A New Preventive Routing Method Based on Clustering and Location Prediction in the Mobile Internet of Things

Mahyar Sadrishojaei, Nima Jafari Navimipour*, Midia Reshadi, and Mehdi Hosseinzadeh

***Abstract*— In the world of the Internet of Things (IoT), Wireless Sensor Networks (WSN) are an impressive technology. These networks are extremely resource-constrained and require the design of energy-efficient routing techniques. The Clustering and Location Prediction Routing Method based on Multiple Mobile Sinks (CLRP-MMS) for Mobile Internet of Thing (MIoT) is presented in this article. Recently, mobile sinks are used in routing more durability and energy saving in WSN. In this work, first, the entire nodes are divided into clusters, and then each cluster selects a Cluster Head (CH) by calculating the CH Choosing Function (CHCF). When clustering runs on networks with moving nodes, the possibility of disconnecting the nodes from CH nodes will cause a lot of data loss. It will change the amount of energy and rate of data received, but the amount of wasted energy is reduced by predicting the location and reducing the sink and CH nodes' distance. The simulation results using NS-2 clearly showed that the proposed method improves energy consumption at least 28.12% and increases throughput at least 26.74% compared to EERAMSS and HALPDGSMS methods.**

***Index Terms*— Internet of things; Wireless sensor network; Clustering; Routing protocol; Location prediction; Mobile sink.**

I. INTRODUCTION

Internet of Things (IoT) is one of the growing innovations that allows physical devices to communicate through heterogeneous networks [1, 2]. This smart grid uses embedded technology to communicate, sense, control, and plan [3]. IoT provides instant access to information on any high-efficiency and high-performance device [4]. Forecasts show that by 2020 we will have about 50 billion devices connected, of which nearly 5 billion smart devices are now connected [2, 3]. Humans will have a tiny share of producers and recipients in the massive traffic that will occur [5]. It illustrates the reason for exploring the world of IoT in different research areas because of its opportunities and challenges.

Wireless Sensor Networks (WSN) are essential in IoT [6, 7], as these networks include many vital IoT applications. In an IoT network, just like WSN, the nodes have batteries that accommodate converters to check and receive data from the environment [5]. Nodes transmit sensed data autonomously by preparing wireless networks and using embedded wireless radio. They are connected to external networks or the Internet to transmit sensed data to remote users. Although nodes have severe limitations concerning battery life, storage, communication, and computing, nodes working together can do a more critical job effectively [8].

Hierarchical or clustered routing is a better option for sensor networks than flat routing. In cluster-based approaches, scalability is more important, and these methods try to reduce overhead. These methods attempt to keep the network performance at an optimum level, although the network may have many moving nodes [9]. Cluster Head (CH) nodes are responsible for receiving data in cluster-based approaches, and besides, they play a role in controlling the node's task cycle [10]. CH nodes are periodically updated to share routing responsibilities between nodes. Clustering can reduce redundant and duplicate data transfer and also reduces the loss of data. In recent years, several clustering techniques [11] have been proposed to save energy [12]. Based on the existing features, clustering consists of two types; equal and unequal [11]. Regarding energy efficiency, the unequal clustering strategy [13, 14] is more promising than the equal clustering strategy.

In the Mobile Internet of Thing (MIoT), the nodes' movement causes many changes in the topology, disrupting the connection of the CH nodes and the Cluster Member (CM) nodes, which results in slow data transfer rates, and high data loss. Due to these reasons, in addition to location and energy, the mobility of nodes is also considered as an essential factor in clustering techniques, such as Low Energy Adaptive Clustering Hierarchy Mobile Enhanced (LEACH-ME) [15], LEACH-Mobile [16], etc. [17, 18].

In many wireless networks, nodes with less distance from the sink have more traffic than nodes beyond the sink [10, 19], so mobile sinks are used as an effective solution to this problem in

Mahyar Sadrishojaei is with the Department of Computer Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran (Email: mahyar_sadri@srbiau.ac.ir)
Nima Jafari Navimipour is with the Future Technology Research Center, National Yunlin University of Science and Technology, 123 University Road, Section 3, Douliou, Yunlin 64002, Taiwan, R.O.C. and the Department of Computer Engineering, Tabriz Branch, Islamic Azad University, Tabriz, Iran (corresponding author) (*Email: JNNima@Yuntech.edu.tw, Jafari@iaut.ac.ir)
Midia Reshadi is with the Department of Computer Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran (Email: reshadi@srbiau.ac.ir)
Mehdi Hosseinzadeh is with the Institute of Research and Development, Duy Tan University, Da Nang 550000, Vietnam and Mental Health Research Center, Psychosocial Health Research Institute, Iran University of Medical Sciences, Tehran, Iran (Email: hosseinzadeh.m@iums.ac.ir)

WSN. The benefits of sink mobility are as follows. First, the problem of "hot spots" [20-22] is greatly reduced by moving the sink. Second, it reduces overall energy consumption [23-25]. Third, it increases network throughput. Finally, under distributed or separate sensor networks, connectivity can be guaranteed. Although introducing sink mobility has many benefits, it presents some problems and challenges. The mobile sink location must be repeatedly broadcast or predicted by the nodes, which may increase the network load. The sink mobility pattern must also use an optimized design to work well for data transfer [26]. In this work, a method for location prediction and cluster routing is proposed to help multiple mobile sinks reduce energy consumption, increase reliability and network lifetime.

Briefly, the contributions of the presented method are summarized as follows.

- Presenting a method for solving a routing problem of MIoT using Clustering and Location Prediction Routing Method based on Multiple Mobile Sinks (CLRP-MMS);
- Modeling the location prediction, clustering network, and highlighting their features;
- Offering a routing method for optimization of lifetime and energy consumption;
- Evaluating the performance of clustered routing and location prediction with multiple mobiles sinks.

The rest of the article is as follows. Section II reviews the previous related work. Section III contains CLRP-MMS with details. Section IV provides performance evaluation. Finally, the conclusion and future work are discussed in Section V.

II. LITERATURE REVIEW

Wang, Cao [27] have described energy-efficient dynamic routing with mobile sinks based on clustering for WSN. Depending on the residual energy, the CH nodes are selected. The lifespan of the WSN is extended by optimal routes and the limitation of sending update messages to a certain number of CH nodes. The CH node changing mechanism reduces the hotspot problem. Lack of support of unequal clusters and node mobility are the main disadvantages of this method.

Sasirekha and Swamynathan [28] have introduced a routing algorithm called Cluster Chain Mobile Agent Routing clustering (CCMAR) that deploys WSN in several clusters that run in two steps. In the first step, nodes in the cluster are performed chain formation to aggregate the data into the CH nodes. In the second step, a Mobile Agent (MA) from the sink node is sent to collect data from all the CH nodes. CCMAR is better than LEACH and PEGASIS in terms of power consumption, transmission latency, and network lifetime. Data collection by different routing methods seems to be greatly affected by the underlying network topology. The MA is computationally superior, but effective dissemination of information on this algorithm is one of the disadvantages of this method due to fault tolerance and security problems in MA use.

Also, Koosheshi and Ebadi [29] have proposed unequal clustering with multiple sinks using fuzzy logic, considering the residual energy, the distance to the nearest Rendezvous Nodes (RN), and the calculated density as the input variables of fuzzy logic. It means that these variables are considered to measure the competitive radius of each experimental CH node. It has also created and proposed a way to select the mobile sink path intelligently. This method increases the lifespan of the network. Still, optimizing the mobile sink movement path and using multiple mobile sinks are some of the weaknesses of this method.

Gharaei, Bakar [30] have presented the Collaborative Mobile Sink Sojourn Time Optimization (CMS2TO) scheme to optimize the duration of MS stay in each cluster to balance the lifespan of CH nodes in different network layers. Many mobility-based schemes use unpredictable mobility patterns, which increase energy consumption. THE CMS2TO uses a collaborative scheme in which all CH nodes work together to calculate the mobile sink residence time in each cluster, which gives the CH nodes balanced longevity. CMS2TO increases network lifespan, the number of live nodes, and the amount of residual energy. However, it does not support node mobility and is not suitable for large scale networks.

Furthermore, Kim and Chung [16] have presented a mobile-based protocol for WSN that supports moving nodes for a typical "hot zone" environment. The introduced protocol goes beyond LEACH by reducing data packet loss for moving nodes. It sends a message that transmits the data transfer request to the mobile sensor node from the cluster within a specified time interval in the Time Division Multiple Access (TDMA) schedule. Because the moving node and the CH node confirm that the moving node is in a particular cluster and in the same time slot in the TDMA, it has better network quality and data transfer than LEACH. However, compared to LEACH, the energy lost is increased.

Vahabi, Eslaminejad [31] have described the Integration of Geographic and Hierarchical Routing (IoGHR) with mobile sinks to save energy in the WSN. The network model used in IoGHR consists of the main section with many virtual parts, each containing a CH node. The direction of the movement of the mobile sink is predetermined and is moving back and forth inside the virtual parts of the central section. This algorithm increases the lifetime of the network by increasing the amount of remaining energy. IoGHR has less latency and higher delivery ratio than existing algorithms, but it does not consider a variety of topics, such as optimal route and multiple mobile sinks.

In addition, Zhu, Quan [32] have proposed a High-Available and Location Predictive Data Gathering Scheme using Mobile Sinks (HALPDGSMS). In this strategy, time sync helps nodes find sink locations, thereby reducing nodes' power consumption to update sink locations; also, data collection will generally continue if some sinks are unable to work. One can also balance the energy consumption of the nodes near stationary points by adjusting the direction of a mobile sink's movement. However, when the nodes are mobile, and there is an obstacle in the place of residence, the data upload to the mobile sink is significantly affected.

Huang, Liu [33] have explained a low-cost Baseline Data based Verifiable Trust Evaluation (BD-VTE) security scheme that includes effective trust assessment, rational incentives, and route adjustment. This method uses unmanned aerial vehicles (UAVs) to assess the reliability of mobile vehicles (MVs). The

BD-VTE design increases accuracy and improves data collection. The cost of collecting information is more logical, and security is also ensured more effectively. High overload, lack of support for clustering, and high complexity are the disadvantages of this method.

In addition, Li, Liu [34] have described Trust Data Collections in the Smart Internet of Things (T-SIoTs). To optimize security, the Data Center (DC) selects trusted vehicles as mobile collectors through analysis and then builds several static data collection stations to ensure coverage of all data areas. DC uses uAVs to collect data from trusted vehicles and static stations. In this scheme, the first short path for UAVs is designed to reduce UAV energy consumption. Improving security in T-SIoTs is another advantage of this method. Unfortunately, the cost of this method is high, and it has a high overload.

Huang, Zhang [35] have presented a low-latency, energy efficiency, and reliable marine data collection scheme using AUV. In this article, clustering has been investigated using K-means, AUV path optimization through a greedy algorithm, and data collection based on matrix completion. The criterion for selecting the CH nodes in this method is the amount of distance. This scheme reduces the power consumption of nodes and AUVs as well as delays in data collection. It also increases network lifetime. Select optimized secondary cluster heads to optimize network performance further. Lack of support for multiple MAs for data collection and the non-optimal selection of CH nodes are the most critical weaknesses of this article.

Finally, Wang, Gao [36] have suggested the Energy Efficient Routing Algorithm with Mobile Sink Support (EERAMSS) as effective ways to improve WSN performance. This method first divides all the different nodes into several segments of the same size and selects a CH node for each segment according to its member weight. CM nodes calculate the path with optimal energy consumption for data transfer in single-hop and multi-hop to relevant CH nodes. Subsequently, the CH nodes adopt a greedy method to form chains for cluster communication. The authors investigated the effect of various parameters on network performance and improved it. A disadvantage of this method is the lack of support for the nodes' mobility, which disrupts the network's communication.

A side-by-side comparison of the methods examined in clustering with their main advantages and disadvantages is shown in Table I. The main problem with the studied methods in this section is high energy consumption, lack of support for node mobility, and incompatibility with mobile sinks. In the proposed method, the mentioned cases are solved using mobile sinks and selecting the CH node and the sink information exchange point.

TABLE I
SIDE BY SIDE COMPARISON OF DISCUSSING THE CLUSTERING MECHANISM

Mechanism	Approach	Advantage	Weakness
Wang, Cao [27]	Energy-efficient dynamic routing with mobile sinks	✓ reducing the hotspot problem ✓ extending network lifespan	• Without supporting of node mobility • Without supporting unequal clusters
Sasirekha and Swamynathan [28]	Cluster chain MA routing clustering	✓ Low power consumption ✓ Low latency ✓ High network lifetime	• Fault tolerance in MA • Security problems in MA
Koosheshi and Ebadi [29]	Unequal clustering with multiple sinks by using fuzzy logic	✓ Increasing network lifespan	• Without using of multiple mobile sinks • non-optimal mobile sink path
Gharaei, Bakar [30]	Collaborative Mobile Sink Sojourn Time Optimization	✓ High residual energy ✓ Increasing network lifespan ✓ Increasing the number of live nodes	• Without supporting of node mobility • Not suitable for large scale networks
Kim and Chung [16]	LEACH-Mobile	✓ Quality of the network ✓ Success data transfer	• Increasing energy loss
Vahabi, Eslaminejad [31]	Integration of geographic and hierarchical routing with mobile sinks	✓ High residual energy ✓ Increasing the lifetime	• Without supporting of an optimal route • Without using of multiple mobile sinks
Zhu, Quan [32]	High-available and location predictive data collection scheme using mobile sinks	✓ Balancing the energy	• Without supporting of node mobility • Without supporting paths with the obstacle
Huang, Liu [33]	Low-cost baseline data based verifiable trust evaluation	✓ Improving data collection ✓ Increasing accuracy	• Without supporting of clustering • High complexity
Li, Liu [34]	Trust data collections in the smart IoT	✓ Reducing energy consumption ✓ Improving security	• High overload • High cost
Huang, Zhang [35]	Low-latency AUV-assisted data gathering	✓ Reducing the power consumption ✓ Increasing network lifetime ✓ Low latency	• Without supporting of node mobility • Without using of multiple MAs • Non-optimal CH node selection
Wang, Gao [36]	Clustering and Mobile sink technology	✓ Improving network performance	• Without supporting of node mobility

III. PROPOSED METHOD

This section introduces a new method called CLRP-MMS to overcome the various problems of previous mechanisms. This method is more efficient in the number of live nodes, the total energy consumption, and packets received by the sink. The main advantages of the proposed method and its differences from the existing methods include the following:

- ✓ Node mobility supporting
- ✓ Simultaneous implementation of clustering and location prediction
- ✓ On-demand re-clustering
- ✓ Using multiple mobile sinks

The following sections describe the CLRP-MMS method in detail. The first section discussed the system model; next, the problem statement is expressed; finally, the proposed routing method has been provided.

A. System Model

Assuming N and S are the numbers of nodes and sinks, in which the path of mobile sinks is circular and predictable, these paths are ring-shaped. Uneven clusters are formed based on these paths in different segments. Mobile sinks have unlimited battery power, high storage capacity, and ample computing power. IoT devices continuously monitor the environment and send the collected data to the mobile sinks through their CH nodes [37]. The intra-cluster transition is planned in TDMA. CH nodes receive data from CM nodes and transmit the compressed data to the mobile sinks through single-hop communications. Transferring single-hop data to mobile sinks is a very effective way to extend the lifetime of wireless networks. Since the nodes are mobile and, in many cases, it is not possible to replace their batteries and also the power consumption has the most critical priority, the proposed method uses a one-hop connection between CM nodes to CH nodes as well from CH nodes to the sink, but this data transfer model may cause network latency.

It is necessary to consider the following logical assumptions in the system model.

- Homogeneous nodes are randomly distributed.
- The initial energy of the nodes is the same.
- All nodes are aware of their speed and location.
- The mobile sinks have unlimited battery power and high storage capacity.
- Data transmission and reception are the most important energy consumption activities.
- All links have sufficient data transfer capacity

In this method, the power consumption E_{TX} per node is related to the distance to the destination node and the size of data sent and is obtained by (1)[38, 39].

$$E_{TX}(l,d) = \begin{cases} l \times E_{elec} + l \times \varepsilon_{fs} \times d^2, & if\ d < d_0 \\ l \times E_{elec} + l \times \varepsilon_{mp} \times d^4, & if\ d \geq d_0 \end{cases} \tag{1}$$

l and d represent the number of data bits sent and the distance to the receiving node, respectively. The energy consumed per bit is given by E_{elec} when transmitting data ε_{fs} represent the coefficient of transfer amplification in open space. The amplification coefficient is shown by ε_{mp} when sending multi-path. The transfer threshold for nodes is set to d_0 and is usually equal to $\sqrt{(\varepsilon_{fs}/\varepsilon_{mp})}$ [40]. For the l bits in the receiver, the amount of energy consumed by the receiver is the E_{RX} value specified by (2)[38]:

$$E_{RX}(l) = l \times E_{elec} \tag{2}$$

Environmental monitoring programs require proper data routing to utilize network energy. In this article, the number of segments is determined by their angle, then the clusters are formed, and the CH node is selected based on the appropriate function. Finally, by moving the sinks in the specified paths, the data are collected from the CH nodes.

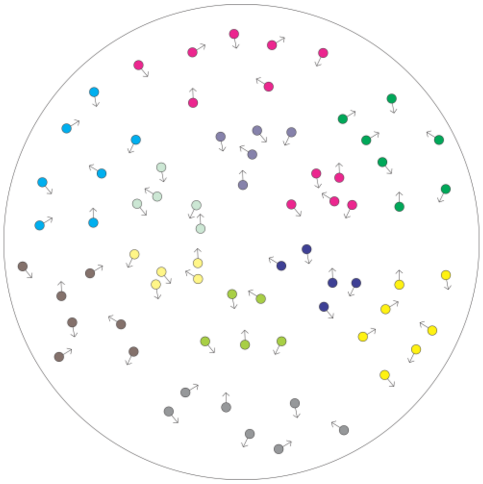

Fig. 1. Network model (the colored circles are the nodes and the arrows indicate their direction of movement)

B. Problem statements

In recent years, WSN is evolving rapidly and is used to collect environmental information. In the past, only static nodes were used to collect environmental information, but today, with the advancement of technology, mobile nodes are being used to gather information [8]. Nodes in an IoT network produce data at fast speeds and send it to the sink for specific purposes [41].

In this work, a cluster-based method with multiple mobile sinks is used. The mobile sink, which is usually mounted on a high-powered mobile vehicle, begins its periodic movement from a certain point and finally returns. The data of CH nodes are collected during the move. After planning the route, the mobile sink can move near the CH nodes and collects the data. Therefore, it consumes less energy. Although it is more challenging to implement hierarchical routing when nodes are moving, the combination of location prediction and clustering techniques in IoT networks works successfully.

In this method, the sinks are mobile and move very close to the CH node to receive the collected data. Therefore, the path loss between the CH node and the sink is negligible. Besides, due to the proximity of the sink to the CH node at the time of data collection, the probability of error is minimal, and no data retransfer is required.

C. Proposed routing method

The WSN operation uses a round-based approach that involves two main phases. Setup is the first phase and includes network deployment, cluster creation, CH selection, and re-clustering. The second one is the communication phase that defines the intra-cluster and inter-cluster relationship between nodes, CH, and sink. The number of rounds depends on network

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usage and lifetime. The phases of the research are generally significant in Fig. 2.

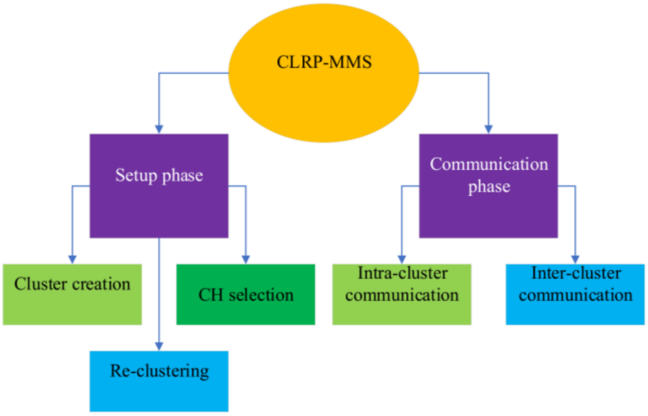

Fig. 2. Different phases of the method

Setup phase: This phase is about cluster creation, electing CH, and re-clustering. In the CLRP-MMS method, all nodes are eligible to become CH nodes and are selected through a new function. There are three sub-phases in this phase, cluster creation, CH selection, and re-clustering. The steps of the setup phase, with its general description, are shown in Fig. 3.

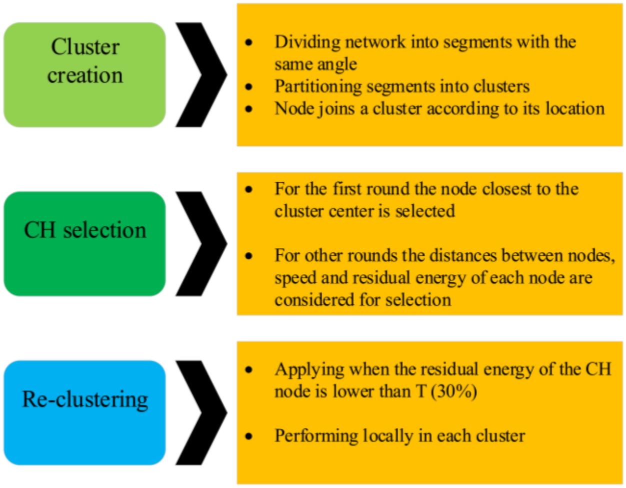

Fig. 3. Stages of the setup phase

1) Cluster creation: This new method uses multiple mobile sinks instead of a fixed sink where each sink is responsible for a certain number of clusters that can prevent data conflict from being sent to the mobile sink. In this sub-phase first, the entire nodes are divided into several segments, and the number of mobile sinks determines the number of clusters. The number of sinks was used to determine the angles of the segments. The proposed method uses two mobile sinks to collect data. Because when only one sink is used, in some cases, an inappropriate and considerable distance between the CH node and the sink increases energy consumption. Also, a lot of data is sent to the sink, which causes a lot of traffic and overload. In this article, the number of clusters should be even due to two mobile sinks. The ANG, which represents each cluster's angle in the network, is determined by (3).

$$ANG = \frac{2\pi}{\frac{K}{2}} \tag{3}$$

Where, K represents the number of clusters used in this work. In Fig. 4, an example of a network segmentation based on the angle calculated from the (3) can be observed.

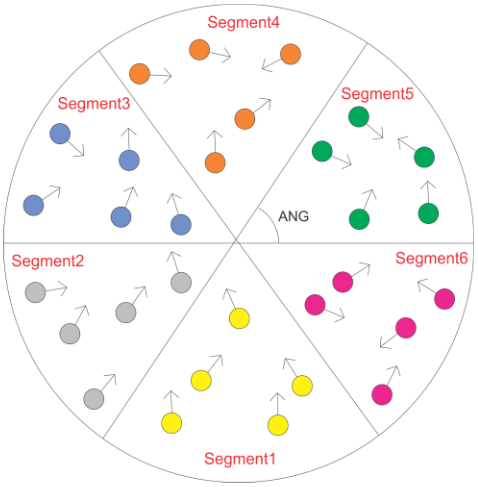

Fig. 4. Segmentation of the whole network

Fig. 5 shows an example of a network with unequal clusters containing 12 clusters $C_1, C_2, \dots, C_{12}$.
The number of nodes in each segment and each cluster is calculated from the following equations.

$$n_i = n * \frac{ANG}{2\pi} \tag{4}$$

$$nc_i = n_i * \frac{(2i-1)}{4} \quad (i = 1 \text{ to } 2) \tag{5}$$

Where n_i specifies the number of nodes in each segment and nc_i represents the number of nodes in each cluster (each cluster has $nc_i - 1$ CM nodes and only one CH node).

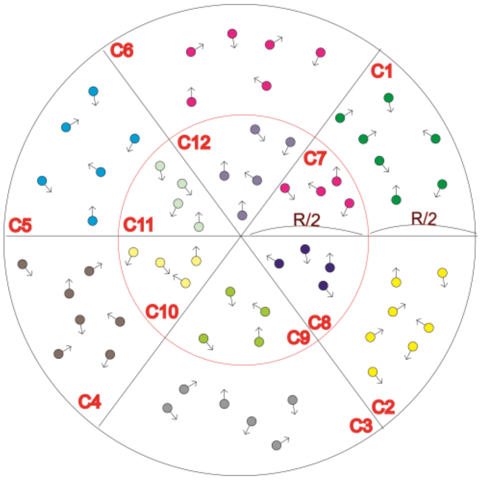

Fig. 5. Example of cluster creation

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*2)CH selection***:** Choosing the CH node is a complicated task because several factors must be considered to select the cluster's best node. New surveys conducted on the LEACH algorithm indicate that most CH selections are based on node distance from the sink or the residual energy [42-45]. Still, mobility can cause a node to leave a cluster, disrupting data transfer and destroying a cluster's stability. Therefore, besides the factors mentioned above, paying attention to slower nodes as desirable candidates is very important. In this article, for the first round, the closest node to the cluster's central area (Fig. 6) becomes CH since all nodes have the same energy [46].

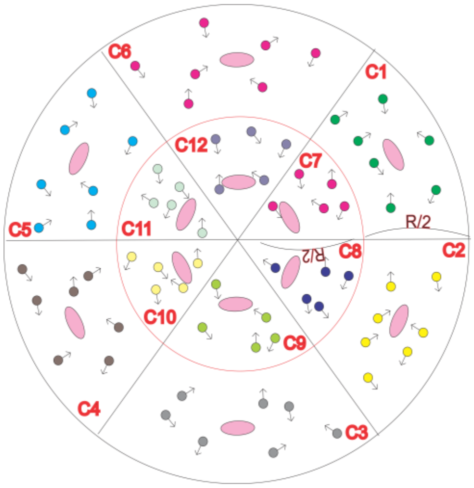

Fig. 6. The node closest to the center of the cluster (pink oval) is selected as the CH

After the first round, when the CH node needs to be selected, nodes calculate its CH Choosing Function (CHCF) using (6) based on the sum of distances between nodes, mobility speed, and the remaining energy in the node and sends the value to the current CH node [47]. Factors affecting the CHCF are not of equal value, so a coefficient is considered for each due to its importance. The node with the highest CHCF value is selected as the new CH node for the next round by the CH node in the same cluster. It broadcasts the location of the new CH node to the CM nodes. Nodes with the highest remaining energy and the lowest spatial distance are more likely to be CH node. Besides, nodes with lower speeds are less likely to leave the cluster range, so they are a better option to be chosen as CH nodes. Compared to the centralized clustering algorithm, the CH node's re-selection is a distributed method in which the sink does not interfere, so it requires less power consumption for the control packet transfer.

$$CHCF = \frac{W_1 E_{res}}{(W_2 d) * W_3 V_n} \tag{6}$$

$$\sum_{i=1}^{3} W_i = 1 \tag{7}$$

In CHCF E_{res} specifies the remaining energy of a node, d specifies the total amount of node distance from other nodes, V_n the velocity of each node, and *ED* shows the Euclidean Distance (ED) between nodes. W_1, W_2 and W_3 are the coefficients of the importance degree of each mentioned factor and the sum of their values is equal to one [48].

$$ED(q\,,p) = \sqrt{\sum_{i=1}^{d} (q_i - p_i)^2} \tag{8}$$

$$d_i = \sum_{j=1}^{i-1} ED(CM_i\,, CM_j) + \sum_{j=i+1}^{nc_i - 1} ED(CM_i\,, CM_j) + ED(CM_i\,, CH_i) \tag{9}$$

The ED between nodes p and q indicates the linear length between them and is expressed by (8). To obtain the sum of the distances in a cluster, we use the *ED* function, given that there are *nc* nodes in each cluster, and it is assumed that the node *i* is CH node. In the first two parts of the (9)[49], each node's total distance from the CM nodes is determined. Also, in the third part of (9), the distance from the CH node is added to the previous two values.

Fig. 7 shows a sample of clusters with six nodes in which the value of the distance between two nodes is visible on edge. The amount of remaining energy and velocity of the nodes is also presented next to each node. Table II is an example of a *CHCF* calculation, according to (6). The values of W_1, W_2 and W_3 are 0.5, 0.35, and 0.15, respectively. As it is clear from the values, D is selected as the CH node.

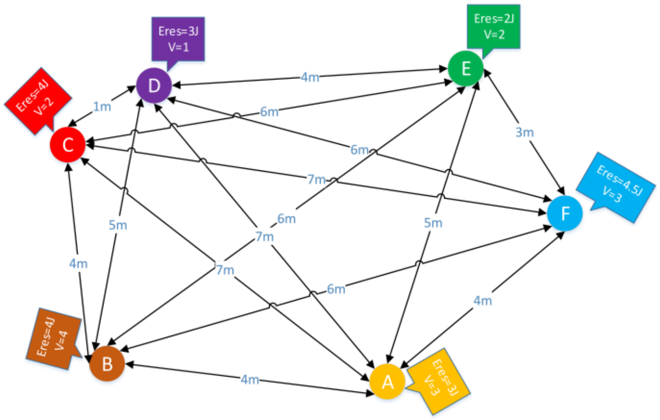

Fig. 7. CH selection scheme

TABLE II
EXAMPLE OF CHCF VALUES

Node	CHCF
A	0.352
B	0.352
C	0.761
D	1.242
E	0.366
F	0.550

3)Re-clustering: The re-clustering plays a vital role in the routing because the loads applied to CH nodes are much heavier than those applied to normal nodes that cause the energy of CH nodes to decrease rapidly. If a CH node does not work correctly, all data in this cluster will be lost. Therefore, to prevent CH node failure [39, 50, 51], the re-clustering process must be done periodically [23]. Selecting the right value for the re-clustering interval is very complicated. If the value is too small (clustering is performed for each data-gathering cycle [19]), there will be a lot of network overload. Besides, during clustering, the network

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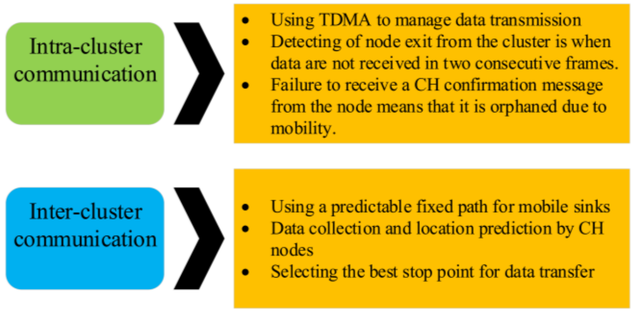
cannot perform any other activity. However, when a very large value is selected, due to a high probability that a CH node's energy will be discharged during data collection [52], the packet loss is significantly increased.

In the alternative method, re-clustering is only allowed when the CH node energy is lower than a certain value [19, 53]. It can prevent packets lost due to CH node failure. Because of the above, the following is suggested based on the analysis.

- A new CH node is selected from existing nodes when the current CH node's residual energy is lower than a predetermined energy threshold *T*. In this study, *T* is set to 30% of the initial energy.
- Re-clustering is performed instead of the entire network in each cluster as needed. This type of local re-clustering avoids imposing additional overhead on the network.

*Communication phase***:** This phase is related to the CM nodes' communication to the CH node and then the CH node to the mobile sink. The CLRP-MMS method uses a single-hop design during inter-cluster and intra-cluster communications [26]. Intra-cluster and inter-cluster communication are two parts of this phase. The steps of the communication phase, with its general description, are shown in Fig. 8.



- Using TDMA to manage data transmission
- Detecting of node exit from the cluster is when data are not received in two consecutive frames.
- Failure to receive a CH confirmation message from the node means that it is orphaned due to mobility.

- Using a predictable fixed path for mobile sinks
- Data collection and location prediction by CH nodes
- Selecting the best stop point for data transfer

Fig. 8. Steps of the communication phase

The membership message is sent to the neighboring nodes by the node selected as the CH. If a node receives this message from two or more CHs, the CH node with the highest Received Signal Strength (RSS) is selected. Hence, this process avoids cluster overlap, which in turn extends the network lifetime [54]. The CH node provides the TDMA schedule for cluster management and optimal energy consumption of the CM nodes, which determines each node's sleep and wake status. Data transfer is performed according to the time slot assigned to each CM node. Idle nodes are always switched off except CH nodes. After the data are delivered from the CM nodes, the data are aggregated by the CH node and sent to the sink [8, 55]. This process is then continued to drain all the energy of the nodes.

1)Intra-cluster communication: The list of nodes for each cluster exists in the CH node. Each node is omitted from the list when it does not send any data in two consecutive frames [16], and related nodes are notified of the updated TDMA schedule. Cumulative ack is used to manage mobility, which is distributed by CH node after each frame. CH node confirms receiving information from its nodes. If a node does not receive a confirmation message from its CH node, it is orphaned because of its mobility. The orphan node requests and cooperates with the new CH node by sending a Join Request (JReq). When a new node joins a cluster, the CH node updates its list and updates its TDMA schedule and then shares it with all the cluster members. In this network, the nodes in one cluster are not allowed to communicate with other cluster nodes. When a node can communicate with another node of neighboring clusters, it avoids this connection, saving more energy in the node [54].

After the data transfer of all the CM nodes in the cluster is completed, the CH node starts data processing. CH node aggregates data to eliminate any redundancy and compresses data as far as possible for fair use of bandwidth [10, 56]. CH nodes are then ready to transfer the data to the sink by single-hop communications.

*2)Inter-cluster communication***:** There are different types of motion for a mobile sink. In this study, the predictive mobility of the sink was used. When the mobile sink path is constantly changing, and there is a need for frequent updates of the sink position, the total energy consumption in the network will increase, and many collisions will occur. Besides, the proposed method supports several mobile sinks in the network, which will cause less energy consumption in the network. According to the sink's schedule and position, CH nodes transmit data to the sink at the appropriate time based on the periodic motion. As shown in Fig. 9, the mobile sink's motion model is circular with constant angular velocity.

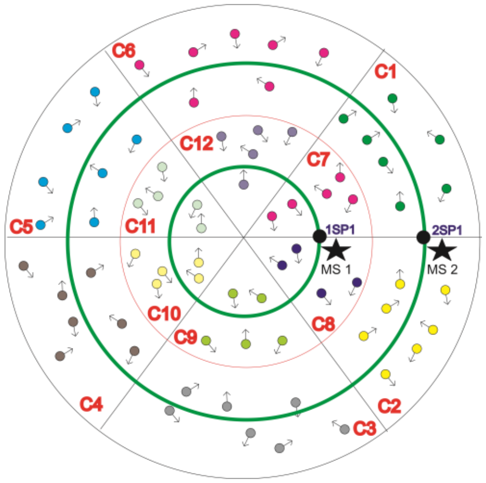


Fig. 9. Path of Mobile sinks MS1 and MS2 with start points 1SP1 and 2SP1

$1SP_1, 2SP_1$ are assumed to be the starting points for mobile sinks, and after a time interval Δt, the mobile sinks move to the new stop points $1SP_2, 2SP_2$, as shown in Fig. 10 [57]. The predetermined paths are at a good distance from each other and are designed in the network's right position, which minimizes energy consumption. In other words, energy consumption is distributed among the nodes. Therefore, the nodes of one part of the network will not be destroyed sooner than the other parts, and the network will have a longer lifetime. The predictions of mobile sinks depend on the CH node's clock's sync and the calibration of the location information.

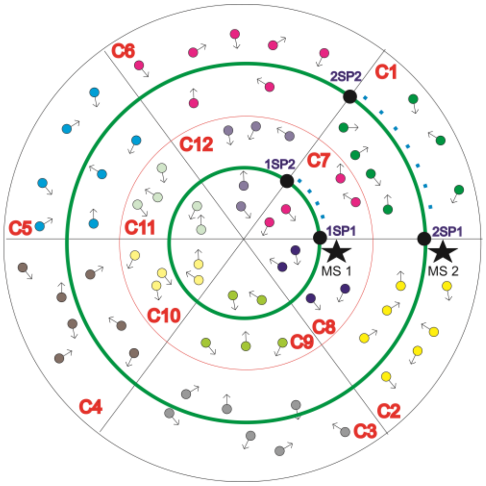


Fig. 10. Positions of mobile sinks after Δt

The mobile sink has its clock as well as every node in the network. The loose time sync is the first step during a Receive Data Period (RDP). When a mobile sink enters the network, it broadcasts a Motion Preparation (MP) message to the entire network. The MP message contains information of the start point of the mobile sink *S(x, y)*, current time *t*, mobile sink speed Vs_i, the number of stop points on the route, the residence time at each stop point, and the radius of the circular route *r*. Moving mobile sinks to the starting points is done after broadcasting the MP messages and the time sync [57]. As shown in Fig. 9, the coupled sinks MS_1 and MS_1 reach the starting points $1SP_1$ and $2SP_1$, respectively.

After finishing broadcasting MP messages, each mobile sink starts moving along a predetermined route and resides at stop points for data collection, then returns to the starting point, waits for a fixed time t_a (the period can be used to set the route) and repeat the previous process. This iteration process is called a Receive Data Loop (RDL). The sink radio receiver is on at stop points only, and receiving data from CH nodes only occurs at stop points. The stop time in stop points is t_s and the interval of movement between the two stopping points is denoted by t_m. *SP* represents the number of multiple stop points, and they are evenly distributed along the sink path. It is assumed that all mobile sinks have the same t_s and t_m, concerning the above, the $t_m$is obtained by (11) to facilitate the prediction of CH nodes for mobile sinks for all moving sinks to have the same RDL length.

$$SP = \frac{K}{2} \tag{10}$$

$$t_m = \frac{2\pi Rs_i}{SP * Vs_i} \tag{11}$$

Where Rs_i represents the radius of the movement of each mobile sink. T_r is the time of each RDL calculated in (12)[32].

$$t_r = SP(t_s + t_m) \tag{12}$$

T_c the length of time a mobile sink passes in RDL, which can be calculated by (13)[32]:

$$t_c = t - \left\lfloor \frac{t}{t_r + t_a} \right\rfloor (t_r + t_a) \tag{13}$$

$$p = \left\lfloor \frac{t_c}{t_s + t_m} \right\rfloor \tag{14}$$

Parameter *p* and *t* represent the number of passed stop points, and the time elapsed, respectively.

The CH node that needs data transfer calculates the mobile sink's current position using (15) to (23) equations.

$$\theta = \frac{(t_c - t_s p)Vs_i}{2\pi Rs_i} \tag{15}$$

IF

$$0 < (t_c - t_s p)Vs_i < \frac{\pi r}{2} \tag{16}$$

Then

$$Location(t) = (cos\theta Rs_i \,, sin\theta Rs_i) \tag{17}$$

IF

$$\frac{\pi r}{2} < (t_c - t_s p)Vs_i < \pi r \tag{18}$$

Then

$$Location(t) = \left(-\sin\left(\theta - \frac{\pi}{2}\right) Rs_i \,, \cos\left(\theta - \frac{\pi}{2}\right) Rs_i\right) \tag{19}$$

IF

$$\pi r < (t_c - t_s p)Vs_i < \frac{3\pi r}{2} \tag{20}$$

Then

$$Location(t) = (-\cos(\theta - \pi)Rs_i \,, -\sin(\theta - \pi)Rs_i) \tag{21}$$

IF

$$\frac{3\pi r}{2} < (t_c - t_s p)Vs_i < 2\pi \tag{22}$$

Then

$$Location(t) = \left(\sin\left(\theta - \frac{3\pi}{2}\right) Rs_i, \cos\left(\theta - \frac{3\pi}{2}\right) Rs_i\right) \tag{23}$$

In the wireless propagation energy model, the power transmission level is related to the distance's square. So, more distance means higher energy consumption. To reduce the energy consumption in the CH nodes, selecting the nearest connection point is proposed. The CH nodes select one of the two stop points for data exchange according to the calculation of speed and time to have more energy storage.

This method uses location prediction, and each cluster can use two stop points for data transfer. So, considering the CH node movement and time's velocity and direction, the stop points where the exchange of information between the CH node and the mobile sink occurs is selected. It will reduce energy consumption. In Fig. 11, you can see that CH_6 selects one of the two points $2SP_2$ or $2SP_3$ for the data transfer, as mentioned above. The following equations determine the angle at which each CH node is located. Also, concerning this angle and the time factor, they determine which stop point is best suited for data transmission.

$$\begin{cases} if\ x > 0\,, y > 0 \ \rightarrow \ \beta = \tan^{-1}\frac{y}{x} \\ if\ x < 0\,, y > 0 \ \rightarrow \ \beta = \pi - \tan^{-1}\frac{y}{x} \\ if\ x < 0\,, y < 0 \ \rightarrow \ \beta = \pi + \tan^{-1}\frac{y}{x} \\ if\ x > 0\,, y < 0 \ \rightarrow \ \beta = 2\pi - \tan^{-1}\frac{y}{x} \end{cases} \tag{24}$$

$$m = \left\lfloor \frac{\beta}{ANG} \right\rfloor \qquad (25)$$

m specifies which network segment each CH node belongs to

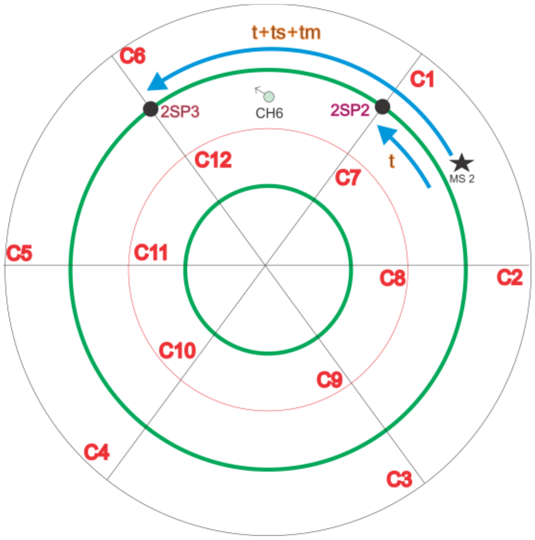


Fig. 11. An example of choosing 2SP2 or 2SP3 by CH6 according to the speed and direction of movement in C6

In each cluster, CH node distance with SP_{m-1} at interval $t + (m-1)t_s + (m-1)t_m$ is compared to CH node distance with SP_m at interval $t + mt_s + mt_m$ and lower value, chosen as the data transfer point to reduce energy consumption.

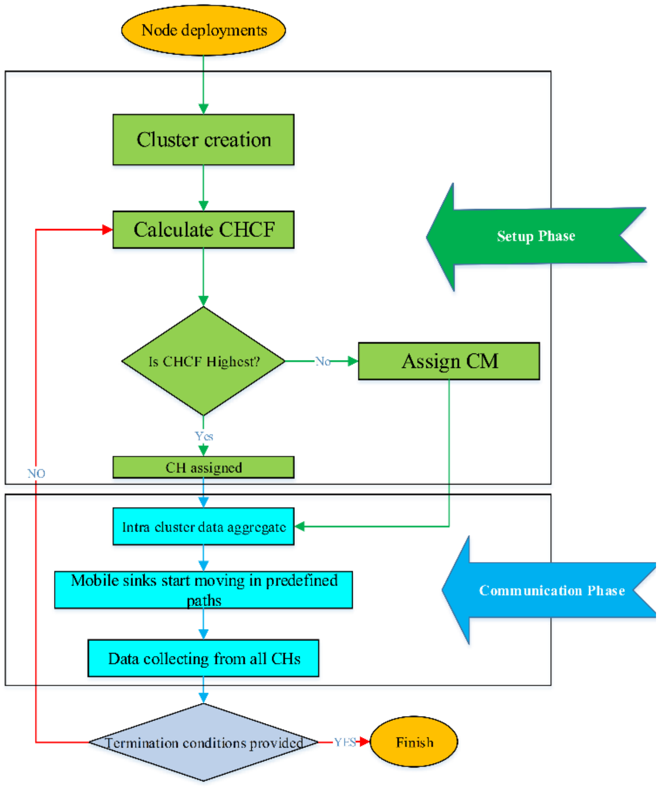


Fig. 12. Flowchart of the proposed method

The general trend of this method is shown as a flowchart in Fig. 12. After the nodes are established and the system is configured, clusters are formed. The most important part of the setup phase is the CH node selection [58]. This stage is done in the first round only based on the node distance from the cluster center. Still, in other rounds, the factors in CHCF are used, which include speed, distance, and residual energy. In the communication phase, the CM nodes send their data to CH nodes, and the CH nodes transfer the received data to the mobile sinks at appropriate times [58, 59].

IV. PERFORMANCE EVALUATION

In this section, CLRP-MMS's performance is compared to EERAMSS [36] and HALPDGSMS [32], specifically designed for the routing problem. This method's advantages are the energy consumption, the network life (the number of live nodes in a given period during the simulation), and throughput. The novelty of this method is that all mobile nodes are clustered, and instead of using a fixed sink, the moving type is used. Two mobile sinks are used simultaneously for optimal energy management and throughput improvement. Also, the re-clustering policy contributes to the superiority of this method. The following sections are planned for testing variables and their values.

A. Simulation tool

NS-2 version 2.35 is used to evaluate the performance of many variables in the WSN environment, and the MATLAB R2017a simulation environment is used to show and plot the result of the proposed method. NS-2 is used in many articles for WSN simulation because it has the following advantages over other simulators or languages [60]:

- Flexibility and modular nature
- It includes countless models of the new standard wireless protocols.
- Also, due to the nature of its open-source, NS-2 has different levels of configuration
- Able to modify several parameters in separate layers and have the ability to create custom applications and protocols.

B. Simulation parameters

The simulation parameters must be adjusted to simulate the proposed method better and obtain more reliable results. The same network model is assumed for different methods to evaluate the performance fairly. Table III shows the parameters for simulating the network model in NS-2.

TABLE III
SIMULATION PARAMETERS

Parameter name	**Value**
Network radius(R)	500m
Mobile sink radius(r)	0.25R, 0.75R
Mobile sink speed	[π/20, π/10, π/5]
Node velocity	(min =5m/s, max=15 m/s)
Total number of mobile nodes	300
Data packet size	1024 byte
Transmission range	50m
Initial node energy	0.5 J
E_{elec}	50 nJ/bit
ε_{fs}	10 pJ/bit/m^2
ε_{mp}	0.0013 pJ/bit/m^4
Distance threshold (d_0)	$\sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}$ m

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C. Results and analysis

These subsections show the simulation results by comparing the performance of the methods to obtain the sum of energy, lifetime, delay, throughput, and the number of dead nodes.

1) Lifetime: Network lifetime depends on the number of live nodes in a network. If nodes continue to live longer, the data collection will take longer, thereby prolonging network performance and increasing data delivery to the sink. The number of live nodes (dependent on the number of rounds) is visible in Fig. 13. It represents a comparison of the number of alive nodes of CLRP-MMS, EERAMSS, and HALPDGSMS. It is clear that for the first 153, rounds, the number of live nodes for EERAMSS is the same as HALPDGSMS and CLRP-MMS. After round 153, CLRP-MMS is better than other methods. This method's advantage is the simultaneous use of node residual energy, node speed, and node distances in CH node selection. Another important factor is in CLRP-MMS, CH nodes find the closest stop point to sinks and direct their data to reduce energy consumption and increase lifetime. However, in the other two methods, the nodes cannot send their information to the closest stop points and use the multi-hop transfer.

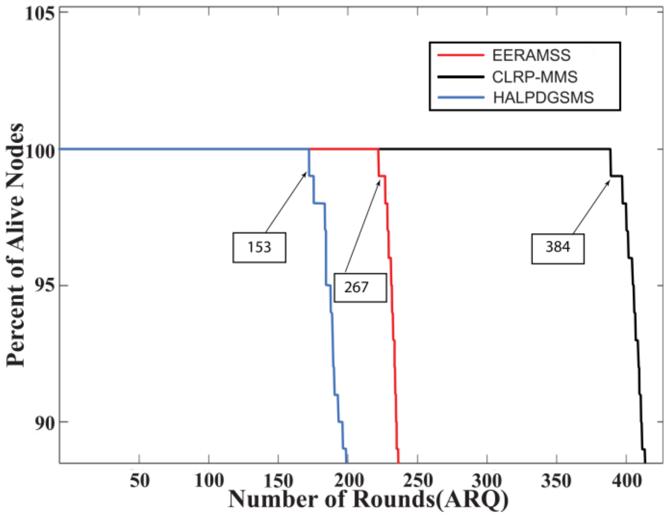

Fig. 13. Percentage of alive nodes

2) Delay: In Fig. 14, the delay or data delivery latency of the HALPDGSMS, EERAMSS, and this work is compared. In these two methods, location prediction is not performed to find the nearest sink and CH node stop points, and data transfer is possible at each stop point. Therefore, HALPDGSMS and EERAMSS have a less delivery delay. Another reason for further delay in this method is the use of single-hop communication, where the CH nodes can communicate with the mobile sinks only at the stop points specified for each cluster

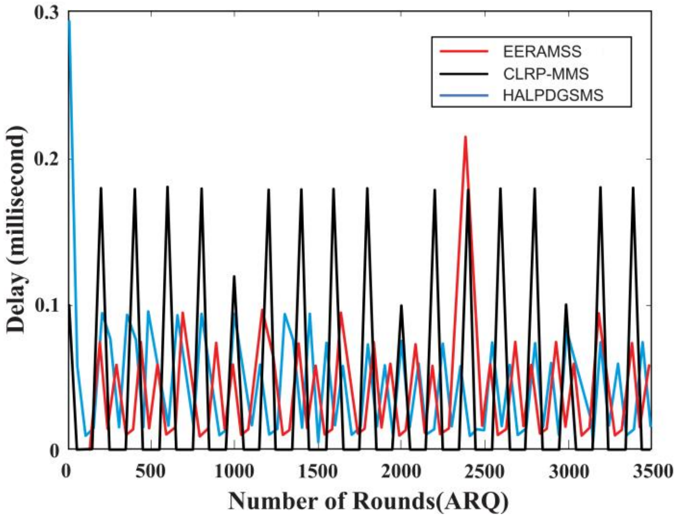

Fig. 14. Data delivery latency

3) Throughput: Reduced power consumption of nodes increases network lifetime by increasing the number of live nodes. This increment over the network's lifetime increases the performance of data collection and transmission over the network. Throughput shows the ratio between packets sent and received successfully at the destination. There will be better performance when this ratio is larger. Fig. 15 shows the throughput diagram of the three methods. The proposed method is 32.12% better than the HALPDGSMS's method and shows a 26.74% improvement compared to EERAMSS's method. The CH nodes in this method are only re-selected if needed. It results in energy balancing between the nodes in the cluster and improving the whole network's throughput whereas compared to the other two methods. The EERAMSS does not use the optimal method to re-select the CH nodes, and the HALPDGSMS does not support clustering. Another influential factor is the CLRP-MMS method that selects the optimal stopping point for transferring data to the mobile sinks under a predefined pattern. This pattern protects energy and improves throughput. Although HALPDGSMS and EERAMSS use a mobile sink with a predictable path, in some cases, the non-optimal stopping point is selected, and energy consumption increases.

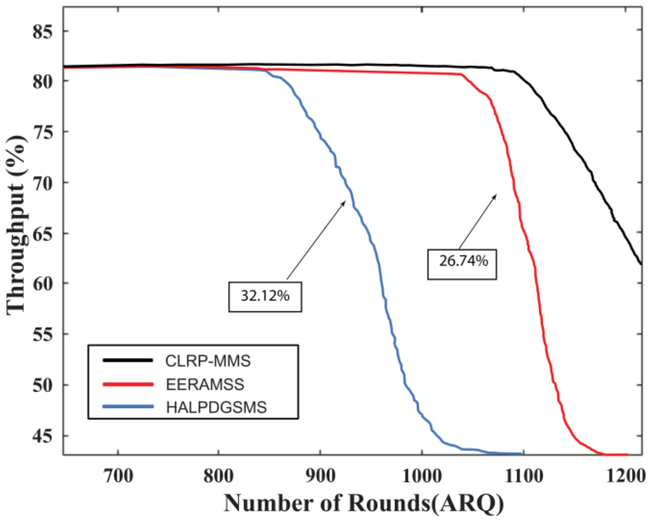

Fig. 15. The total percent of the successfully transmitted packet

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4) Sum of Energy: The sum of energy consumption as the main parameter of the operating nodes is required to perform various tasks. Fig. 16 compares the energy consumption across all methods. As shown in the diagram, the CLRP-MMS method performs better and consumes 34.61% and 28.12% less energy than the EERAMSS and HALPDGSMS methods, respectively. The reason for this better performance is the simultaneous use of the following.

- ✓ Selecting the CH nodes using an optimized function
- ✓ Re-clustering only when necessary
- ✓ Location prediction and stop point selection with the least distance to move data

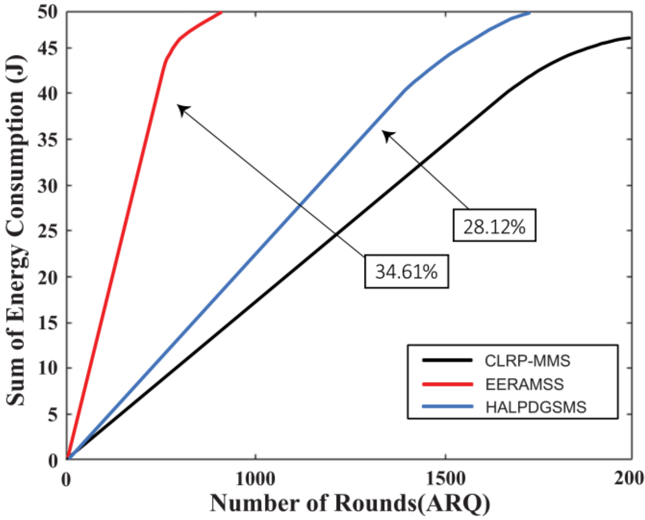

Fig. 16. Comparison of total energy consumption

In Fig. 17, the energy consumption is evaluated when the node sensing radius varies from 5 m to 30 m. It has been observed that as the sensing radius and the energy consumption increases as the node accuracy decreases. In CLRP-MMS, the distance between the CH node and mobile sinks is reduced due to selecting the appropriate stop point for data transfer. However, the HALPDGSMS method does not use the clustering method, and in EERAMSS, the optimal stop point selection is not performed. The above explanations related to location prediction and clustering in the CLRP-MMS method make the proposed method superior in all ranges.

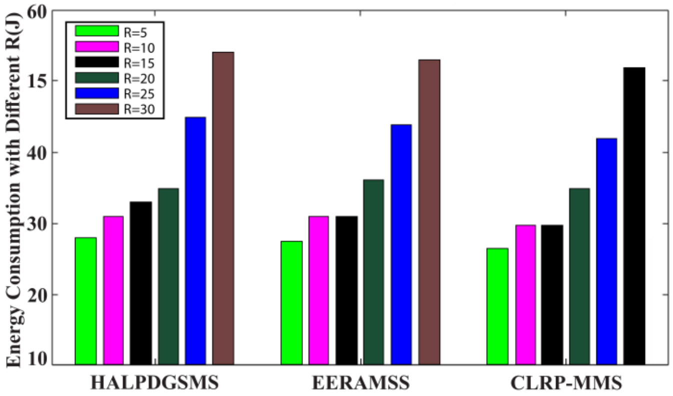

Fig. 17. Energy consumption with different node sensing radius

5) Dead Node: Fig. 18 shows that this new method can save more energy on nodes and networks, which significantly increases the network's lifetime. The first HALPDGSMS node dies at 750 rounds, and the first EERAMSS node dies at 770 rounds. In contrast, it happens for this work at 1120 rounds. The power consumption of the control packets during the selection of the new CH node affects the network's lifetime. In the CLRP-MMS method, re-clustering is done locally and only when needed, resulting in the exchange of fewer control packets between CM nodes and CH node. Therefore, adjusting the appropriate threshold value for re-clustering is very important. In this method, 30% of the remaining energy was considered and implemented. This threshold value result is better than others, which greatly improves the lifespan of the network and reduces the number of dead nodes.

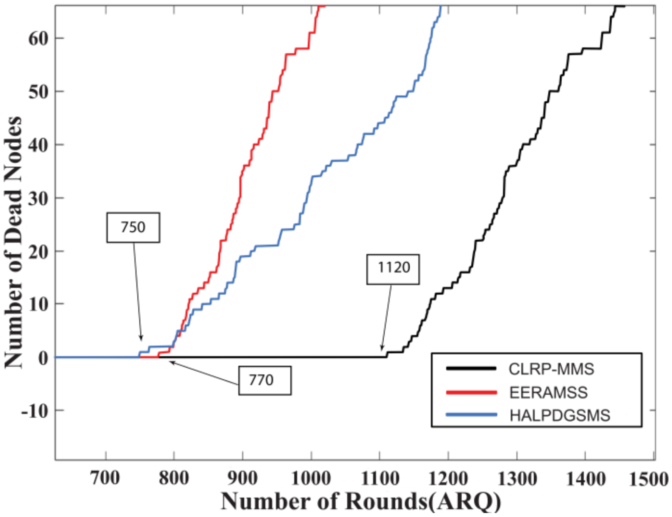

Fig. 18. Number of dead nodes

V. CONCLUSION AND FUTURE WORKS

Considering the importance of energy and lifespan in designing routing methods, a great deal of research is being done to achieve optimal energy consumption and extend the lifespan. Clustering is one of the most effective ways in this regard. In this article, at first, all the nodes are divided into several clusters of unequal sizes and then select CH nodes according to CHCF. The CH node rotates locally as necessary for balanced energy consumption between the nodes in the same cluster, and a location prediction plan with multiple mobile sinks is also suggested. The CH nodes do the calculation of the location of the moving sinks according to the time sync. The simulation results show that this proposed method improves energy consumption, increases network lifetime and throughput, and reduces node mobility's destructive effects.

In the future, we can try to optimize the CLRP-MMS with the obstacle scenario and look for the optimal path of different mobile sinks. It is also possible to test real scenarios to show the abilities of the proposed method.

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Mahyar Sadrishojaei received his B.S. in Computer Engineering, Hardware Engineering, from University of Isfahan, Isfahan, Iran, in 2010; the M.Sc. in Computer Engineering, computer architecture, from Science and Research Branch, Islamic Azad University, Tehran, Iran in 2012. From 2014, he is a Ph.D. student in Department of Computer Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran. His research interests include Computer Networks, WSN, RFID, IoT.

Nima Jafari Navimipour received his B.S. in computer engineering, software engineering, from Tabriz Branch, Islamic Azad University, Tabriz, Iran, in 2007; the M.Sc. in computer engineering, computer architecture, from Tabriz Branch, Islamic Azad University, Tabriz, Iran, in 2009; the Ph.D. in computer engineering, computer architecture, from Science and Research Branch, Islamic Azad University, Tehran, Iran in 2014. He has published many papers in various journals and conference proceedings. His research interests include cloud computing, IoT, traffic control, computational intelligence, evolutionary computing, and wireless networks.

Midia Reshadi is currently an Assistant Professor in Computer Engineering Department at Science and Research Branch of Azad University since 2010. His research interest is Network-on-chip including performance and cost improvement in topology, routing and application-mapping design levels of various types of NoCs such as 3D, photonic and wireless. Recently, he has started carrying out research in NoC based deep neural network accelerators and Silicon interposer based NoC with his team consists of MSc and PhD students.

Mehdi HosseinZadeh received his B.S. degree in computer hardware engineering, from Islamic Azad University, Dezfol branch, Iran in 2003. He also received his M.Sc. and the Ph.D. degree in computer system architecture from the Science and Research Branch, Islamic Azad University, Tehran, Iran in 2005 and 2008, respectively. He is currently an Associate professor in Iran University of Medical Sciences (IUMS), Tehran, Iran. He is the author/co-author of more than 120 publications in technical journals and conferences, and his research interests include SDN, Information Technology, Data Mining, Big data analytics, E-Commerce, E-Marketing, and Social Networks.