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A Combined Dual Leader and Relay Node Selection for Markov Cluster Based WSN Routing Protocol

K. Rajeshwari[1], Dr. N. Rajendran[2]
[1]Research Scholar
Bharathiyar University
Coimbatore, Tamilnadu, India
saraji.4205phd@gmail.com
[2]Principal
Vivekanandha College for Women
Tiruchengode, Tamilnadu, India

Abstract— The major challenge in Wireless Sensor Networks (WSNs) is to increase the node's lifespan and decrease energy utilization. To avoid this issue, many Clustering Routing Protocols (CRPs) have been developed, where Cluster Head (CH) in each cluster accumulates the data from each other node and transfers it to the sink through Relay Nodes (RNs). But both CHs and RNs dissipate more energy to aggregate and transfer data. As a result, it is vital to choose the appropriate CHs and RNs concurrently to reduce energy utilization. Hence, this article proposes a Weighted Markov Clustering with Dual Leader and Relay node Selection based CRP (WMCL-DLRS-CRP) in WSNs. This protocol aims to lessen energy dissipation during inter- and intra-cluster communication. Initially, a Markov Clustering (MCL) algorithm is applied by the sink to create nodes into clusters based on a threshold distance. Then, a dual leader selection scheme is proposed to elect dual CHs in each cluster according to the node weighting factor that considers the node's remaining energy, the distance between CHs and sink, the distance among all nodes, and abundance. Also, an RN selection scheme is proposed to choose the appropriate RNs based on a new Predicted Transmission Rate (PTR) factor. Moreover, the elected RNs transfer the data from the CHs to the sink, resulting in a tradeoff between the node's energy utilization and lifetime. At last, extensive simulations illustrate that the WMCL-DLRS-CRP achieves better network performance compared to the existing protocols.

Keywords- WSN, Clustering, Markov clustering, Energy efficiency, Network lifetime, Relay node, Cluster head

I. INTRODUCTION

WSN is a system that collects data from numerous sensors placed throughout a specific region [1–3]. Each sensor's task is to fetch data and forward it to a central hub, which will then forwards it for analysis. The sensors in a network typically cover a large area, but each sensor has a finite amount of power and is deployed at random [4]. As a result of this uneven distribution, data transmission rates vary across industries. Data correlation is high in high-density sectors, while coverage issues arise in low-density sectors due to the early demise of individual sensors. Research into wireless sensor networks has been conducted in various contexts, from military [5–6] and environmental monitoring [7–8] to industrial process control [9–10] and home monitoring [11–12]. The amount of energy used by data transmission within a network is a major concern for all WSNs because it affects the lifespan of sensors' batteries [13]. As a result, developing efficient routing protocols that use little power is a focus of research. CRPs have proven to be the most effective means of increasing network lifetime [14]. These protocols comprise two major phases: cluster creation and CH selection. In CRPs, nodes form clusters based on specified criteria, and a few nodes are chosen as CHs. Each node can connect directly with close CHs rather than forwarding all data to a more remote sink node [15–18].

To maximize the network's longevity and reduce the amount of energy wasted by the nodes, clustering can either be fixed or adaptive. CH selection schemes can be centralized at the sink, disseminated at the node level, or hybrid. CRPs should aim for an equilibrium between maximizing network stability and maximizing coverage efficiency [19]. There have been numerous efforts to reduce energy usage while increasing network efficiency, scalability, and data routing. LEACH [20] and its variants TEEN [21], APTEEN [22], PEGASIS [23], and HEED [24] are the most popular clustered routing protocols for WSNs. The process by which these protocols build clusters, choose CHs, and transmit sensor information to the sink varies. Currently, the MCL-BCRP has been explored, wherein clusters were formed and CHs were chosen according to sensor location and residual energy [25]. When compared to HEED, LEACH, PEGASIS, and TEEN, this MCL-BCRP has superior network longevity and coverage.

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From this viewpoint, Abbad et al. [26] developed an enhanced MCL called the Weighted MCL-BCRP (WMCL-BCRP), wherein the CH was chosen by the weighting sensors based on the abundance and remaining energy of the sensor nodes. It can enhance the flexibility of complex networks by handling sensor distribution randomness and non-uniformity (heterogeneity) precisely. Based on the resultant sensor abundance in various network regions, energy utilization was controlled. Also, the transmission of redundant information in node-dense zones was decreased, and node-sparse zones were preserved for longer by decreasing the system's mean energy use. The amount of dead nodes were kept controllable, and the network longevity was increased in contrast with the classical CRPs. Nonetheless, the effectiveness between weighting and non-weighting the CH choice was not satisfactory whilst considering the WSNs having uniform (homogeneous) node distribution. Also, the CHs aggregate sensor nodes' information and send it to the sink through RNs, which should dissipate some energy to transmit data between the source nodes and the CH. This causes an energy balance problem in the RNs and CHs.

This study focuses on solving these problems by selecting the optimal dual CHs and RNs that can balance the energy utilization in the WSNs with both uniform and non-uniform node distributions. Therefore, in this manuscript, the WMCL-DLRS-CRP is proposed to compromise energy usage in each node and maximize the network longevity effectively. The major contributions of this study are the following:

- First, centralized cluster formation is performed based on the MCL algorithm, which assembles adjacent nodes into clusters according to a threshold distance. This task is conducted by the sink node only after the expiration of an attractor (i.e., vertices in a graph that attract simple vertices to create clusters), which saves energy during cluster formation.
- Second, dual leader selection is proposed that chooses two distinct CHs (i.e., primary and secondary CHs) in each cluster based on their remaining energy, Euclidean distance between all nodes, distance between the CH and sink, and abundance. These parameters define a novel metric called a node weighting factor. One CH is used for aggregating information and another is used for transferring information. This can lessen energy utilization during both intra- and inter-cluster transmission.
- Third, an RN selection is proposed to elect optimal RNs according to the PTR factor, resulting in balancing both energy utilization and lifetime for WSNs.
- Moreover, the nodes in every cluster transfer information to the nearest CH based on the Time Division Multiple Access (TDMA) scheduling. The CHs aggregate the received information and send them to the sink through the decided RNs in Channel Division Multiple Access (CDMA) scheduling. Accordingly, this WMCL-DLRS-CRP can increase energy efficiency by handling both uniform and non-uniformity of the node distribution in the WSN.
- Finally, the NS2 platform is considered, and results are achieved to comprehend the performance of the WMCL-DLRS-CRP regarding Packet Delivery Ratio (PDR), End-to-End Delay (E2D), energy utilization, and network lifespan.

The rest of the manuscript is prepared as follows: Section II gives the literature survey. Section III discusses the WMCL-DLRS-CRP and Section IV exhibits its performance. Section V outlines the findings.

II. LITERATURE SURVEY

This section reviews recent energy-efficient CRPs developed by many researchers to guarantee network longevity and energy efficiency.

An Energy-Efficient Reliable Routing Algorithm [27] based on DS evidence theory (DS-EERA). Initially, different attribute indexes were created as evidence by accounting for the adjacent nodes' remaining energy, traffic, proximity of their route to the direct route, and so on. After that, the entropy weight scheme was used to calculate the weight of such indexes. The merging policy of DS evidence theory was adopted to combine the basic probability assignment function of all indexes to choose the next hop. But it needs to cluster the network and choose the optimal CH for improving the network's lifetime.

An Energy-Aware Distance-based CH selection and Routing (EADCR) [28] protocol is used to enhance the WSN lifespan depending on the fuzzy C-means method, the remaining energy of the nodes, their relative Euclidean distances from the Base Station (BS), and the cluster center. A novel clustering method was applied, in which the CH was chosen depending on the new fitness function. On the other hand, the node density and other factors must be considered for CH selection.

Improved Energy-Efficient CH selection protocol [29] called IE2-LEACH in WSNs to find the CH based on the minimum level of energy consumption. Initially, the setup stage in the LEACH protocol was modified to choose CHs according to the transmission cost with BS, remaining energy, location, and network size. The redundant data transmission was avoided by detecting many vices for all CHs. Moreover, the scheduling strategy was used to place the CH and its vices correctly. But it did not consider the steady-state stage to maintain the cluster and routing path.

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The LEACH and Quadrant cluster-based LEACH (Q-LEACH) [30] to decrease energy utilization and obtain more suitable coverage. The remaining energy and the distance from the centroid of all nodes were determined by the BS for each alive node in all clusters to elect the CH. But it did not consider other factors like node density and node load to further improve the CH selection. A Trust Management-based and LEACH (LEACH-TM) [31] protocol in WSNs. The cluster size was limited to enhance energy efficiency and prevent additional energy utilization of a node based on the number of adaptive decision CH nodes, remaining energy, and density of adjacent nodes. Also, the TM method was applied to mitigate internal attacks. But further enhancement was needed to choose the best RNs for increasing network longevity.

An improved energy-efficient CRP by electing RNs in WSNs [32] to decrease the long-distance transmission between CHs and BS. The node information merging method was used with the selected RNs to decrease the packet count in information exchange. But other factors, like node density, etc., were needed to choose the optimal CH efficiently. An energy use optimization-based CRP [33], in which the network was gridding by a hexagon. The CHs were chosen depending on the remaining energy of nodes and their distance from the centroid of the hexagon. For CHs, the adaptive time slot allocation method was used to assign a time slot for their cluster members. Moreover, the Dijkstra algorithm was applied to create the direct route between CHs in inter-cluster transmission, reducing the distance of data transfer. But it did not analyze the PDR and E2D.

A hybrid-LEACH protocol [34] is used to increase cluster performance by applying direct transmission of nodes, which are close to BS. All clusters have a vice CH along with the CH to decrease data loss. But it needs to consider other factors like node density, energy utilization, etc. for CH selection. An energy-efficient CRP by utilizing hybrid fuzzy with grey wolf optimization in WSNs [35] to choose CH. It considered the remaining energy, node centrality, and neighborhood overlap when electing the node as a CH. However, it must elect RNs to further reduce energy consumption and delay in data transmission. A fuzzy-based cluster routing protocol in WSN [36] that utilizes network zoning and node remaining energy factors, node distance to the centroid of all zones, and node-to-BS angle as fuzzy input to elect CH. But other factors such as network density, etc., to select the CH efficiently.

From the literature, it is apparent that many academics developed energy-efficient CRPs in WSNs using many criteria. None of them selects both CH and RNs simultaneously to efficiently minimize energy utilization and maximize network longevity. In contrast with those protocols, the WMCL-DLRS-CRP is a new protocol for improving the energy conservation and lifespan of the WSN with uniform and non-uniform node distribution.

III. PROPOSED METHODOLOGY

This section briefly describes the WMCL-DLRS-CRP, which includes two phases as shown in Fig. 1: (i) the centralized configuration phase and (ii) the distributed communication phase.

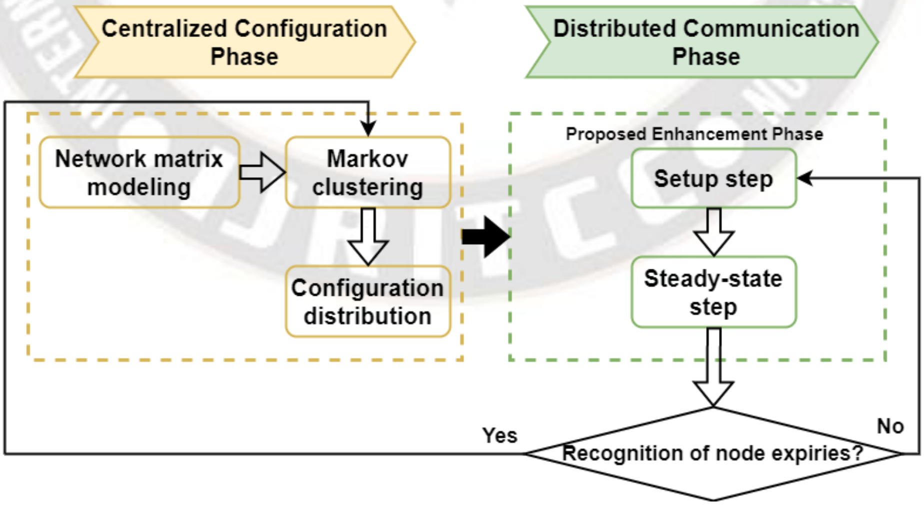

Figure 1. Overall Flow of Proposed Study

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A. Network Model

Consider N sensor nodes positioned in the region as illustrated in Fig. 2, and prepared the below assumptions:

1. Each node and sink node is static nodes with equal capabilities and importance.
2. All nodes can handle any kind of traffic and the sink does not expire.
3. The initial energy is dispersed equally for each node.
4. Every node has a predetermined transmission power and will modify it according to the distance of the under-radius receiver.
5. All nodes can compute distance with the help of Received Signal Strength (RSSI) and all node-to-node connections are symmetric.
6. Each node runs in both sensing and transmission modes.
7. The neighboring nodes are identified to be correlative. As a result, the CH aggregates information acquired from its adjacent cluster into predetermined-size data.

B. Energy Utilization Model

A simple energy utilization model is adopted for data transmission in WSNs. The node radio dissipates E_{ele} to operate its transmitter or receiver system. The energies needed to strengthen transferred signals in the free-space and multi-path models are represented by E_{fs} and E_{mp}, correspondingly. So, to send a g-bit data over a distance d, the transmission module consumes

$$E_{TX}(g,d) = \begin{cases} E_{TX-ele}(g) + E_{TX-fs}(g,d), & d < d_0 \\ E_{TX-ele}(g) + E_{TX-mp}(g,d), & d \geq d_0 \end{cases} \quad (1)$$

$$= \begin{cases} E_{ele} * g + E_{fs} * g * d^2, & d < d_0 \\ E_{ele} * g + E_{mp} * g * d^4, & d \geq d_0 \end{cases} \quad (2)$$

In Eq. (2), $d_0 = \sqrt{E_{fs}/E_{mp}}$ denotes a threshold distance. To get a g-bit data, the transmission module consumes

$$E_{RX}(g) = E_{RX-ele}(g) \quad (3)$$

$$= E_{ele} * g \quad (4)$$

An energy consumed on data processing is trivial than the utilization in information transfer. But data accumulation by all CHs is an energy-intense process, and for a g-bit data, it is calculated by

$$E_{DA}(g) = E_{DA} * g \quad (5)$$

In Eq. (5), E_{DA} denotes the energy utilized per bit for data aggregation in all CHs.

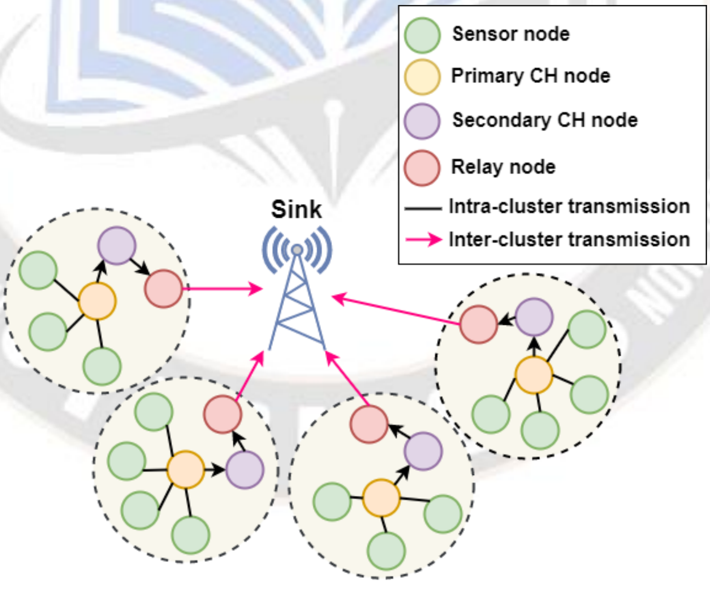

Figure 2. WSN Architecture using WMCL-DLRS-CRP

C. Weighted Markov Clustering-Dual Cluster Head and Relay Selection

The major concept of MCL is that when a walk begins arbitrarily from one node to another, a huge probability of walking is exist in a similar cluster than traveling to the other cluster. So, clusters are found by discovering variations in the node density of the flow space. With this fact, the WMCL algorithm is applied [26] for cluster formation to enhance energy management in WSNs. It enables only a percentage of the nodes in each cluster to transmit data to the CH. This algorithm involves two phases:

1. Centralized configuration phase: It is performed by the sink and triggered each time an attractor expires, requesting network reconfiguration.

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2. Distributed communication phase: It defines each data transmission in the network, from specific nodes to their CHs and from CHs to the sink via RNs.

1) Centralized Configuration Phase

It is the initial step in establishing the WSN structure, which is managed by the sink node. This should be done before transmission between nodes and the sink node is initialized. This phase involves network matrix modeling, MCL, and topology distribution [26].

1. Network matrix modeling: The MCL approach takes the network matrix as the input. Every node sends its positions to the sink with the help of GPS units to calculate the Euclidean distance among each node. An average distance is defined by

$$d_{avg} = {(d_{min} + d_{max})}/{2} \tag{6}$$

In Eq. (6), d_{min} and d_{max} are the minimum and maximum Euclidean distances among the nodes, correspondingly. The threshold distance is a factor of node distribution over the sensing region and is calculated as:

$$d_{th} = {d_{avg}}/{I} \tag{7}$$

In Eq. (7), I is a positive integer. Moreover, a matrix M related to the WSN comprising N nodes is described by

$$M_{xy} = \begin{cases} 1, & d_{xy} \le d_{th} \\ 0, & d_{xy} > d_{th} \end{cases}, x, y = 1, \dots, N \tag{8}$$

2. Markov clustering: It splits the WSN into clusters by determining the Markov matrix created from M . After clustering, the sink discards the cluster smaller than η% of node density and allocates its nodes to adjacent clusters.

3. Configuration distribution: For all clusters, the sink calculates the minimum energy below which a node should declare its expiration to the remaining clusters. To differentiate between node-sparse and node-dense areas, the sink computes a threshold value. Each node is then given the following initial density:

$$den_x = 1 + \left(\frac{N_x}{N}\right) \tag{9}$$

In Eq. (9), N_x denotes the number of alive adjacent nodes of node x within a specified range, and $x = 1, \dots, N$. The network density threshold is calculated by

$$den_{th} = \frac{\sum_{x=i}^{N} den_x}{N} \tag{10}$$

Here, den_{th} is modified every interval the WSN is restructured. Eventually, the sink distributes these different factors as a configuration message to each node in the network.

2) Distributed Communication Phase

Consider both inter- and intra-cluster transmission in WSNs. In an intra-cluster manner, the transmission between various nodes and their CHs is allowed by the TDMA scheme, i.e. all nodes are allocated a timeslot to send their data to the CH. In an intra-cluster manner, the CDMA scheme is utilized rather than enabling multiple CHs to forward the accumulated information to the sink. This phase is performed in regular intervals, namely rounds. Every round has setup and steady-state steps.

a) Setup Step (Dual CH and Relay Node Selection)

In this step, the following processes are performed before data transmission.

1. Remaining energy distribution: All nodes broadcast their remaining energy via distributing it based on earlier TDMA scheduling or broadcast its expiration while their remaining energy hits the threshold determined during setup. So, nodes in every cluster adjust the remaining energies and their cluster table by removing nodes acknowledged dead.
2. Dual CH selection: In this new WMCL-DLRS-CRP, two CHs are chosen for every cluster: (i) a Primary CH (PCH) for data aggregation and (ii) a Secondary CH (SCH) for data transmission. The CHs are chosen according to the four parameters including the remaining energy of the node, the distance of the node from the sink, the distance of the CH from the other nodes in the cluster, and the abundance (node distribution). The remaining energy is measured and the nodes having more remaining energy have a greater chance of being chosen as CHs. The energy utilized on intra-cluster transmission relies on the distance of the CH from the other nodes in the cluster. So, it is measured when determining the candidate of a node to be the CH. Because the amount of energy used in transmitting information from the CH to the sink relies on the distance between them, it is also an essential factor to choose the CH. Additionally, CHs in dense areas preserve nodes' remaining energy because the distance between nodes and their CHs is normally small. So, it is vital to differentiate low and high-density (abundance) areas in the network for CH selection. Therefore, the fitness of a node to be chosen as the CH is determined as the mean weighted sum of these factors. In i^{th} cluster having N_i^{clus} nodes, the fitness $(F_{i,y})$ of y^{th} node to be either PCH or SCH is determined as follows:

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$$F_{i,y} = \frac{\omega_1 \frac{E_{i,y}^{rem}}{E_i^{mean}} + \omega_2 \frac{1}{C_{i,y}} + \omega_3 \frac{d_{sink_i}^{mean}}{d_{sink}^{i,y}} + \omega_4 \frac{den_{i,y}}{den_i^{mean}}}{4},$$

$$y = 1, \dots, N_i^{clus}; i = 1, \dots, c \qquad (11)$$

In Eq. (11), $\omega_1, \omega_2, \omega_3, \omega_4$ denote fixed weighting variables, $E_{i,y}^{rem}$ is the remaining energy of y in i, E_i^{mean} is the mean remaining energy of the nodes in i, $C_{i,y}$ is the centrality factor for y in i, $d_{sink_i}^{mean}$ denotes the mean distance of the nodes in i from the sink, $d_{sink}^{i,y}$ is the distance of y in i from the sink, $den_{i,y}$ is the density of y in i, den_i^{mean} denotes the mean density of the nodes in i, and c represents the overall quantity of clusters in the network.

Here, E_i^{mean}, $d_{sink_i}^{mean}$, and den_i^{mean} are determined by

$$E_i^{mean} = \frac{1}{N_i^{clus}} \sum_{y=1}^{N_i^{clus}} E_{i,y}^{rem} \qquad (12a)$$

$$d_{sink_i}^{mean} = \frac{1}{N_i^{clus}} \sum_{y=1}^{N_i^{clus}} d_{sink}^{i,y} \qquad (12b)$$

$$den_i^{mean} = \frac{1}{N_i^{clus}} \sum_{y=1}^{N_i^{clus}} den_{i,y} \qquad (12c)$$

The centrality factor $(C_{i,y})$ is calculated by

$$C_{i,y} = \begin{cases} 1, & N_i^{clus} = 1 \\ \delta \left(\frac{\sum_{z=1}^{N_i^{clus}} d_i^{y,z}}{N_i^{clus} - 1} \right)_{z \neq y}, & or\ else \end{cases}, \ y = 1, \dots, N_i^{clus}; i = 1, \dots, c \qquad (13)$$

In Eq. (13), δ is normalization constant, and $d_i^{y,z}$ is the Euclidean distance between nodes y and z in i^{th} cluster.

The fitness of y^{th} node in i^{th} cluster to be the PCH $(F_{i,y}^P)$ is determined by Eq. (3.11), such that providing 100% weight to the $E_{i,y}^{rem}$, 50% weight to the $C_{i,y}$, 2% weight to the $d_{sink}^{i,y}$, and 25% weight to the low-abundance (or 50% weight to the high-abundance) clusters. Similarly, to obtain the fitness of y^{th} node in i^{th} cluster to be the SCH $(F_{i,y}^S)$, Eq. (3.11) is calculated by providing 100% weight to the $E_{i,y}^{rem}$, 5% weight to the $C_{i,y}$, 20% weight to the $d_{sink}^{i,y}$, and 15% weight to the low-abundance (or 25% weight to the high-abundance) clusters.

The node with the maximum $F_{i,y}^P$ is considered $F_i^{P_{best}}$ and the node with the second maximum $F_{i,y}^P$ is considered $F_i^{P_{next}}$. Likewise, the node with the maximum $F_{i,y}^S$ is considered $F_i^{S_{best}}$ and the node with the second maximum $F_{i,y}^S$ is considered $F_i^{S_{next}}$. After that, the PCH and the SCH are chosen as follows:

$$PCH_i = \begin{cases} F_i^{P_{best}}, & if\ F_i^{P_{best}} \neq F_i^{S_{best}} \\ F_i^{P_{best}}, & if\ F_i^{P_{best}} = F_i^{S_{best}}\ \&\ E_i^{mean} \leq 0.1 \\ F_i^{P_{next}}, & f\ F_i^{P_{best}} = F_i^{S_{best}}\ \&\ E_i^{mean} > 0.1 \end{cases} \qquad (14)$$

$$SCH_i = \begin{cases} F_i^{S_{best}}, & if\ F_i^{P_{best}} \neq F_i^{S_{best}} \\ F_i^{S_{next}}, & if\ F_i^{P_{best}} = F_i^{S_{best}}\ \&\ E_i^{mean} \leq 0.1 \\ F_i^{S_{best}}, & f\ F_i^{P_{best}} = F_i^{S_{best}}\ \&\ E_i^{mean} > 0.1 \end{cases} \qquad (15)$$

3. Relay node selection: Once the PCH and SCH are successfully elected, a novel factor named PTR is introduced to predict the link quality and node status for choosing the best RN. It is utilized to define the ability of a node to transfer how many packets to another node. The PTR can be defined by remaining energy, transmission power, and link quality. A node with a high PTR value has a high chance of becoming a RN. To measure the link quality between nodes y and z in i, an Expected Transmission Rate (ETR) is defined by

$$ETR_i^{yz} = \frac{1}{fPDR_i^{yz} \times rPDR_i^{yz}} \qquad (16)$$

In Eq. (16), $fPDR_i^{yz}$ is forward PDR and $rPDR_i^{yz}$ is reverse PDR from y to z in i. The forward PDR refers to the amount of data effectively delivered at the receiver, and the reverse PDR is the effective acceptance of the ACK (acknowledgment). Therefore, once a node gets data from its adjacent node, the PTR is computed as:

$$PTR_i^{yz} = \frac{RE_{i,y}^{rem}}{ETR_i^{yz} \times E_{TX}(g,d)} \qquad (17)$$

In Eq. (17), $RE_{i,y}^{rem}$ represents the remaining energy of node y in i and $E_{TX}(g,d)$ is computed by Eq. (2). The node having the maximum PTR is elected as a RN for effective data transfer.

After electing both CHs and RNs, the sink confirms the TDMA scheduling for intra-cluster transmission in all clusters. The data about the CHs, the TDMA lists, and the RNs for SCH is broadcast by the sink to each node through control packets. Thus, it ends the setup step.

b) Steady-State Step

In the steady-state step, intra- and inter-cluster transmissions are conducted. In intra-cluster transmission, data is collected by each node and transmitted to the PCH in their scheduled interval based on the TDMA scheme. After, the PCH aggregates the collected data and transfers it to the SCH. It terminates intra-cluster transmission.

In inter-cluster transmission, data is acquired by the sink node from the CHs. The sink sequentially requests all SCHs to transmit its information. The chosen SCH transmits the information to the sink via the selected RNs. Accordingly, this WMCL-DLRS-CRP can balance the energy utilization of CHs

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and RNs during both inter- and intra-cluster transmission effectively. Also, it can improve the network lifetime and PDR in the WSNs.

IV. SIMULATION RESULTS

This section presents the effectiveness of the WMCL-DLRS-CRP in comparison with the existing protocols. The essential codes for proposed and existing protocols are simulated in the NS2 platform in the Ubuntu environment. The existing protocols considered for comparison are WMCL-BCRP [26], IE2-LEACH [29], Q-LEACH [30], LEACH-TM [31], and Hybrid-LEACH [34]. The simulation parameters for network configuration are given in Table 1.

Table 1. Simulation Parameters

Parameter	Range
Simulation tool, OS	NS2.35, Ubuntu
Simulation area	1110×1110 m^2
No. of sensor nodes	100
No. of sink node	1
Sink x, y coordinates	(50 m, 50 m)
Propagation type	Two Ray Ground
Antenna type	Omni directional
MAC layer	IEEE802.11
Data packet size	520 bytes
Control packet size	50 bytes
Traffic source	Constant Bit Rate (CBR)
Initial energy	0.5 J
Density range	5 m
E_{ele}	50 nJ/m^2
E_{mp}	0.0013 pJ/bit/m^2
E_{fs}	10 pJ/bit/m^4
Data aggregation energy	5 nJ
No. of rounds	1000
Round time	20 s
Transmission range	250 m

Four network metrics such as PDR, E2D, energy utilization, and network lifespan are determined to measure the performance of various CRPs.

A. Total Energy Utilization

It defines the total energy dissipated by each node in the network to transfer data packets during a given interval.

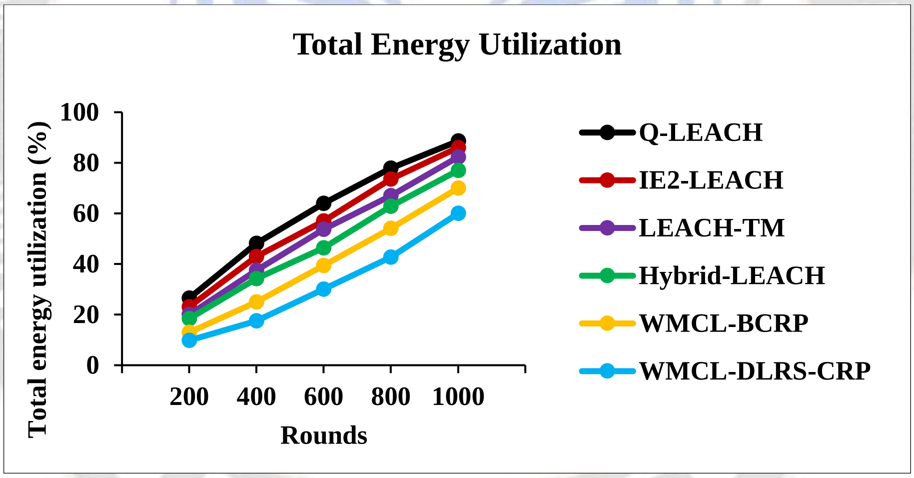

Figure 3. Total Energy Utilization vs. Rounds

Fig. 3 exhibits the total energy utilization for different CRPs for 100 nodes in various rounds. It is observed that the WMCL-DLRS-CRP lessens the total energy dissipation of each node in the network during data transfer due to the selection of both CHs and RNs based on the weighting factors. The total energy utilization of the WMCL-DLRS-CRP is 32.3%, 30.2%, 27.1%, 22.1%, and 14.3% lower than the Q-LEACH, IE2-LEACH, LEACH-TM, Hybrid-LEACH, and WMCL-BCRP after 1000 rounds, respectively.

B. Mean Remaining Energy

It is the amount of remaining energy in each node after data transmission. During simulation, an initial energy level is set to 10 Joules. The mean remaining energy values of the network using various protocols for different rounds are drawn in Fig. 4. It is noticed that the WMCL-DLRS-CRP has a mean remaining energy of 4J at the termination of 1000 rounds, whereas the Q-LEACH, IE2-LEACH, LEACH-TM, Hybrid-LEACH, and WMCL-BCRP have mean remaining energy values of 0J, 0.8J, 1.6J, 2.4J, and 3.2J, respectively. This indicates that the WMCL-DLRS-CRP can improve the energy efficiency of the other CRPs for data transfer with the help of PCH, SCH, and RNs in the WSNs.

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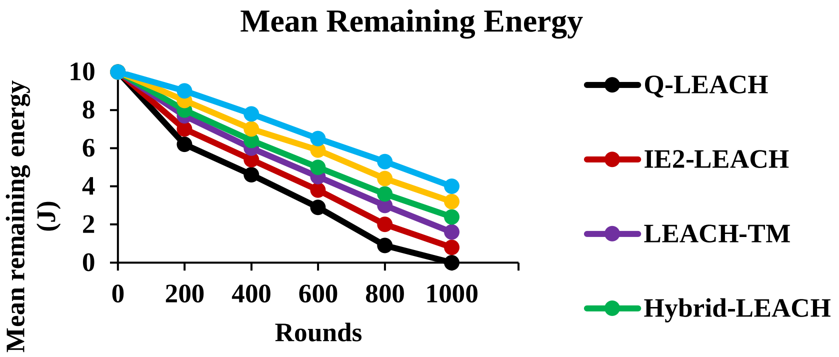

Figure 4. Mean Remaining Energy vs. Rounds

C. *Network Lifespan*

It defines the number of rounds until all nodes are expired. Fig. 5 illustrates the number of rounds for various protocols using a varying number of nodes. The WMCL-DLRS-CRP exhibits 1000 rounds when using 100 nodes in the network, whereas the Q-LEACH, IE2-LEACH, LEACH-TM, Hybrid-LEACH, and WMCL-BCRP execute 330, 500, 680, 800, and 890 rounds, correspondingly. It is indicated that the WMCL-DLRS-CRP enhances the network lifespan while increasing the nodes in the WSN.

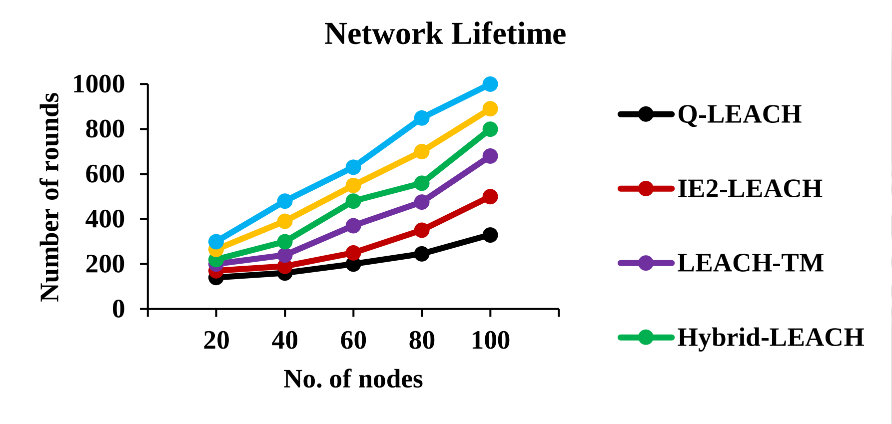

Figure 5. Network Lifetime vs. No. of Nodes

D. *E²D*

It represents the interval needed to receive data at the receiver from the transmitter.

$$E^2D = T_{recv} - T_{tran} \tag{18}$$

In Eq. (18), T_{recv} is the time when a data packet is delivered to the receiver and T_{tran} is the time when a data packet is transferred from the transmitter.

Fig. 6 illustrates the E^2D results for the proposed and existing protocols with varying a number of nodes. It is noted that the WMCL-DLRS-CRP decrease the E^2D for 100 nodes by 33.33%, 28.74%, 22.5%, 17.33%, and 11.43% compared to the Q-LEACH, IE^2-LEACH, LEACH-TM, Hybrid-LEACH and WMCL-BCRP, respectively. This is because of selecting the CHs and RNs based on their distance from the sink node.

E. *PDR*

It measures the percentage between data delivered to the receiver and data forwarded by the transmitter.

$$PDR = \frac{Number\ of\ data\ delivered}{Number\ of\ data\ transmitted} \times 100 \tag{19}$$

In Fig. 7, a comparison of proposed and existing CRPs is plotted in terms of PDR for different rounds. It is realized that the WMCL-DLRS-CRP increases the PDR ranges from 89% to 94.1% after 1000 rounds by transmitting the data from each node to the sink through CHs and RNs. This is improved up to 12.43%, 9.42%, 6.93%, 3.98%, and 2.28% compared to the Q-LEACH, IE2-LEACH, LEACH-TM, Hybrid-LEACH and WMCL-BCRP, respectively.

Accordingly, these findings inferred that the influence of energy dissipation on the network lifespan is resolved by the MCL-DLRS-CRP according to the selection of dual CHs and RN for

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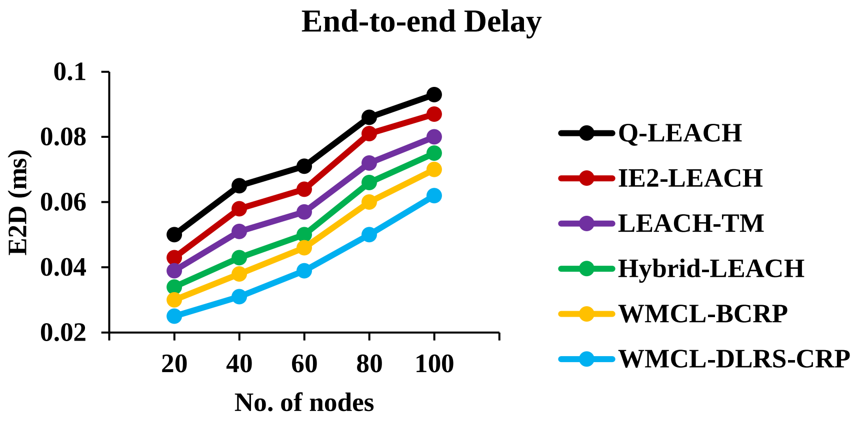

Figure 6. E^2D vs. No. of Nodes

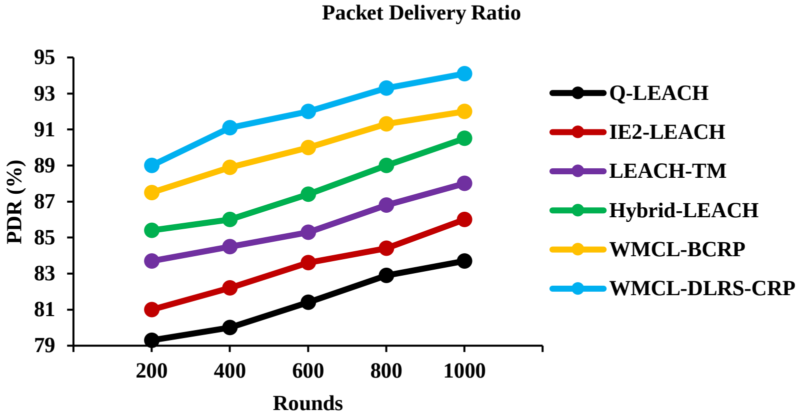

Figure 7. PDR vs. Rounds

data transfer in WSNs This WMCL-DLRS-CRP can be efficient to balance energy utilization and network longevity by guaranteeing both uniformity and non-uniformity of node distribution compared to the existing protocols.

V. CONCLUSION

In this study, the WMCL-DLRS-CRP was developed to alleviate the problem of balancing energy dissipation and network lifetime while transmitting data in WSNs with both uniform and non-uniform node distributions. At first, the network was partitioned into clusters using the MCL algorithm. After that, the PCH and SCH nodes were chosen by determining the node weighting factor for intra-cluster transmission. Also, a RN for SCH was elected by the PTR for inter-cluster data transmission. Further, the collected data by the SCH nodes was sent to the sink via the selected RNs with less energy utilization and high longevity. Finally, the simulation outcomes proved that the WMCL-DLRS-CRP has 60% total energy utilization, 4J mean remaining energy, 94.1% PDR, 0.062ms E2D, and 1000 rounds longevity contrasted with the other CRPs in WSNs. However, it did not consider the link failures during data transmission, which may impact the performance of data transfer. So, future work will focus on adopting a technique to identify and restore the link failures for the successful transferring of data packets in WSNs.

REFERENCES

[1] S. R. Jondhale, R. Maheswar, J. Lloret, S. R. Jondhale, R. Maheswar, and J. Lloret, "Fundamentals of wireless sensor networks," Received Signal Strength Based Target Localization and Tracking Using Wireless Sensor Networks, pp. 1-19, 2022, https://doi.org/10.1007/978-3-030-74061-0_1.

[2] M. S. BenSaleh, R. Saida, Y. H. Kacem and M. Abid, "Wireless sensor network design methodologies: a survey," Journal of Sensors, 1-13, 2020, https://doi.org/10.1155/2020/9592836.

[3] D. Kandris, C. Nakas, D. Vomvas and G. Koulouras, "Applications of wireless sensor networks: an up-to-date survey," Applied System Innovation, vol. 3, no. 1, pp. 1-24, 2020, https://doi.org/10.3390/asi3010014.

[4] K. Gulati, R. S. K. Boddu, D. Kapila, S. L. Bangare, N. Chandnani and G. Saravanan, "A review paper on wireless sensor network techniques in Internet of Things (IoT)," Materials Today: Proceedings, vol. 51, pp. 161-165, 2022, https://doi.org/10.1016/j.matpr.2021.05.067.

[5] D. Suhag, S. S. Gaur and A. K. Mohapatra, "A proposed scheme to achieve node authentication in military applications of wireless sensor network," Journal of Statistics and Management Systems, vol. 22, no. 2, pp. 347-362, 2019, https://doi.org/10.1080/09720510.2019.1580909.

[6] S. Singh, A. Malik and P. K. Singh, "A threshold-based energy efficient military surveillance system using heterogeneous wireless sensor networks," Soft Computing, vol. 27, pp. 1163-1176, 2023, https://doi.org/10.1007/s00500-021-06033-4.

[7] T. M. Behera, S. K. Mohapatra, U. C. Samal, M. S. Khan, M. Daneshmand and A. H. Gandomi, "I-SEP: An improved routing protocol for heterogeneous WSN for IoT-based environmental monitoring" IEEE Internet of Things Journal, vol. 7, no. 1, pp. 710-717, 2019, https://doi.org/10.1109/JIOT.2019.2940988.

[8] S. L. Ullo and G. R. Sinha, "Advances in smart environment monitoring systems using IoT and sensors," Sensors, vol. 20, no. 11, pp. 1-18, 2020, https://doi.org/10.3390/s20113113.

[9] Mujawar, S. S. ., & Bhaladhare, P. R. . (2023). An Aspect based Multi-label Sentiment Analysis using Improved BERT System . International Journal of Intelligent Systems and Applications in Engineering, 11(1s), 228–235. Retrieved from https://ijisae.org/index.php/IJISAE/article/view/2497

[10] V. M. Mishra and A. Kumar, "FPGA integrated IEEE 802.15. 4 ZigBee wireless sensor nodes performance for industrial plant monitoring and automation," Nuclear Engineering and Technology, vol. 54, no. 7, pp. 2444-2452, 2022, https://doi.org/10.1016/j.net.2022.01.011.

[11] M. Majid, S. Habib, A. R. Javed, M. Rizwan, G. Srivastava, T. R. Gadekallu and J. C. W. Lin, "Applications of wireless sensor networks and internet of things frameworks in the industry revolution 4.0: A systematic literature review," Sensors, vol. 22, no. 6, pp. 1-36, 2022, https://doi.org/10.3390/s22062087.

[12] J. Yu, M. T. Hassan, Y. Bai, N. An and V. W. Tam, "A pilot study monitoring the thermal comfort of the elderly living in nursing homes in Hefei, China, using wireless sensor networks, site measurements and a survey," Indoor and Built Environment, vol. 29, no. 3, pp. 449-464, 2020, https://doi.org/10.1177/1420326X19891225.

[13] S. W. Nourildean, Y. A. Mohammed and M. T. Abdulhadi, "Investigating the impact of network topologies on the IoT-based WSN in smart home monitoring system," Eastern-European Journal of Enterprise Technologies, vol. 6, no. 9, pp. 6-14, 2022, doi.10.15587/1729-4061.2022.266990.

[14] Kwame Boateng, Machine Learning-based Object Detection and Recognition in Autonomous Systems , Machine Learning Applications Conference Proceedings, Vol 3 2023.

[15] J. Amutha, S. Sharma and J. Nagar, "WSN strategies based on sensors, deployment, sensing models, coverage and energy efficiency: review, approaches and open issues," Wireless Personal Communications, vol. 111, pp. 1089-1115, 2020, https://doi.org/10.1007/s11277-019-06903-z.

[16] F. Fanian and M. K. Rafsanjani, "Cluster-based routing protocols in wireless sensor networks: a survey based on methodology," Journal of Network and Computer Applications, vol. 142, pp. 111-142, 2019, https://doi.org/10.1016/j.jnca.2019.04.021.

[17] I. Daanoune, B. Abdennaceur and A. Ballouk, "A comprehensive survey on LEACH-based clustering routing protocols in wireless sensor networks," Ad Hoc Networks, vol. 114, pp. 1-21, 2021, https://doi.org/10.1016/j.adhoc.2020.102409.

[18] L. Chan, K. Gomez Chavez, H. Rudolph and A. Hourani, "Hierarchical routing protocols for wireless sensor network: a compressive survey," Wireless Networks, vol. 26, pp. 3291-3314, 2020, https://doi.org/10.1007/s11276-020-02260-z.

[19] T. M. Behera, U. C. Samal, S. K. Mohapatra, M. S. Khan, B. Appasani, N. Bizon and P. Thounthong, "Energy-efficient routing protocols for wireless sensor networks: architectures, strategies, and performance," Electronics, vol. 11, no. 15, pp. 1-26, 2022, https://doi.org/10.3390/electronics11152282.

[20] Sivakumar, D. S. (2021). Clustering and Optimization Based on Hybrid Artificial Bee Colony and Differential Evolution Algorithm in Big Data. Research Journal of Computer Systems and Engineering, 2(1), 23:27. Retrieved from https://technicaljournals.org/RJCSE/index.php/journal/article/view/15

[21] R. K. Yadav and R. Mishra, "Cluster-based classical routing protocols and authentication algorithms in WSN: a survey based on procedures and methods," Wireless Personal Communications, pp. 1-57, 2022, https://doi.org/10.1007/s11277-021-09265-7.

[22] M. F. Alomari, M. A. Mahmoud and R. Ramli, "A Systematic Review on the Energy Efficiency of Dynamic Clustering in a Heterogeneous Environment of Wireless Sensor Networks (WSNs)," Electronics, vol. 11, no. 18, pp. 1-20, 2022, https://doi.org/10.3390/electronics11182837.

[23] G. K. Nigam, "A comprehensive review on successors of LEACH protocols in wireless sensor networks," International Journal of Sensors Wireless Communications and Control, vol. 12, no. 6, pp. 463-477, 2022, https://doi.org/10.2174/2210327912666220615115331.

[24] A. Manjeshwar and D. P. Agrawal, "TEEN: a routing protocol for enhanced efficiency in wireless sensor networks," In Proceedings of 15th International Parallel and Distributed Processing Symposium, vol. 1, pp. 1-7, 2001.

[25] A. Manjeshwar and D. P. Agrawal, "APTEEN: A hybrid protocol for efficient routing and comprehensive information retrieval in wireless sensor networks," In Proceedings of 16th International Parallel and Distributed Processing Symposium, pp. 1-8, 2002.

[26] S. Lindsey and C. S. Raghavendra, "PEGASIS: Power-efficient gathering in sensor information systems," In Proceedings, IEEE Aerospace Conference, 3, pp. 1125-1130, 2002, https://doi.org/10.1109/AERO.2002.1035242.

[27] O. Younis and S. Fahmy, "HEED: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks," IEEE Transactions on Mobile Computing, vol. 3, no. 4, pp. 366-379, 2004, https://doi.org/10.1109/TMC.2004.41.

[28] Ana Oliveira, Yosef Ben-David, Susan Smit, Elena Popova , Milica Milić. Enhancing Data-driven Decision Making with Machine Learning in Decision Science. Kuwait Journal of Machine Learning, 2(3). Retrieved from http://kuwaitjournals.com/index.php/kjml/article/view/200

[29] M. T. Brahim, H. Abbad and S. Boukil-Hacene, "A low energy mcl-based clustering routing protocol for wireless sensor

networks," International Journal of Wireless Networks and Broadband Technologies, vol. 10, no. 1, pp. 70-95, 2021, DOI: 10.4018/IJWNBT.2021010105.

[30] L. Abbad, A. Nacer, H. Abbad, M. T. Brahim and N. Zioui, "A weighted Markov-clustering routing protocol for optimizing energy use in wireless sensor networks," Egyptian Informatics Journal, vol. 23, no. 3, pp. 483-497, 2022, https://doi.org/10.1016/j.eij.2022.05.001.

[31] L. Tang, Z. Lu and B. Fan, "Energy efficient and reliable routing algorithm for wireless sensors networks," Applied Sciences, vol. 10, no. 5, pp. 1-16, 2020, https://doi.org/10.3390/app10051885.

[32] A. Panchal and R. K. Singh, "Eadcr: energy aware distance based cluster head selection and routing protocol for wireless sensor networks," Journal of Circuits, Systems and Computers, vol. 30, no. 04, pp. 1-21, 2021, https://doi.org/10.1142/S0218126621500638.

[33] S. S. Saleh, T. F. Mabrouk and R. A. Tarabishi, "An improved energy-efficient head election protocol for clustering techniques of wireless sensor network," Egyptian Informatics Journal, vol. 22, no. 4, pp. 439-445, 2021, https://doi.org/10.1016/j.eij.2021.01.003.

[34] H. R. Farahzadi, M. Langarizadeh, M. Mirhosseini and S. A. Fatemi Aghda, "An improved cluster formation process in wireless sensor network to decrease energy consumption," Wireless Networks, vol. 27, pp. 1077-1087, 2021, https://doi.org/10.1007/s11276-020-02485-y.

[35] W. Fang, W. Zhang, W. Yang, Z. Li, W. Gao and Y. Yang, "Trust management-based and energy efficient hierarchical routing protocol in wireless sensor networks," Digital Communications and Networks, vol. 7, no. 4, pp. 470-478, 2021, https://doi.org/10.1016/j.dcan.2021.03.005.

[36] K. Guleria, A. K. Verma, N. Goyal, A. K. Sharma, A. Benslimane And A. Singh, "An enhanced energy proficient clustering (EEPC) algorithm for relay selection in heterogeneous WSNs," Ad Hoc Networks, vol. 116, pp. 1-14, 2021, https://doi.org/10.1016/j.adhoc.2021.102473.

[37] X. Huibin and Z. Mengjia, "An energy-efficient clustering routing for wireless sensor networks based on energy consumption optimization," International Journal of Digital Multimedia Broadcasting, pp. 1-11, 2022, https://doi.org/10.1155/2022/5566365.

[38] M. A. Khan and A. A. Awan, "Intelligent on demand clustering routing protocol for wireless sensor networks," Wireless Communications and Mobile Computing, pp. 1-10, 2022, https://doi.org/10.1155/2022/7356733.

[39] J. Singh, J. Deepika, J. Sathyendra Bhat, V. Kumararaja, R. Vikram, J. Jegathesh Amalraj and S. Sakthivel, "Energy-efficient clustering and routing algorithm using hybrid fuzzy with grey wolf optimization in wireless sensor networks," Security and Communication Networks, pp. 1-12, 2022, https://doi.org/10.1155/2022/9846601.

[40] A. Naderloo, S. A. Fatemi Aghda and M. Mirfakhraei, "Fuzzy-based cluster routing in wireless sensor network. Soft Computing, 27, 6151-6158, 2023, https://doi.org/10.1007/s00500-023-07976-6.