MLCA: A Multi-Level Clustering Algorithm for Routing in Wireless Sensor Networks

[1]Ramin Yarinezhad and [2]Amir Sarabi
[1]*Department of Mathematics and Computer Science, Amirkabir University of Technology, Tehran, Iran*
[2]*Department of Electrical Engineering, Ilam Branch, Islamic Azad University, Ilam, Iran*
yarinezhad.ramin@gmail.com, amir.sarabi88@gmail.com
Corresponding author: yarinezhad.ramin@gmail.com

Abstract- **Energy constraint is the biggest challenge in wireless sensor networks because the power supply of each sensor node is a battery that is not rechargeable or replaceable due to the applications of these networks. One of the successful methods for saving energy in these networks is clustering. It has caused that cluster-based routing algorithms are successful routing algorithm for these networks. In this paper, a new routing algorithm based on a hierarchical clustering is proposed for these networks. In each level of this hierarchical clustering, the appropriate nodes are selected as cluster heads and then formed the clusters. The proposed algorithm is distributed and selects cluster heads and forms the clusters with the smallest number of the control messages. Moreover, while clustering is performed, an efficient routing among cluster heads towards the sink is created which does not need sending any more control messages in the network. Simulation results show that the proposed algorithm has better performance than other similar algorithms.**

Index Terms- Clustering, Energy Consumption, Wireless Sensor Network.

I. INTRODUCTION

A Wireless Sensor Network (WSN) consists of a set of sensors called nodes or sensor nodes and a base station also called sink. The main task of a sensor network is to monitor phenomena or events that occur in a specific region. The sensor nodes collect data from the region and transfer them to the sink. The wireless sensor networks are broadly used in different areas. For example, in military applications (track enemy targets or monitor their activities) and fire prevention (by the deployment of a wireless sensor network in an area such as a forest fire can be prevented by monitoring the temperature of the region) [1]–[4]. Traditional wireless network algorithms cannot be used in wireless sensor

Manuscript received day-Month-year and revised day-Month-year,
Accepted on day- month-year
P- ISSN: 2322-4088
E- ISSN: 2322-3936

networks because sensor nodes in wireless sensor networks have a number of limitations such as short radio range and power supply constraints [5], [6].

The radio range of sensor nodes is limited. Therefore, most of the sensor nodes cannot transfer their data to the sink directly and they use other nodes to transfer their data to sink called multi-hop communication [7], [8]. The multi-hop communication is such that each sensor node that is not within the communication range of the sink, transfers its data to the sink by its neighboring nodes [1]. Each sensor node uses a battery to supply its required energy. The battery of each sensor nodes is not usually rechargeable or replaceable due to some applications of these networks. Therefore, to increase the network lifetime, the energy consumption of sensor nodes must be minimized. The energy consumption is an important issue in this networks [1], [2], [7], [9].

In addition to the limitations of sensor nodes in wireless sensor networks, an important issue in these networks is that the nodes, which are near the sink, should send their data and also other nodes' data to the sink. Thus, energy consumption in these nodes is more than the rest of the nodes leading to the earlier death of these nodes and create a gap in the network, which disconnects the rest of nodes from the sink. This issue is called the energy hole problem [7], [9].

Various methods have been proposed to solve these problems including clustering method in which the network is divided into several clusters and each cluster has a Cluster Head (CH) that collects data from cluster members and sends them to the sink. The studies that have been conducted in this area indicate using clustering improves the network lifetime [10], [11]. In hierarchical cluster-based protocols, higher-energy nodes are used to process and send the information, while low-energy nodes are used to perform the sensing in the proximity of the target. The creation of clusters and assigning special tasks to CHs can greatly contribute to overall system scalability, lifetime, and energy efficiency [12], [13]. A hierarchical cluster-based WSN has many advantages such as it can reduce energy consumption significantly because only cluster heads need to be involved in data aggregation and routing process and also clustering can considerably conserve communication bandwidth as the sensor nodes need to communicate with their CHs only and can avoid exchange of redundant messages among them. Furthermore, the clusters can be more easily managed as they can localize the route set up and require small routing tables for the sensor nodes [14]–[16].

In this paper, a hierarchical clustering routing algorithm is proposed with regard to the energy consumption of the sensor nodes. The highest level of this hierarchical clustering is the sink that invites all its neighboring nodes to form clusters by sending a message. Then the proper nodes are selected as the cluster heads. After that, the selected cluster heads send a message to all cluster members with a maximum distance from the sink to start next level of clustering. This procedure continues until every node in the network becomes a cluster head or a member of a cluster. Some key features and the contributions of this paper are highlighted as follows:

- Providing a new routing algorithm for wireless sensor networks that is fully distributed. Each node uses its own data and its neighbors to form clusters. In this algorithm, when clustering is in progress, there is no need to run any centralized algorithm or interference of the sink, which makes clustering be very low cost.
- In the proposed algorithm, when clustering is performing at a level, routing is also performing simultaneously, and the next-hop of each cluster head is determined. Therefore, in the proposed algorithm, the cluster heads do not need to transfer their data to the sink directly and by the help of other nodes, they can transfer their data to the sink with the least possible hops.
- During all steps of the proposed algorithm, sensor nodes only need to send and receive data within their radio range and they do not need to send messages in a more range, and this will reduce the energy consumption of the nodes.
- Comparing the performance of the proposed algorithm with the other similar algorithms in different scenarios by using simulation.

The rest of this paper is organized as follows: Next section describes the related work. Section 3 describes the network model used in our algorithm. Section 4 presents our proposed algorithm in detail. To evaluate the performance of the proposed algorithm, the simulation setup and results are presented in section 5. Finally, Section 6 concludes the paper.

II. RELATED WORKS

In this section, we present some typical clustering methods, which are proposed and improves network lifetime of wireless sensor networks.

Low Energy Adaptive Clustering Hierarchy (LEACH) [17] is a clustering protocol proposed for periodical data gathering applications in wireless sensor networks. In LEACH, a sensor node independently elects itself as the cluster head with a probability. Cluster heads receive and aggregate data from cluster members and send the aggregated data to the base station (BS) by single-hop communication. Despite the implementation of LEACH is simple, the performance in heterogeneous networks is not well because it does not consider the residual energy of nodes.

Hybrid Energy-Efficient Approach (HEED) [18] is a clustering protocol for wireless sensor networks. In HEED before a node starts executing HEED, it sets its probability of becoming a cluster head (CH_p) based on its residual energy. Using this probability, each node decides to become a tentative head or not. Tentative heads, declare themselves to their neighbors using a cluster-head message, and their CH_p probability. Once CH_p in a node reaches 1, it becomes a final head. Nodes, which are not head (tentative or final), upon receiving a cluster-head message, join to the declared cluster. HEED improves network lifetime over the LEACH. However, the performance of clustering in each round imposes significant overhead in the network. This overhead causes noticeable energy dissipation that result in decreasing the network lifetime. Similarly, many clustering algorithms are proposed like TEEN [19], APTEEN [20] and CEBCRA [21]. However, these are suffering from overhead and constructing a cluster in multiple levels is very complex task. Power-efficient gathering in sensor information systems (PEGASIS) is an energy efficient protocol for wireless sensor network [22] that improves LEACH. However, PEGASIS leads to significant redundant data transmission in the network. As a result, more energy consumption arises in the network.

Enhanced Centralized LEACH (ECLEACH) [23] is a new cluster-based protocol for wireless sensor networks. ECLEACH selects the cluster heads based on their residual energy, their distance to other sensor nodes and the residual energy of the other sensor nodes. ECLEACH keeps a minimum distance between every cluster head and the next in order to have a better distribution of cluster heads over the network. The simulation results show that ECLEACH has better performance than LEACH.

In [24], a new method is used for clustering in wireless sensor networks. In this method, the selection of cluster heads is more intelligent. In LEACH, cluster heads are selected randomly but in this algorithm, cluster head selection is based on a qualifying factor which is determined based on a series of specific parameters. In fact, in this method, the effect of choosing the cluster heads on routing optimization in wireless sensor networks is discussed.

In [25], the Particle Swarm Optimization (PSO) algorithms are applied to solve the clustering and routing problem in wireless sensor networks. In this method, first nodes transmit their information to the sinks. After that, the sink uses the PSO algorithm to solve the routing problem. Then once again, the sink uses PSO algorithm and solves the clustering problem. These two problems are NP-hard optimization problems. Thus, meta-heuristic algorithms can be used to solve these problems but these methods are centralized i.e. PSO algorithm is implemented in the sink.

In [26], a centralized balance clustering routing protocol based on location is proposed for wireless sensor network with the random distribution. In this protocol, a systematic algorithm has been designed for clustering to keep clustering balanced through the whole lifetime of the network and adapt to the non-uniform distribution of sensor nodes. In this protocol, first, the algorithm determines the number of clusters according to the condition of the network, and adjusts hexagonal clustering results to balance the number of nodes of each cluster. Second, it selects cluster heads in each cluster base on the energy and distribution of nodes, and optimizes the clustering result to minimize energy consumption. Finally, it allocates suitable time slots for transmission to avoid collision.

In [27], a hierarchical clustering algorithm for WSNs is presented. In this algorithm, it is assumed that the sink has the information of all sensor nodes in the network. In this algorithm, deployment area of the network is divided into several layers based on the radio range of the sensors and the farthest node of the sensor to the sink, then a number of cluster heads are characterized according to the distance of layers to the sink, then clustering will be done. In addition, in the routing section, sink finds the shortest path by using Dijkstra’s algorithm and then informs each cluster head about their next-hop. The main problem of this method is that some clustering steps need to get help from the sink, which makes the method be not completely distributed. In addition, sensor nodes must store their information like position in the sink.

In [28], a new clustering algorithm using differential evolution is proposed for WSNs. There are two types of nodes in this network: normal sensor nodes and gateway nodes. The gateway nodes acting as cluster heads. In this method, by considering the energy consumption of the nodes, it has been tried to maximize the lifetime of the network. The weakness of this method is that the differential evolution algorithm does not guarantee that the results always be good.

In [29], an energy-efficient routing protocol in wireless sensor networks has been proposed. In this protocol, particle swarm optimization (PSO) is used and clustering and routing among cluster heads are solved. The routing algorithm builds a trade-off between energy efficiency and energy balancing, whereas the clustering algorithm takes care of the energy consumption of gateways as well as sensor nodes. However, this method is a centralized method and consumes more energy in the clustering phase.

In [30], the clustering and routing problem in WSNs have been studied and a new routing protocol has been introduced for these problems. The proposed algorithm is based on a pareto optimization-based approach. In order to define an exact definition of the clustering and routing problem in WSNs, the authors in this work use parameters such as the number of cluster heads, the number of clustered nodes, the link quality between the cluster members and cluster heads and the link quality of the constructed routing tree. The simulation results show that this method improves network performance. However, this method is a centralized method and the delay in this method is high.

In [31], an energy-efficient clustering algorithm based on Fuzzy-C is proposed for WSNs. The main purpose of this method is to balance the energy consumption in the network and extend the network lifetime. This method uses improved Fuzzy-C to divide the sensor nodes into a specified number of clusters. A single hop communication mode is used for exchanging message in each cluster and a multi-hop communication mode is used for exchanging messages between cluster heads and the sink. This method extends the network lifetime. However, the delay in this method is high.

By reviewing these methods, in this paper, a hierarchical clustering routing algorithm is proposed for WSNs that increases the network lifetime. The hierarchical clustering routing algorithm is designed with regard to the energy consumption of the nodes. The sink, which is the highest level of this hierarchical clustering, invites all its neighboring nodes to form clusters by sending a message and then the proper nodes are selected as the cluster heads. Then clusters are formed. Before explaining the proposed algorithm, the next section describes the network model used in this paper.

III. NETWORK MODEL

In this paper, the wireless sensor network includes a number of homogenous sensors that are deployed in a square region randomly with uniform distribution. Each sensor node is aware of own position in the network. The network includes a sink that there is no energy constraint on it. The sink is located at the center of the region. The sensor nodes and sink are stationary after deployment and their location is fixed. In this paper, the distance between two nodes is the Euclidean distance.

The energy model used in this paper is similar to [32]. The required energy to transfer k-bit data on distance d is calculated by equation (1).

$$E_{Tx}(k,d) = \begin{cases} kE_{elec} + k\varepsilon_{fs}d^2 & d < d_0 \\ kE_{elec} + k\varepsilon_{mp}d^4 & d \geq d_0 \end{cases} \tag{1}$$

The consumed energy to receive this message is based on equation (2).

$$E_{Rx}(k) = kE_{elec} \tag{2}$$

Where E_{elec} is the electron energy, ε_{fs} and ε_{mp} indicate the amplifier energy and d_0 is a threshold value.

IV. PROPOSED ALGORITHM

This paper proposes a hierarchical clustering algorithm called Multi-Level Clustering Algorithm (MLCA) for WSNs. In the hierarchy of MLCA, the sink is in the first level and clustering begins with the sink. First, the sink sends a message to invite all its neighbors to start the first level of clustering. Each node that receives the clustering invitation message analyzes its parameters such as the remaining energy, the distance to the sink and the number of neighbors and shares them with its neighbors. Each node that has the best value for these parameters is selected as the cluster head and invites the rest of nodes to join the cluster. After that, the cluster heads are determined in the first level and clustering is conducted, the selected cluster heads analyze the member sensor nodes of the cluster and choose one (or more) of their cluster members with the maximum distance to the sink and send a next level clustering message to it (or they). Then, selected sensor nodes by cluster heads, broadcast Start-Clustering-Level-2 message. The sensor nodes that receive this message and are not cluster head or cluster member, start the second-level of clustering like the first-level. This procedure continues until all nodes become a member of a cluster or selected as the cluster head. Different parts of the MLCA algorithm are discussed in detail below. The used messages list is given in Table 1.

A. Start Clustering and First Level of Hierarchy

The first level of clustering begins with the sink. The sink broadcasts the "Start-Clustering-Level-1" message to its neighbor nodes and invites them to a competition to cluster heads selection. Only the nodes that receive the “Start-Clustering-Level-1” message start clustering. This message includes the

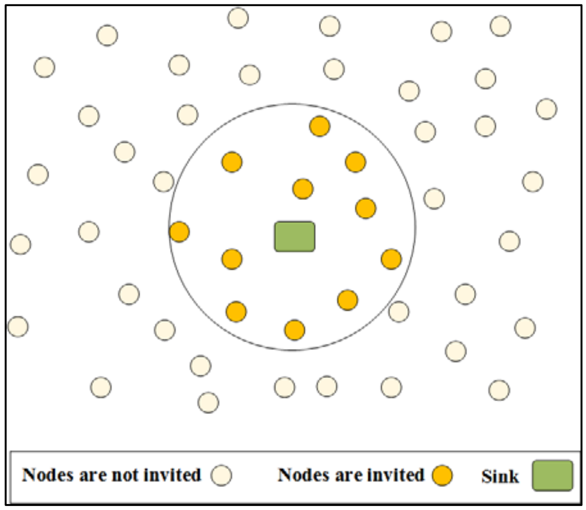

Fig. 1. Start clustering in the first level.

Table 1. Messages list.

Message	**Description**
Start-Clustering-Level-1	Start clustering in the first level
Clustering notification	This is a message to the farthest cluster member
Start-Clustering-Level-2	Start clustering in the second level
Start-Clustering-Level-*n*	Start clustering in *n*-th level

sink information such as its position. Initially, each sensor node calculates its distance to the sink and puts it in Dist.-To-Sink variable. Then it puts the energy value and the number of neighboring sensor nodes in Residual-Energy and Number-Of-Neighbor respectively.

After that, each node calculates a value based on these three parameters which represent the amount that the node qualify to be the cluster head. The Dist.-To-Sink parameter is more important than the other two parameters because the closer node to the sink could transmit data messages to the sink with lower power consumption (based on the applied energy model). Therefore, this parameter' weight must be more than the other two parameters. The residual-energy parameter is more important than Number-Of-Neighbor because a cluster head endure more traffic. Therefore, the weight of Residual-Energy parameter should be higher than Number-Of-Neighbor parameter.

Calculating the node qualify to be cluster head is as follows:

$$\text{Qualify} = a \times \left(\frac{DistToSink}{AreaSize}\right) + b \times \left(\frac{ResidualEnergy}{maximumEnergy}\right) + c \times \left(\frac{NumberOfNeighbor}{numberOfNodes}\right), \tag{3}$$

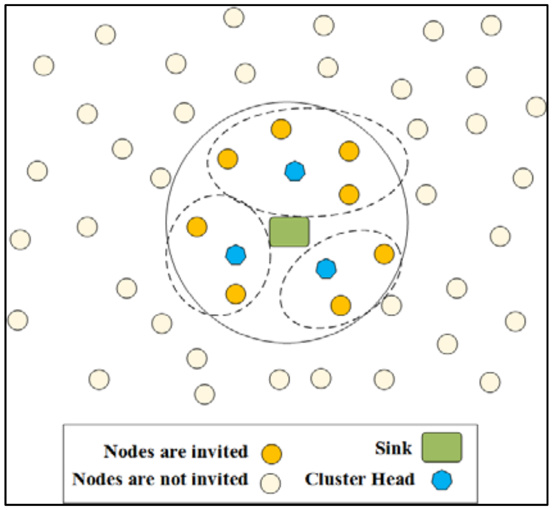

Fig. 2. After clustering in the first level.

where $a + b + c = 1$, $a > b$, $a > c$ and $b > c$ and $a, b, c \in \mathbb{Q}$. The values of these parameters are determined by simulation in Section V. Fig. 1 presents the wireless sensor network when clustering starts in the first level.

As shown in Fig. 1, the nodes within the radio range of the sink receive the invitation message to clustering and enter the first level of clustering.

After each sensor node calculates its qualify value, it shares this amount with own neighbors. Sensor nodes compare their qualify value with other neighbors. If the value of the node is greater than its neighbor nodes, that node changes its status to a cluster head node. Otherwise, it will remain as a normal sensor node and waits to receive the message to join a cluster.

Each node that changed its status to a cluster head sends a "Join" message to its neighbors. Each normal sensor node that receives the "Join" message and it is not a cluster member selects the "Join" message sender node as its cluster head. If a node receives multiple "Join" messages, it selects the node with the maximum qualify as its cluster head. After selecting a cluster head, it sends a "Request-Join" message to the cluster head and becomes a cluster member.

Fig. 2 shows the wireless sensor network after the first level of clustering. In this figure, the dotted circular shapes present the clusters where there are three clusters in this example.

B. Second Level of Hierarchy

After the first level of clustering and determining the cluster heads, it is the second level of clustering turn. Each cluster node analyzes the list of the cluster member nodes in the first level, chooses one (or more) cluster member node with the greatest distance from the sink and sends a next level "Clustering notification" message to it (or them). As soon as receiving the message, each sensor

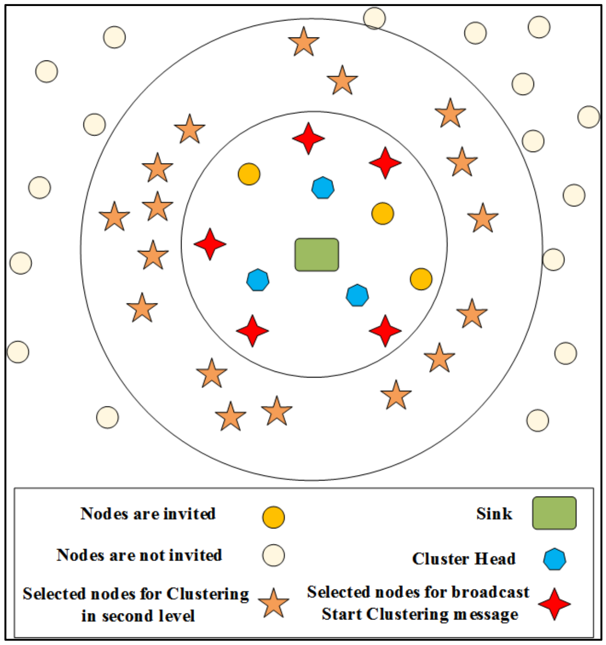

Fig. 3. The second level of clustering and invited nodes.

node specified in "Clustering notification" message sends the "Start-Clustering-Level-2" message to its neighboring nodes and invites them to a competition to select the cluster heads. At this level, only the nodes that received the "Start-Clustering-Level-2" message and are more distant from the sink and are not a member of any cluster, start their second level of clustering (i.e. the nodes that are farther from the sink, participate in the second level of clustering). In this message, the data about the sink position and message transmitter position is saved. The sensor nodes that receive the message begin clustering.

Fig. 3 presents the network for the second level of clustering. In this figure, the inviting nodes and the invited nodes for clustering in the second level are presented. Some of the cluster members in the first level of clustering (red stars) with greater distance to the sink are selected as the inviting nodes and broadcast the start clustering message to the second level of clustering in the network.

The invited nodes to the second level of clustering calculate their qualify value according to the equation (3) and share this value with their neighbors as the previous level. Sensor nodes compare their qualify value with their neighbors. If the value of the node is greater than its neighbors, the node changes its status to a cluster head. Otherwise, it remains as a normal sensor node and waits to receive the massage to join a cluster.

Each node that changed its status to a cluster head sends a "Join" message to its neighbors. Each normal sensor node that receives the "Join" message and it is not a cluster member, selects the "Join" message sender node as its cluster head. If a node receives multiple "Join" messages, it selects the node with the maximum qualify as its cluster head. After selecting a cluster head, it sends a "Request-

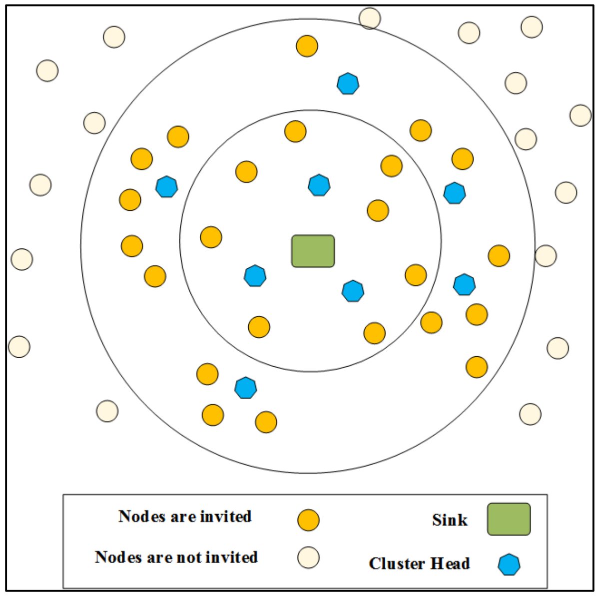

Fig. 4. After clustering in the second level.

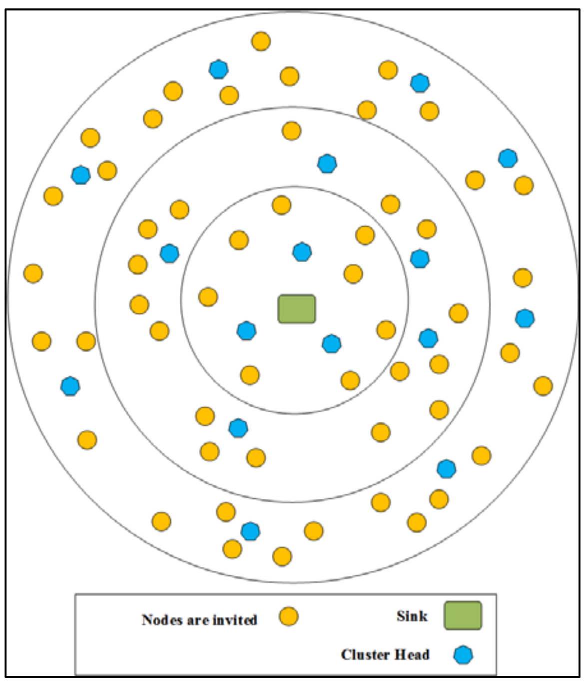

Fig. 5. After clustering in n-th level.

Join" message to the cluster head and becomes a cluster member. Fig. 4 shows the wireless sensor network status after the second level of clustering.

C. *n-th Level of Hierarchy*

When clustering in level $n-1$ is done, to clustering in level n, the cluster heads in level $n-1$, find the farthest cluster member nodes to the sink and send them the "Clustering notification" message. The selected cluster member nodes send a "Start-Clustering-Level-n" message to their neighbors. Then the invited nodes begin calculation of qualify value and similar to the first and second levels, the cluster heads are elected and conduct clustering. Fig. 5 shows the network structure for clustering in level n.

This procedure continues until all nodes become a cluster head or a member of a cluster.

D. *Routing in MLCA Protocol*

The nodes send their data to their cluster heads. The cluster heads should transfer their data to the sink. In order to send data by cluster nodes to the sink, the next-hop of each cluster head node should be one node towards the sink. In the first level of clustering, the next-hop of each cluster head is the sink. In the next level, the next-hop of each cluster head is the node that has sent the "Start-Clustering-Level-2" message. In general, the next-hop of a cluster head in the level n is equal to the "Start-Clustering-Level-$n-1$" message transmitter node that will be a member of a cluster in level $n-1$. The pseudocode of the clustering section is as follow:

Pseudocode 1: Clustering in MLCA protocol

```
1. Sink Broadcasts "Start-Clustering-Level-1"
2. If ( Message Received == "Start-Clustering-Level-n" ) // n = 1, 2, 3, …
   2.1. Compute Dist-To-Sink
   2.2. Compute Residual-Energy and Number-Of-Neighbor
   2.3. Compute f = a × DistToSink + b × ResidualEnergy + c × NumberOfNeighbor
   2.4. Broadcast f
   2.5. If ( f be bigger than neighbors)
        2.5.1. Change type to Cluster Head
        2.5.2. Broadcast "Join"
        2.5.3. Broadcast "Clustering notification"
   2.6. End if
3. End if
4. If ( Message Received == "Join" and NodeType == Normal Node )
        4.1.1. Send "Requst-Join" to Cluster Head
5. End if
6. If ( Message Received == " Requst-Join " and NodeType == Cluster Head )
        6.1.1. Save sender to cluster member list
7. End if
8. If ( Message Received == "Clustering notification" )
   8.1. Broadcast "Start-Clustering-Level-i" // i ∈ {2,3,4, ... }.
9. End if
```

E. *Re-clustering*

In the proposed algorithm, we assume each round is equivalent to the time it takes for all nodes to

Table 2. Simulation parameters.

Parameter	**Value**
Number of nodes	100
Sensor field	$200\text{m} \times 200\text{m}$
Sink position	x=100,y=100
Data packet size	500 bytes
Control packet size	200 bits
Communication Range	30 m
The initial energy of nodes	1-4 J
$\boldsymbol{E_{elec}}$	50 nJ/bit
$\boldsymbol{\varepsilon_{fs}}$	$10\ \text{pJ/bit}\ \text{m}^2$
$\boldsymbol{\varepsilon_{mp}}$	$0.0013\ \text{pJ/(bit}\ \text{m}^4)$
$\boldsymbol{E_{sen}}$	$0.2\ \text{J/bit}$

send their data to their cluster headers, and then the cluster heads transfer the data to the sink. When clustering is done, the cluster head nodes are more overhead, and the relay nodes that are chosen by cluster heads to send data to the sink consume more energy. In order to energy consumption be balanced and also increasing the network lifetime of the network, clustering operation should re-perform periodically. In fact, after completing a number of rounds, the sink resends the "Start-Clustering-Level-1" message to its neighbors, and the clustering operation is re-executed. The number of rounds between each clustering should not be too low because it makes clustering operation execute more and the nodes' energy is spent on clustering operations. On the other hand, this amount should not be too much because it causes some nodes to finish their energy sooner. In this paper, the number of rounds between each clustering is equal to 70, which is obtained based on the simulation accomplished in the next section and it is the optimal amount.

V. PERFORMANCE EVALUATION

In this part, the proposed algorithm (MLCA) will be evaluated by simulation. All simulations are done by OMNeT++. The sink is fixed and located at the center of the region. Sensor nodes are deployed randomly with uniform distribution in the region. The size of the region is $200\ m \times 200\ m$. The initial energy of the nodes is a random amount within the range of $[1J, 4J]$. In Table 2, the full list of the simulation parameters is presented.

In the MLCA algorithm, the selected values are equal to 0.5, 0.3 and 0.2 for parameters a, b and c, respectively. The proposed algorithm is compared with LEACH (Low-Energy Adaptive Clustering Hierarchy) [17], HEED (Hybrid Energy-Efficient Distributed clustering) [18] and ECLEACH (Enhanced Centralized LEACH) [23]. LEACH selects the cluster heads randomly. In this method, the

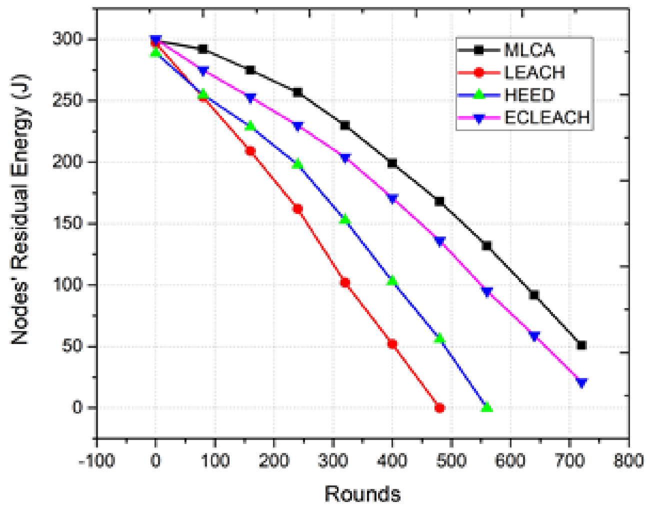

Fig. 6. Comparison of residual energy.

cluster heads send the data to the sink directly. The algorithm HEED is an improved version of LEACH that uses the energy level of the nodes to choose the cluster heads. The algorithm ECLEACH use three parameters residual energy, distance to other sensor nodes and the residual energy of the other sensor nodes to select cluster heads. LEACH, HEED, and ECLEACH are three fundamental clustering algorithms that are suitable criteria for evaluating the efficiency of the proposed algorithm in this paper. Furthermore, these algorithms are very similar to the proposed algorithm in this paper and comparison with these algorithms better shows the performance of the proposed algorithm. In addition, in designing the proposed algorithm of this paper, these three fundamental algorithms are considered and the weaknesses and advantages of these three algorithms are reviewed and the proposed algorithm tries to eliminate the weaknesses of these algorithms. All simulations have been done with the same parameters based on Table 2.

A. Residual Energy

Fig. 6 shows the residual energy in algorithms. Energy consumption is higher in LEACH because this algorithm randomly selects cluster heads and direct data transfer from the cluster head to the sink causes more energy consumption. HEED algorithm has less energy consumption than LEACH regarding the energy consumption for clustering.

Energy consumption of ECLEACH is less than LEACH and HEED algorithm because it considers more parameters to select the cluster head and cluster heads are selected properly. MLCA algorithm has more residual energy in comparison with other algorithms because it does not use a random process to choose cluster heads and they are elected according to equation (3). In addition, next-hop of each cluster head is selected to message transmitting to the sink with less hop. As it is clear from this diagram, the LEACH algorithm operates for fewer than 500 rounds, and the energy finishes. In

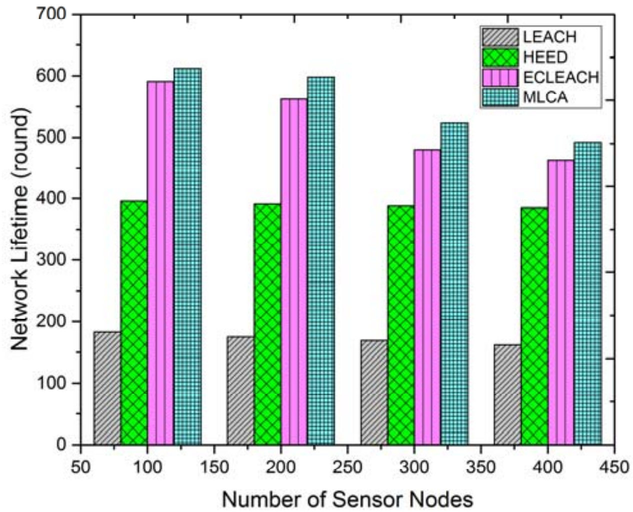

Fig. 7. Network Lifetime under different number of nodes.

the HEED algorithm, there are about 560 rounds, and then the energy finishes. At the round of 720 in the ECLEACH and MLCA algorithms their energy has not finished yet, but in this round, the remaining energy of MLCA algorithm is close to 50 Jules, and in the ECLEACH algorithm, it is close to 20 Jules.

B. Network Lifetime

In this paper, network lifetime reflects the time span from the network's initial deployment until the first node dies. Fig. 7 displays the network lifetime for algorithms based on this definition. In this diagram, simulation is done for various size of network, 100, 200, 300 and 400 nodes. The network lifetime is measured based on the round.

As this diagram shows, by increasing the number of nodes in the network, the network lifetime is reduced because of the number of messages transmitted in the network increases. In fact, by increasing the number of nodes in the network, the control messages broadcasted for clustering and routing in the network are increased and also more data messages are sent to the sink. Therefore, the network lifetime is reduced but MLCA has a longer lifetime than other methods because the cluster heads are selected properly and they transfer data to the sink in a shorter distance. In addition, in this algorithm, cluster heads are selected based on different parameters, so that the cluster heads are chosen more appropriately and a cluster head does not send its data to the sink directly and uses a multi-hop connection with the least hops. In the LEACH and ECLEACH algorithms, the cluster heads transfer their data to the sink directly, which increases the energy consumption of nodes and reduces the network lifetime. The MLCA algorithm uses more parameters to select cluster heads than the HEED algorithm, this makes choosing a cluster head to be more accurate than the HEED algorithm.

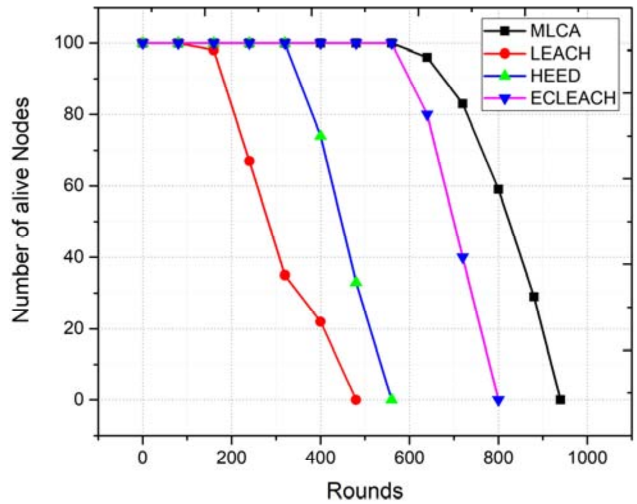

Fig. 8. Comparison of alive nodes.

C. Alive Nodes

Fig. 8 shows the number of alive nodes in each round for all algorithms with 100 sensor nodes. HEED algorithm optimizes the LEACH algorithm by considering the nodes' energy to cluster heads selection. ECLEACH algorithm optimizes the LEACH algorithm by considering three parameters to cluster heads selection. And also cluster heads selection procedure in MLCA algorithm, is done by considering three important parameters. However, in the MLCA algorithm, we do not use randomization in selecting cluster heads and their selection are based on node qualify. Also does not transmit data from cluster heads to the sink directly, because direct transmitting from cluster heads to the sink causes high energy consumption and nodes die sooner. As it is clear from this figure, there are no alive nodes in the ECLEACH algorithm in round 800, but in the MLCA algorithm, there are about 60 nodes alive at the same round.

VI. CONCLUSION

In this paper, the MLCA protocol, which is a multi-level clustering algorithm for routing in wireless sensor networks, has been proposed. In this protocol, the CHs are selected appropriately such that the locations of the CHs are appropriate and the cost of selecting the CHs and forming the clusters is very low. Simultaneously with selecting the CHs and forming the clusters, an optimal routing tree is formed in the network that connects the CHs to the sink. This protocol reduces energy consumption by providing a better clustering in the network and creating an optimal routing tree with the help of the virtual layer structure. Furthermore, the proper distribution of the CHs and the virtual layer structure distribute the traffic load on more nodes in the network, which increases the network lifetime. The simulation results show that the proposed protocol has lower energy consumption and a longer network lifetime than similar methods.

REFERENCES

[1] S. Srivastava, M. Singh, and S. Gupta, "Wireless Sensor Network: A Survey," *2018 Int. Conf. Autom. Comput. Eng. ICACE 2018*, vol. 38, no. 4, pp. 159–163, 2019.

[2] S. Vahabi, M. Lahabi, M. Eslaminejad, and S.E. Dashti, "Geographic and Clustering Routing for Energy Saving in Wireless Sensor Network with Pair of Node Groups," *Journal of Communication Engineering*, vol. 8, no. 1, pp. 146-157, Winter and Spring 2019.

[3] K. M. Modieginyane, B. B. Letswamotse, R. Malekian, and A. M. Abu-Mahfouz, "Software defined wireless sensor networks application opportunities for efficient network management: A survey," *Comput. Electr. Eng.*, vol. 66, pp. 274–287, Feb. 2018.

[4] H. Yetgin, K. T. K. Cheung, M. El-Hajjar, and L. Hanzo, "A Survey of Network Lifetime Maximization Techniques in Wireless Sensor Networks," *IEEE Commun. Surv. Tutorials*, vol. 19, no. 2, pp. 828–854, Secondquarter 2017.

[5] K. Sha, J. Gehlot, and R. Greve, "Multipath routing techniques in wireless sensor networks: A survey," *Wirel. Pers. Commun.*, vol. 70, no. 2, pp. 807–829, May 2013.

[6] R. Yarinezhad, "Reducing delay and prolonging the lifetime of wireless sensor network using efficient routing protocol based on mobile sink and virtual infrastructure," *Ad Hoc Networks*, vol. 84, pp. 42–55, Mar. 2019.

[7] H. Toral-Cruz, F. Hidoussi, D. E. Boubiche, R. Barbosa, M. Voznak, and K. I. Lakhtaria, "A survey on wireless sensor networks," *Next Gener. Wirel. Netw. Secur. Priv.*, vol. 71, pp. 171–210, 2015.

[8] R. Yarinezhad and S. N. Hashemi, "An efficient data dissemination model for wireless sensor networks," *Wirel. Networks*, vol. 25, no. 6, pp. 3419–3439, Aug. 2019.

[9] N. Kaur, S. Verma, and Kavita, "A survey of routing protocols in Wireless Sensor Networks," *Int. J. Eng. Technol.*, vol. 7, no. 4, pp. 20–25, 2018.

[10] O. Boyinbode, H. Le, A. Mbogho, M. Takizawa, and R. Poliah, "A survey on clustering algorithms for wireless sensor networks," *Proc. - 13th Int. Conf. Network-Based Inf. Syst. NBiS 2010*, vol. 30, no. 14–15, pp. 358–364, 2010.

[11] M. M. Afsar and M. H. Tayarani-N, "Clustering in sensor networks: A literature survey," *J. Netw. Comput. Appl.*, vol. 46, pp. 198–226, Nov. 2014.

[12] S. Tyagi and N. Kumar, "A systematic review on clustering and routing techniques based upon LEACH protocol for wireless sensor networks," *J. Netw. Comput. Appl.*, vol. 36, no. 2, pp. 623–645, March 2013.

[13] R. Yarinezhad and S. N. Hashemi, "A cellular data dissemination model for wireless sensor networks," *Pervasive Mob. Comput.*, vol. 48, pp. 118–136, Aug. 2018.

[14] H. Echoukairi, K. Bourgba, and M. Ouzzif, "A survey on flat routing protocols in wireless sensor networks," *Lect. Notes Electr. Eng.*, vol. 366, pp. 311–324, Feb. 2016.

[15] K. Guleria and A. K. Verma, "Comprehensive review for energy efficient hierarchical routing protocols on wireless sensor networks," *Wirel. Networks*, vol. 25, no. 3, pp. 1159–1183, April 2019.

[16] R. Yarinezhad and S. N. Hashemi, "Distributed faulty node detection and recovery scheme for wireless sensor networks using cellular learning automata," *Wirel. Networks*, vol. 25, no. 5, pp. 2901–2917, May 2019.

[17] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-efficient communication protocol for wireless microsensor networks," in *Proceedings of the Hawaii International Conference on System Sciences*, 2000, p. 223.

[18] C. H. Lin and M. J. Tsai, "A comment on 'HEED: A Hybrid, Energy-Efficient, Distributed clustering approach for ad

hoc sensor networks,'" *IEEE Trans. Mob. Comput.*, vol. 5, no. 10, pp. 1471–1472, Oct. 2006.

[19] A. Manjeshwar and D. P. Agrawal, "TEEN: A routing protocol for enhanced efficiency in wireless sensor networks," in *Proceedings - 15th International Parallel and Distributed Processing Symposium, IPDPS 2001*, 2001, vol. 1, pp. 2009–2015.

[20] A. Manjeshwar and D. P. Agrawal, "APTEEN: A hybrid protocol for efficient routing and comprehensive information retrieval in wireless," in *Proceedings - International Parallel and Distributed Processing Symposium, IPDPS 2002*, 2002, p. 195.

[21] P. Kuila and P. K. Jana, "An energy balanced distributed clustering and routing algorithm for Wireless Sensor Networks," in *Proceedings of 2012 2nd IEEE International Conference on Parallel, Distributed and Grid Computing, PDGC 2012*, 2012, pp. 220–225.

[22] S. Lindsey and C. S. Raghavendra, "PEGASIS: Power-efficient gathering in sensor information systems," in *IEEE Aerospace Conference Proceedings*, 2002, vol. 3, pp. 1125–1130.

[23] M. Bsoul, A. Al-Khasawneh, A. E. Abdallah, E. E. Abdallah, and I. Obeidat, "An energy-efficient threshold-based clustering protocol for wireless sensor networks," *Wirel. Pers. Commun.*, vol. 70, no. 1, pp. 99–112, 2013.

[24] M. Tarhani, Y. S. Kavian, and S. Siavoshi, "SEECH: Scalable energy efficient clustering hierarchy protocol in wireless sensor networks," *IEEE Sens. J.*, vol. 14, no. 11, pp. 3944–3954, 2014.

[25] S. K. Gupta and P. K. Jana, "Energy Efficient Clustering and Routing Algorithms for Wireless Sensor Networks: GA Based Approach," *Wirel. Pers. Commun.*, vol. 83, no. 3, pp. 2403–2423, 2015.

[26] J. Chen, Z. Li, and Y. H. Kuo, "A centralized balance clustering routing protocol for wireless sensor network," *Wirel. Pers. Commun.*, vol. 72, no. 1, pp. 623–634, 2013.

[27] S. Siva Ranjani, S. Radha Krishnan, C. Thangaraj, and K. Vimala Devi, "Achieving energy conservation by cluster based data aggregation in wireless sensor networks," *Wirel. Pers. Commun.*, vol. 73, no. 3, pp. 731–751, 2013.

[28] P. Kuila and P. K. Jana, "A novel differential evolution based clustering algorithm for wireless sensor networks," *Appl. Soft Comput. J.*, vol. 25, pp. 414–425, 2014.

[29] M. Azharuddin and P. K. Jana, "PSO-based approach for energy-efficient and energy-balanced routing and clustering in wireless sensor networks," *Soft Comput.*, vol. 21, no. 22, pp. 6825–6839, 2017.

[30] R. Elhabyan, W. Shi, and M. St-Hilaire, "A Pareto optimization-based approach to clustering and routing in Wireless Sensor Networks," *J. Netw. Comput. Appl.*, vol. 114, pp. 57–69, 2018.

[31] S. El Khediri, A. Thaljaoui, A. Dallali, W. Fakhet, and A. Kachouri, "An optimal clustering mechanism based on k-means for wireless sensor networks," *2018 15th Int. Multi-Conference Syst. Signals Devices, SSD 2018*, vol. 18, pp. 677–682, 2018.

[32] W. B. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan, "An application-specific protocol architecture for wireless microsensor networks," *IEEE Trans. Wirel. Commun.*, vol. 1, no. 4, pp. 660–670, 2002.