [1,7]. Also, the communication between CHs and BS called external communication. These communications, same as internal communication, can be single- or multi-hop communication protocol.

In the single-hop communication protocol, all nodes can send data directly to BS. This communication protocol causes some drawbacks, such as a large transmitting domain and high energy consumption during the transmitting. Therefore, due to the limited source of nodes' energy, the multi-hop communication can be considered a suitable alternative to address the single-hop communication drawbacks. In the multi-hop communication protocol, the transmitting domain of CHs is limited by sending data in several hops to reach BS.

All these two communication protocols have an inevitable challenge of imbalanced energy consumption, resulting in problems such as the increased concentration of data transmission in part of the network and poor performance of the network lifetime. Clustering algorithms consider several criteria to control energy consumption WSNs. These criteria include energy, lifetime calculations, number of hops, distance from CHs, and control form, i.e., centralised or distributed control schemes [8]. Hence, the clustering algorithm is designed to solve problems such as minimising cluster size, CHs selection or re-selection, and operation and maintenance of clusters.

In WSNs, CHs consume the highest energy consumption than other nodes due to their communication with the base station. The major drawback in existing clustering protocols is inefficient distributed CHs. The inefficient distributed CHs cause CHs are located near to each other or close to the edge of a network, or CHs are located in a spars area. When CHs are near each other, data transmission concentration in the area and the energy consumption is increased. In this situation, data traffic of CHs are heavy, and the risk of draining of their energy is increased [9].

If CHs are located close to the edge of a network, the time of data transmitting is increased. Also, if CHs are located in a spars area, the data transmitting range of those CHs are increased. Thus, high data transmitting time and range lead to depleting the energy of nodes.

To address these drawbacks, an optimal clustering protocol is proposed in this paper. The main focus of the proposed EWCP is to select optimal cluster heads by considering minimise the energy consumption and routing method together to enhance the lifetime of WSNs. In the proposed EWCP, the optimal CHs are selected based on the distance from BS, nodes' energy level, and network density. After that, the members for each cluster are chosen based on the distance between nodes and CHs. Moreover, the routing method based on hierarchical clustering protocol has more capability for scalability and communication. This method is adopted to design the proposed protocol.

The remainder of this paper is organised as follows: An overview of related work on clustering protocol provides in section 2. The proposed protocol describes in section 3, which includes the energy dissipation model and network model applied in this paper. Section 4 discusses applying the proposed clustering protocol to the sample network and comparing the protocol with some other clustering protocols. Eventually, Section 5 explain concluding remarks.

2. RELATED WORK

In this section, we review some literature that proposed some clustering protocols to enhance the lifetime of WSNs by reducing energy consumption.

The primary clustering protocol for WSNs is Low Energy Adaptive Clustering Hierarchy (LEACH) protocol proposed by Heinzelman and et al. in [10]. LEACH protocol selects and rotating CHs with the random number. This protocol is a distributed scheme design. Since decisions on, it is still plausible that sensor nodes with low residual energy are selected as CHs. LEACH protocol impossible to ensure that cluster heads are distributed optimally over the network. A various number of the enhanced model of LEACH have been proposed, e.g., HEED [11], TEEN [12] and PEGASIS [13], to overcome mentioned issues. The aim of the proposed Distributed Weight-based Energy-efficient Hierarchical Clustering (DWEHC) protocol in [14] is to develop Hybrid Energy Efficient (HEED) protocol by constructing clusters with balanced size and optimising the topology of clusters. The weight is a locally calculated parameter used as a criterion in CH election and is defined using (1).

$$W_{weight(s)} = \frac{E_{residual(s)}}{E_{initial(s)}} \times \sum_{u} \frac{R-d}{6R} \tag{1}$$

where, $E_{residual}(s)$ and $E_{initial}(s)$ are residual and initial energy levels in sensor node s, respectively. R is the cluster range, and d is the distance from node s to neighbouring node u. Therefore, this protocol is not appropriate for a network with a large area because of its enormous energy consumption. A decentralised energy-efficient hierarchical cluster-based routing protocol that enhances the network's lifetime by protocol comprising a multi-criterion clustering algorithm is proposed in [15]. The protocol contains an Energy-Aware Distributed Clustering EADC algorithm is presented in [16], which can be applied in WSNs with non-uniform node distribution. The protocol includes an energy-aware clustering algorithm and a cluster-based routing algorithm. The whole process is divided into three phases: information collection phase, cluster head competition phase, and cluster formation phase. The protocol initially selects fixed CHs using two weights, including energy and distance to the other nodes. Tang, Chengpei, *et al.* [17] proposed a collaborative weighted clustering algorithm (CWCA) weighted clustering protocol. It used in monitoring the oil pipeline. In this method, the weight of the nodes is assigned by four factors, i.e., degree, Euclidean distance, mobility, and a lifetime of nodes. The weights of nodes are expressed by (2):

$$weight(i) = \alpha_1 \times D_i + \alpha_2 \times P_i + \alpha_3 \times M_i + \alpha_4 \times T_i \tag{2}$$

Consequently, in this equation, the sum of coefficients is one (i.e., $\alpha_1 + \alpha_2 + \alpha_3 + \alpha_4 = 1$) and in the static network without mobility, M_i is assumed zero.

In clustering iterations, this protocol requires a large amount of control overhead compared to the other protocols. The main challenge in clustering algorithms is selecting the optimal CHs. Thus, the computation of selecting the CHs in the large-scale networks is heavy by classical analyses, and it grows exponentially. For example, we need to assess 2^N-1 states to choose optimal CHs for N nodes. We can conclude that this mentioned problem is a Nondeterministic

Polynomial NP-hard [18]. Furthermore, to reach the optimal CHs the optimisation methods should search over a vast space. Due to vast space this problem becomes infeasible. Thus, the efficient solutions in dealing with selecting clusters and cluster members is heuristic optimisation algorithms.

Genetic Algorithm-based Optimized Clustering protocol (GAOC) is proposed in [19-20]. The selection of CHs is made by the genetic algorithm (GA), which the fitness function formulates by integrating residual energy, distance to the BS, and node density. Shuffled frog leaping algorithm (SFLA) proposed in [21] to select CH, which reduced energy consumption. Ant Colony Optimizer (ACO) used in ACO Optimized Self-Organized Tree-Based Energy Balance (AOSTEB) to discovers an efficient route during intra-cluster communication [22]. Evolutionary game is used to formulate the clustering machine-type devices [23]. This model decreases the number of redundant bits transmitted to the BS in order to decrease the transmission power. AOSTEB operates in three phases: cluster-formation, multi-path creation, and data transmission. The desired number of sensor nodes is a candidate as cluster heads (CHs) during cluster-formation, and the remaining sensor nodes join the nearest CHs to create a cluster. The optimised route is selected by using the ACO to consider the shortest distance and less energy consumption to initiate the data exchange process within the cluster. In the literature [24], to reduce the energy consumption of the sensor nodes, used ARSH-FATI algorithm, a metaheuristic algorithm to select CHs (ARSH-FATI-CHS). Particle Swarm Optimization (PSO) algorithm implemented at the BS as a centralised method [25]. In this algorithm, both distance and energy consider as multi-objective function. The objective is to minimise the average Euclidean distance between the cluster members and their assigned CHs and the proportion of the total energy consumption of the entire nodes to the total energy sum of the CH candidates. P. C. Srinivasa Rao *et al.* [26] proposed the cluster heads election by PSO algorithms, which is named PSO-ECHS. In this method, the parameters like intra-cluster distance, distance from the sink and residual energy of sensor nodes are considered, so by these parameters, the particles of algorithms are coded. After CHs selection, the clusters are formed, and the members of every cluster should be elected. In CH formation, (3) express the weight assigned to every node, and the nodes with the highest weight are jointed to the CH.

$$CH_{weight(s_i,CH_j)} = \frac{E_{residual}(CH_j)}{dis(s_i,CH_j)\times dis(CH_j,BS)\times node\_degree(CH_j)} \quad (3)$$

In this section, a review of popular clustering protocols in WSNs is presented, and the advantages and disadvantages of each protocol are studied. This paper focuses on using these advantages and addressing some of the aforementioned disadvantages of these protocols. Consequently, the prominent objective of the proposed protocol, i.e., EWCP, is to minimise the network's energy consumption and prolong the network lifetime simultaneously.

3. Proposed Method

In this section, we explain our clustering method for WSN. The main drawbacks of clustering the WSN are selecting CHs and maximising the network coverage. Before we dive into the details of EWCP, we briefly present the energy model in sub-section 3.1 and the network model, which is adjusted for this protocol in sub-section 3.2.

3.1. Model of Dissipated Energy in One Sensor Node

In this paper, the one node's energy consumption model including dissipated energy in transmitter and receiver of data and control packets. The energy dissipation applied for EWCP is model in [27]. Equations (4) and (5) present energy dissipation in the transmitter and receiver, respectively.

$$E_{Tx}(l,d) = lE_{elec} + l\, e_{amp}d^n \quad (4)$$
$$E_{Rx}(l,d) = lE_{elec} \quad (5)$$

where,

E_{elect}	Present the consumption of energy to run the electronic circuit of transmitter /receiver one bit of data.
e_{amp}	Present the consumption of energy to run the radio amplifier of the transmitting node to transmit one bit of data.
l	Present data package length
d	Present distance between the transmitter and receiver
n	n sets to 2 and 4 for free space and multi-path fading channel models, respectively.

The selection of energy model between free space model and multi-path fading is made according to the distance threshold value, i.e., d_0. In this paper, we assume the threshold to be 87.7 throughout simulations. Therefore, considering the threshold energy consumption model for both free space and multi-path fading channel models is presented by (6).

$$\begin{cases} E_t = lE_{elec} + l\varepsilon_{emp}d^4 + lE_{DA} & if\ \ d > d_0 \\ E_t = lE_{elec} + l\varepsilon_{fs}d^2 + lE_{DA} & if\ \ d \le d_0 \end{cases} \quad (6)$$

where, E_{DA} is the energy consumption to aggregate data. The above energy model use for one sensor node.

3.2. Network Model

The network model with an area of $m\times m$ considered in this protocol includes N sensors distributed randomly in the area and know its location. These sensor nodes include a source of energy that is not rechargeable, and the range of the monitoring and communicating is similar and identical. BS is aware of the positions, energy levels and IDs of all nodes in the network.

The network is split into several layers with a fixed radius, and BS is located at a fixed point. Nodes are uniformly dispersed across the layered network. The network considers as a homogenous network which is shown in Fig. 1. All nodes have similar initial energy and sensing range as same as processing properties.

Fig. 1 is a sample of a *50×50* square network's model with 100 nodes dispersed randomly. The BS node is located at the coordinate of (50,25), and the network is divided into six layers. The nodes shown by × are located in the first layer, and similarly, the nodes are shown by +, □, ◊ and * are located in the second, third, fourth, fifth and sixth layers, respectively.

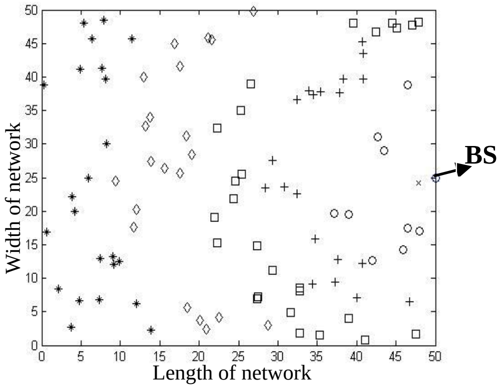

Fig. 1: Network's model with layer and random node distributed.

Once the nodes are distributed over the network, every node finds its neighbouring (the nodes located in its communication radius) by sending a controlling massage. Next, each node creates an information table of its neighbouring nodes, including their residual energy information, associated weight and ID numbers, and saves the table in its memory.

In EWCP, a weight is assigned in every node, which is explained by (7).

$$node.weight = \alpha \times E + \beta \times distance + \delta \times D \qquad (7)$$

In (7), E and distance represent the residual energy of node and normalised Euclidean, which is calculated by (8), respectively. *D* present the density of a node which is calculated using (9). Moreover, α, β, and δ are dynamic coefficients, which dynamically change by the number of rounds in EWCP and can be calculated using (10) to (12).

$$distance = \frac{(max\_distance\_to\_BS) - (distance\_CH\_to\_BS)}{(max\_distance\_to\_BS) - (max\_distance\_to\_BS)} \qquad (8)$$

$$D = \frac{\text{the number of neighboring CH}}{\text{the number of all alive nodes}} \qquad (9)$$

$$\alpha = 0.3333 \times \left(\left(\frac{r}{rmax} \right) + 1 \right) \qquad (10)$$

$$\beta = \frac{0.3333}{\frac{r}{rmax} + 1} \qquad (11)$$

$$\delta = 1 - \alpha - \beta \qquad (12)$$

The EWCP operation is split into various iterations, and *r* represents the current iteration. The maximum possible iteration for the protocol is represented by *rmax* parameter. The parameter α is an energy coefficient. It grows by the increasing number of rounds, hence in the later rounds, the nodes with high residual energy level have larger weight. The parameter β is the distance coefficient, and it declines with the increasing number of rounds, hence in the later rounds, the impact of this parameter drops. The parameter δ is a density coefficient, and its values stay approximately constant in each round. This coefficient is directly proportional to the sum of coefficients α and β. Since these coefficients are varying in opposite directions, their total sum stays approximately constant in each round.

Three parameters of *residual energy*, *distance* and *density* are combined to assign a weight to each sensor node. We note that CHs consume more energy compared with cluster members. Hence, a node with a higher residual energy level is appropriate to become a CH. The residual energy level of the nodes is high at the beginning rounds, whereas it becomes marginal in the later rounds. Hence, it is important to increase the effect of residual energy in later rounds compared to the beginning rounds. This trend is reflected in the dynamic values of coefficient α. Another effective parameter in improving the lifetime of WSNs is the distance to BS. The less distance to BS, the less energy consumption is required to transmit data to BS. Thus, in the energy dissipation model, i.e., (6), if the distance is less than the threshold distance, the free space model (d^2 power loss) is used. The impact of this parameter on the node's weights in EWCP is assumed in the opposite direction of residual energy. At the beginning rounds, the distance coefficient is deemed to be more important than energy residual in the beginning rounds in order to optimise energy consumption. However, when we approach the final rounds, the energy level of nodes becomes marginal, and the impact of this parameter is reduced; hence, energy residual becomes more important. The last parameter included in the calculation of weight factors is density. Generally, to balance the data transmission and reduce the collision, more CHs should be allocated in the specific area in which nodes are concentrated. This allocation leads to reduce consumed energy and improves WSN lifetime. The impact of the density factor is assumed to be constant in the protocol. Fig. 2 present a schematic overview of the EWCP set-up.

In the first step, the nodes whose energy is less than the given threshold, called dead nodes, are removed from the network. The given threshold in this paper is assumed zero. The weight of all the live nodes is calculated using (7). The remain nodes exchange control message which contains their weight information. Then, based on candidates using a distributed cluster head selection, the node selects a number of CH. This selection is made using a multi-layer set-up according to the distance between nodes and BS. The nodes can decide to select their own CH autonomously. The conditions of this selection are listed below:

- The distance of CH candidates to BS must be larger than a given threshold distance calculated by the communication radius of nodes. Hence, this condition distributes CHs and improve network coverage.
- The CH weight, i.e., (7), must be larger than its neighbouring nodes' average weights. This condition balances the total energy consumption of the network.

Next step is to inform the nodes in each layer of the number of CH candidates. In this way, the CH candidates broadcast a control massage (CH-msg) to their neighbours. To have full coverage in each layer, we select one-third of the some nodes are selected as CH candidates from remain nodes existing in the layer to achieve a third of the nodes. In this

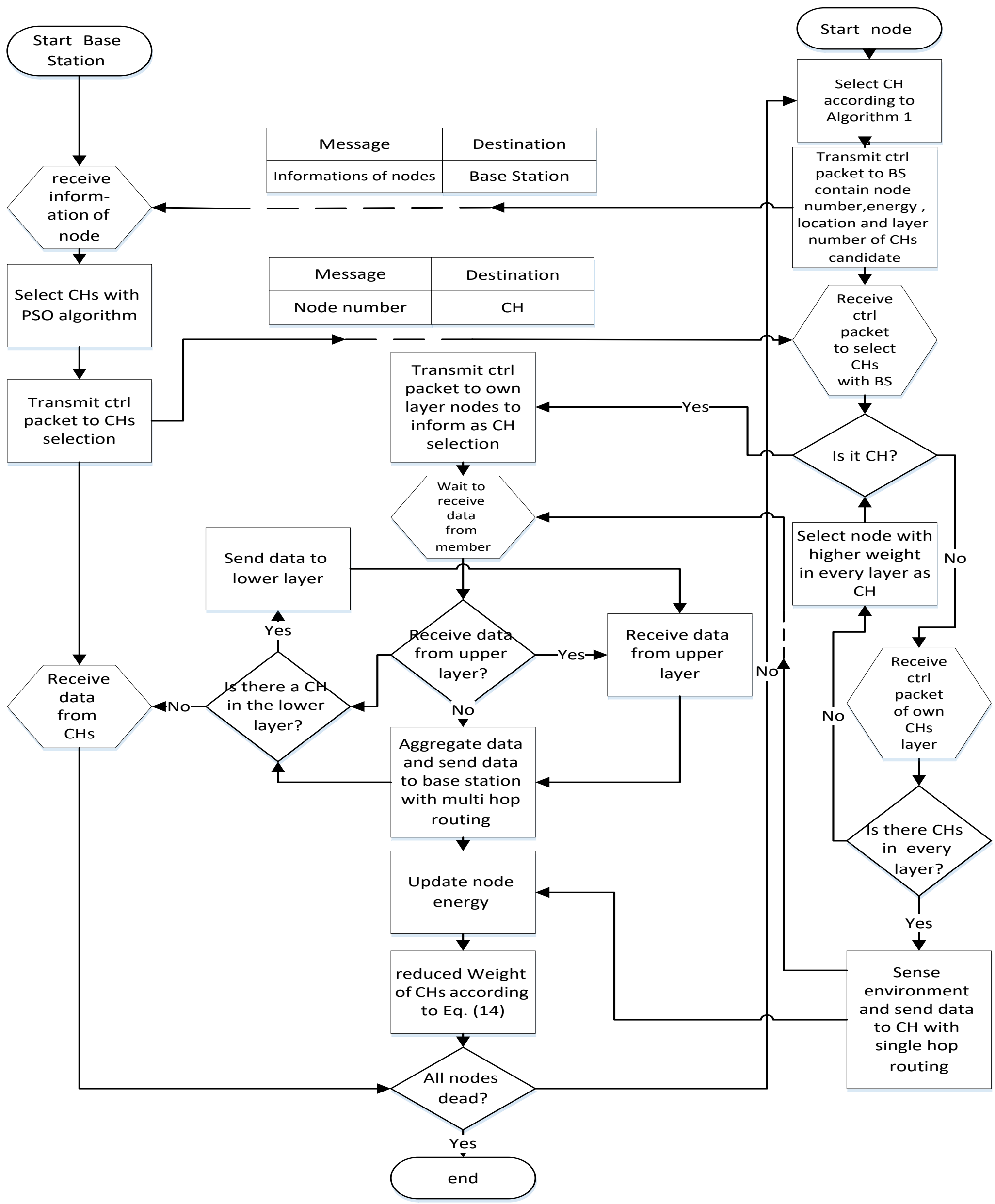

Fig. 2: An overview of EWCP.

situation, the non-candidate nodes with the top highest weight among the nodes are selected as CH candidates. After the candidates are selected, these nodes send a second control message to BS to report their new status, and BS saves the ID number and location information of each node. The algorithm of selecting CH candidates in EWCP is illustrated in Algorithm 1.

In the next step, BS selects appropriate CHs by Particle Swarm Optimisation (PSO) algorithm. In this regards, the selected CH candidates as an initial swarm and their location, transfer communication radius and assigned ID numbers to the PSO algorithm. The fitness value of every particle is calculated using (13).

$$\text{fitness function} = \min \left(\left(1 - \text{network coverage}\right)^2 \times \frac{\text{the number of selected CH}}{\text{the number of candidate CH}} \right) \quad (13)$$

The fitness function in (13) is a minimisation problem, and the objective is to maximise the network coverage with a minimal number of nodes as CHs. In this formula, the square value used for network coverage indicates the importance of this parameter compared with the number of nodes. We have applied the "grid base" method [28] in order to calculate the network coverage. Once the fitness value of each particle is calculated, PSO updates the position and velocity of particles, and this process continues until a termination criterion is achieved. Once the optimum set of CHs is identified, BS sends a control message (Cluster-head-elect) to the selected CH and inform them of their new role. Next, the selected CHs exchange control message with their neighbour nodes and this control massage contains their new role. Thus, the nodes in each layer can identify their CH. If no CH exists in a given layer, the sensor node with the largest weight is selected as a cluster head in the layer.

Afterwards, clusters are constructed from optimal cluster heads and their cluster members. The cluster members sense data from the environment and send them to their assigned

Algorithm 1: Select Candidate of CH in EWCP

Input all WSN nodes
Calculate node's weight using (7)
For each $j \in \{1,2,\dots,layer\}$ **do**
  For each $i \in \{1,2,\dots,node\}$ in j **do**
    Receive energy, node number and weight of neighbour
    If $i\, != CH$ **then**
      If number of CHs $<= \frac{\text{number of live node in layer}}{3}$ **then**
        If node weight > average of neighbour node's weigth **then**
          $i = CH$
          If distance among CHs < node's radious **then**
            Counter_CHs=Counter_CHs+1
          end if
      Else
          max nodes weight in layer $= CH$
          Counter_CHs=Counter_CHs+1
        end if
      end if
    end if
  end for
end for
Select CHs Candidate

Algorithm 1: Select Candidate of CH in EWCP.

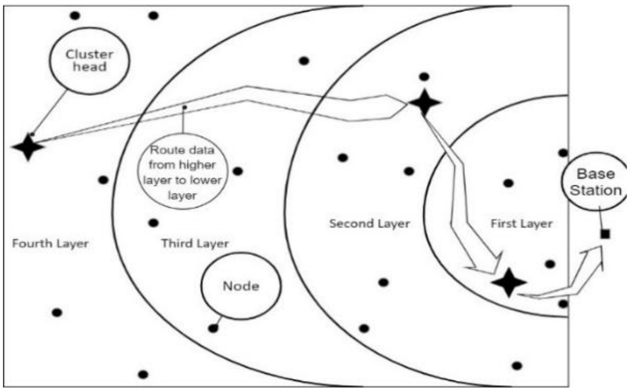

Fig. 3: A data transmitting across the fourth-layered network.

cluster heads. CHs aggregate data and transmit them further to the BS using multi-hop communication. Transmitting data from CH to BS is done in such a way that each CH sends data to the CH in a lower layer until data packages reach the base station. Fig. 3 depicts data transmitting across the fourth-layered network.

As shown in Fig.3, when there is no CH in the third layer, the CH in the fourth layer transmits data to BS via the CH in the second layer and hop over the third layer. When all nodes are dead, the situation is mainly valid in the final iteration. In this situation, data packages are transferred to the lower available layers, which encompass live CH.

Once the data package is transferred to BS, the assigned weight of CH is reduced, based on (14).

$$weight_r = weight_{r-1} - \frac{cluster\_count}{rmax} \quad (14)$$

where $cluster\_count$ is the number of times the node has been a CH. $rmax$ is the maximum number of rounds, and $weight_{r-1}$ is the weight of the node in the previous round. The reduced weight of each node is directly proportional to the number of times it has taken the CH role. The reduction of node's weight decreases the possibility of nodes being selected as CH in the next round. It gives a chance to the other nodes to be selected as CH, and conseq''ently, the load is evenly divided among nodes.

3.3. Model of Total Dissipated Energy in a Layered Network

Total energy consumption in the network includes four elements as follows:

- Energy consumption for intra-cluster data transmission
- Energy consumption for inter-cluster data transmission
- Energy consumption for intra-cluster and inter-cluster transmitting the control packages
- Total energy consumption for receiving data and control packages.

The total energy consumption is presented by (15).

$$E_{total} = \sum_{i=1}^{M} E_{TXinner}(k_i, d_i, N_i) + E_{TXutter}(k_i, D_i, N_i) + E_{TXcontrol}(k_i, d_i, dis_i, N_i) + E_{RX}(k_i, N_i) \quad (15)$$

where intra-cluster communication is single-hop and inter-cluster communication is multi-hop. In inter-cluster communication, CHs route data destination for the BS through intermediate CHs. Thus, intermediate CHs can act as routers for other CHs' data. Energy consumption is reduced by using multi-hop communication among CHs. Therefore, this protocol helps CHs to save their energy and enhances their lifetime. Moreover, we should add the energy consumption of transmitting/receiving control packages.

If we assume the quantity of transmitted bit data for all nodes identically, the total energy consumption of intra-cluster data transmitting is illustrated by (16).

$$E_{TXinner}(k_i, d_i, N_i) = k \sum_{i=1}^{M} [(N_i - 1)(E_{elect} + e_{fs} d_i^2)] \quad (16)$$

where,

M Represent the number of clusters

d_i Represent the distance of nodes in ith cluster and their assigned CH

D_i Represent the distance of ith CH from (i-1) CH or BS

N_i Represent the number of nodes in ith cluster

k_i Represent the length of transmitted bit data

dis_i Represent distance between ith CH and BS

Considering the assumptions of (16), in (15), the inter-cluster transmitting energy consumption can be presented using (17).

$$E_{TXutter}(k_i, D_i, N_i) = k \sum_{i=1}^{M} [(N_i)(E_{elect} + e_{mp} D_i^2)] \quad (17)$$

The energy for transmitting control packets is illustrated by (18).

$$E_{TXcontrol}(k_i, d_i, dis_i, N_i) = k \sum_{i=1}^{M} [(N_i)(E_{elect} + e_{mp} dis_i^2)] \quad (18)$$

$$+k\sum_{i=1}^{M}[(N_i-1)(E_{elect}+e_{fs}d_i^2)]$$

Finally, total energy consumption for total receiving packets in the layered network is expressed in (19)

$$E_{RX}(k_i,N_i)=kE_{elect}\sum_{i=1}^{M}[(N_i-1)+\sum_{j=i+1}^{M}N_j] \qquad (19)$$

4. Result and Analysis

This section investigates the impact of EWCP on the reduction of energy consumption of WSNs. The results of EWCP is compared with other clustering protocols concerning energy consumption, lifetime and coverage of the network. Two examples are introduced to perform the comparison. These examples are determined according to the network model, networks' parameters, and node number. The network model and layers are configured around BS, as shown in Fig. 3.

4.1. First Example

In the first example, network with a 200-nodes which distributed randomly across a 200m × 200m network. The initial energy of 0.5 J is assumed. Implementation of clustering is iterated until all sensor nodes are dead (network's lifetime). The nodes communicate to their CHs using single-hop in all rounds of simulation. Also, CH communicates with the BS by multi-hop communication through network layers. The BS location is (100,250). The node's radius ($R_{sensing}$) and communication radius ($R_{communicatio}$) equals 25 m and 50 m, respectively. The parameters of the applied energy consumption model are shown in Table 1. In addition, Table 2 reports the PSO tuned parameters.

The selected benchmark clustering protocols for comparison in the first example are GCA [29], SCP [30] and UCIFA [31]. Besides these clustering protocols, the research conducted in Mirsadeghi *et al.* [32] (Mir) is selected as an additional benchmark since a similar example is analysed in this research work.

4.1.1 Energy consumption comparison

Network coverage is an effective factor in network energy consumption. So, the rate of network coverage for various clustering protocols are compared in Fig. 4.

As shown in Fig. 4, EWCP has relatively high coverage among other protocols. However, GCA has a higher coverage rate, but the other factors must be considered in comparing protocols.

Another factor that impacts the network lifetime is the number of *orphan nodes.* Orphan nodes cannot communicate with any CH or BS. Therefore, they waste their energy due to aggregate information cannot send to BS. If the network coverage is efficient, the number of *orphan nodes* will be reduced significantly. If the number of orphan nodes is declined, the network can save energy consumption. The number of orphan nodes for different clustering protocols is compared in Table 3. On the other hand, the average number of CHs is another vital factor in evaluating the energy consumption of WSNs. The high number of CHs indicate high energy consumption. Furthermore, this factor is shown in Table 3 as well.

Table 1: Parameters of the network

Parameters	Value
E_{elec}	$50nJ/bit$
E_{DA}	$5nJ/bit\ /signal$
ε_{emp}	$0.0013pJ/bit\ /m^4$
ε_{fs}	$10pJ/bit\ /m^2$
d_0	$87m$
l	$2000bits$

Table 2: PSO Parameters

Parameters	Tuned value
Particles	40
Iterations	200
Inertia weight (W)	0.7298
Learning factor 1 (C1)	1.4962
Learning factor 2 (C2)	1.4962

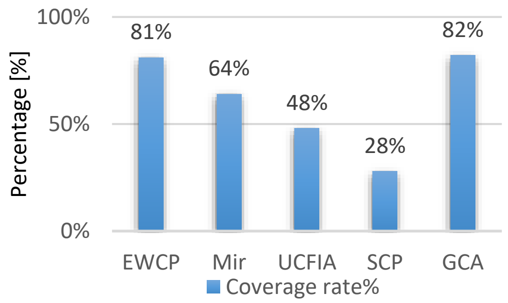

Fig. 4: Coverage rate of different clustering protocols.

Table 3: Orphan node rate

Method	Orphan node rate	Average number of CHs
EWCP	0.9	18
Mir	0.00038	37
UCFIA	9.1	8
SCP	8	15
GCA	1.5	83

Table 3 depicts EWCP has an approximately lower orphan node rate than the other protocols. Mir protocol has a moderately lower orphan node rate than EWCP; however, EWCP has a higher coverage rate than Mir protocol. Moreover, GCA has a higher orphan node rate than EWCP.

According to Table 3, it noted that GCA has the highest coverage rate with a high number of CHs at each round. Thus, the energy consumption of GCA is increased and cannot be considered an effective energy efficient protocol. Also, EWCP improves the energy consumption and provides a proper number of CHs considering its coverage rate and orphan node rate of the network.

The graph of Fig. 5 presents the comparison of the energy consumption of various clustering protocols in 100 iterations. EWCP has the lowest energy consumption in comparison with the other clustering protocols, which is due to its superiority of practical aspects in energy consumption, i.e., parameters considered in node weight presented in (7).

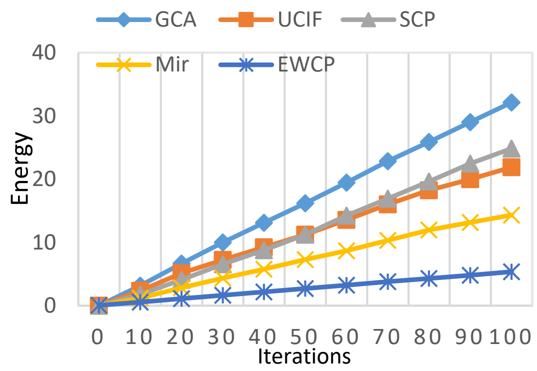

Fig. 5: Energy consumed in 100 iteration

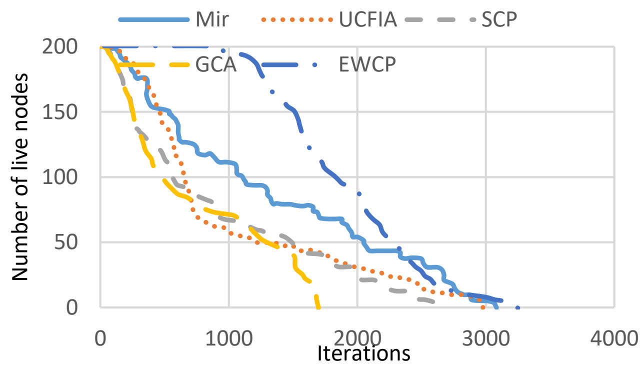

Fig 6: Lifetime of network.

Decreasing energy consumption impact WSN lifetime. Hence, it is expected that the network lifetime is extended by decreasing the energy consumption of the proposed method. The lifetime of different protocols compare based on three criteria which are explained as follows:

- First Node Dies (FND): shows the number of iterations before the first sensor node dies
- Half Nodes Die (HND): indicates the number of iterations when half of the sensor nodes dies.
- Last Node Dies (LND): shows the number of iterations when the last sensor node dies.

4.1.2 Lifetime comparison

In Table 4, all lifetime criteria, i.e., FND, HND, and LND values, compare with various protocols. This table shows that EWCP exhibits a better choice in term of energy-efficient than the other considered protocols. It is obvious in FND and HND criteria.

Fig. 6 present the number of live nodes in each iteration. Based on this figure, EWCP has high live nodes in various iterations in comparison with the other clustering protocols, and it advocates the prior results. It is noted that Mir protocol has more live nodes around iteration 2500; but, EWCP has a longer lifetime than Mir protocol. Thus, it obvious that EWCP has efficient energy consumption over the other protocols.

4.2. Second Example

In this example, we use another method-CWCA [17], for comparing the proposed method. Based on [17], the coefficients of weight in CWCA are assumed to be as (20):

$$\alpha_1 = 0.2\,, \alpha_2 = 0.2\,, \alpha_3 = 0.3, \alpha_4 = 0.1 \quad (20)$$

In this example, we consider the network with 100m × 100m, where 100 nodes randomly distributed over the network with 0.5 J initial energy. The other parameters of the network are explained in Table 5. The nodes send collected data to CHs using single-hop, and CHs send aggregated data further between layers to BS using multi-hop.

The other parameters of the network, such as energy parameters and the tuned parameters of the PSO algorithm, are the same as the previous example, i.e., Tables 1 and 2.

Table 4: Lifetime criteria of WSN

Method	FND	HND	LND
EWCP	933	1811	3242
Mir	122	1118	3077
UCFIA	70	661	2980
SCP	51	554	2609
GCA	61	496	1919

Table 5: Parameters of the network in the second example

Parameters	Value
Range of sensing	15 m
Base station location	150 × 50
Range of sending	20 m
lengh of packet	500 bits

4.1.3 Comparison of lifetime

This subsection compares the lifetime of the proposed method (EWCP) with CWCA method [17] to equating. In this respect, the parameters of the lifetimes such as FND, HND and LND are shown in Table 6. Moreover, the average number of CHs and the number of packets received to BS are included in the Table 6.

As seen in Table 6, the parameters of FND and HND are higher in EWCP than CWCA. However, LND parameters are lower than CWCA, and this is related to the fact that the number of packets that received to BS is higher in EWCP than CWCA, but CHs are approximately similar in two methods, so the impact of this parameter cannot be pronounced indifference of lifetime parameters. The number of live nodes in each iteration is shown in Fig. 7 in both methods. As shown, in most of the iterations, the number of live nodes is dominated in EWCP over CWCA. However, since the sending packets to BS are more in EWCP, the lifetime of this method is lower, and nodes die earlier, but the difference is not very significant.

5. Conclusion

The energy capacity of WSNs is limited, so designing an effective and scalable routing protocol is necessary to improve the network performance and lifetime. Clustering protocols are considered an effective technique to reduce energy consumption and improve the lifetime of WSNs.

This paper has proposed EWCP as a new energy-

Table 6: Lifetime criteria of WSN in the second example

Method	FND	HND	LND	Packets to BS	Average number of CHs
EWCP	1237	4384	5766	68147	11
CWCA	641	3927	6028	63547	10

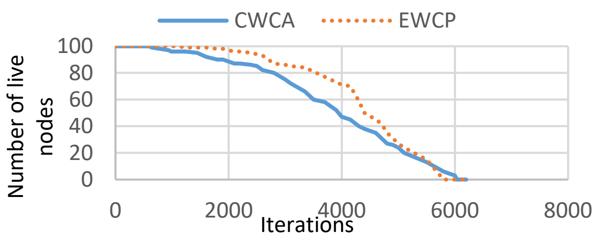

Fig. 7: Lifetime of the network in the second example

efficient clustering protocol. EWCP find the optimal CHs by PSO and find the cluster members of each CH. According to their residual energy level, a proper candidate for CHs is passing into the PSO algorithm, distance to BS, and network density. PSO aims to minimise energy consumption, minimise the number of orphan nodes and maximise coverage. Therefore, this method achieves 81% coverage rate and a under 1% orphan node rate. Moreover, the lifetime of the network is enhanced by 5% approximately.

The EWCP compared with state-of-the-art clustering protocols based performance. EWCP have better performance than the other protocols in orphan nodes, network lifetime, and energy efficiency. The simulation results advocate these claims. It is concluded that selecting CHs and cluster members by considering the energy-efficient parameters has a vital enhancement in increasing the performance of the proposed protocol.

CRediT Authorship Contribution Statement

Ebrahim Farahmand: Conceptualization, Data curation, Formal analysis, Methodology, Software, Visulization, Roles/Writing - original draft. **Ali Mahani:** Conceptualization, Data curation, Formal analysis, Methodology, Supervision, Validation, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The ethical issues; including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy has been completely observed by the authors.

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