SSRG International Journal of Electrical and Electronics Engineering
ISSN: 2348-8379/ https://doi.org/10.14445/23488379/IJEEE-V10I12P102

Volume 10 Issue 12, 8-17, December 2023

Original Article

Technique towards Multi-Objective Clustering in Heterogeneous Wireless Sensor Networks

Santosh V. Purkar[1], Jayant J. Chopade[2], Dnyaneshwar D. Ahire[3]

[1,2,3]*Department of Electronics and Telecommunication Engineering, Savitribai Phule Pune University, Maharastra, India.*

[1]*Corresponding Author : raseeta57@gmail.com*

Received: 02 October 2023 Revised: 05 November 2023 Accepted: 03 December 2023 Published: 23 December 2023

Abstract *- The primary intent and objectives of communication entities and systems have been substantially multiplied by wireless sensor systems or sensors as an end-mile extension. Nevertheless, the sensor unit's power constraints limit their activity and lifetime. As a result, an energy-efficient approach appears to be needed to improve reliability in the form of sensor network lifetime. On the other hand, in the same direction, adding heterogeneity to a Wireless Sensor Network (WSN) and controlling communication activity extends the nodes' lifetime. The intelligent energy-saving approach enhances network stability and lifespan without attention to node deployment or heterogeneity level. Thus, the resulting method reduces administrative expenses of inter-cluster or intra-cluster interactions, optimizes communication stress, succeeds in better load balance within the network, and ultimately boosts network stability. The Multi-Objective Protocol (MOP) for clustering heterogeneous WSN is a proposed design to do the same thing. Finally, the suggested system demonstrates superior performance across diverse deployment situations, varying levels of heterogeneity, and multiple performance criteria. The simulation results of the recommended scheme surpass well-known published design techniques by a factor of more than 1.95 times.*

Keywords *- Heterogeneity, Multilevel, Node index, Received Signal Strength Indicator, Sampling.*

1. Introduction

The sensory system is an essential component of an intelligent communication system. The sensory system makes monitoring remote events simple, but WSNs cannot fully use their potential due to the sensor nodes' limited energy resources. Researchers have proposed many aggregation, routing, and hybrid communication systems as solutions (the transport layer). However, modifications or adjustments to the network layer appear to be the best option among the possibilities presented. Allowing the sink (Base Station) node to move for data collection may also be the optimal solution in a hierarchical network. However, the mobile sink technique increases internal overhead and energy waste. A "heterogeneous WSN"-a sensor network-would function better if it introduced heterogeneity into a homogeneous network.

Here are some examples of heterogeneous networks, such as those having varied nodes, links, and computational energy capacity. This corresponds to actual system components. Weather forecasting, plant health monitoring in agriculture, shortest-distance rescue operations in disaster management, human health conditioning, medical applications, and Industry (I4.0) are just a few of the uses of WSNs or HWSNs. The amount of energy consumed by data transit inside the WSN primarily impacts how much power is kept within the network. A suitable data communication mechanism, an energy management strategy, and a node placement plan are combined to develop an energy-efficient protocol. Compared to other routing systems or communication strategies available, this clustering strategy appears to be the most efficient form of communication. The underpinning network may consume less energy if internal control packets are reduced.

Furthermore, load balancing, emphasising energy-efficient communication mechanisms, and routinely rotating the nodes' responsibility according to defined norms for Cluster Members (CM) or Cluster Heads (CH) dramatically increase energy efficiency. Cluster-based routing strategies improve node (network) connectivity and reduce the strain on faraway nodes [1-3]. Because cluster-based routing extends the longevity and stability time or period of the underlying network (such as an installed network), it improves energy efficiency. Clustering can be classified as balanced, unequal, centralized, distributed, flat model, hierarchical, or multilevel. The cluster structure consists of three components: Base Station (BS), CH, and CM. Here, the BS node serves as the network's primary control element, managing all network activities with the help of the CH node. In most cases, the CM node is utilized for event sensing, CH updating, and reporting to the sink node in compliance with protocol policy. Cluster heads work with CM under the guidance of BS. Several data collection approaches include event-based, query-based, and temporally controlled (driven) methods. First, the CH node collects data for BS on a regular or predefined basis. Second, data collection is contingent on event occurrences such as a landslip or the maximum water level that a dam can withstand.

Finally, BS initiates data collection via CH by posing a query [1-6]. Finally, the current state of Wireless Sensor Network (WSN) research indicates significant gaps that require targeted attention, particularly in diverse WSN installations. Existing research focuses primarily on homogeneous WSNs, ignoring the subtle issues given by sensor node heterogeneity. Few clustering mechanisms are designed to accommodate heterogeneous nodes' capabilities, resulting in inferior performance.

Furthermore, energy-efficient protocols for intra-cluster and inter-cluster communication do not consider the specific properties of heterogeneous WSNs. Validation of proposed solutions frequently relies primarily on a particular level of heterogeneity with a probabilistic clustering approach, ignoring the need for real-time application. Comparative assessments of existing strategies for energy efficiency in diverse WSNs are restricted, preventing a complete knowledge of their respective strengths and drawbacks. Furthermore, the dynamic adaptation of protocols to the diversity of node characteristics and the integration of database modelling and communication techniques are unexplored fields.

This study, or proposed protocol, aims to reduce network energy costs by regulating cluster size for effective communication and selecting the best-suited CH node among other nodes for communication over and within the network. As a result, efforts are directed towards resolving the issues and exploring alternative methods to enhance the performance parameter [7]. It is suggested to use a clustering protocol to divide the network into four groups at first, without considering node density or distribution types like uniform or linear.

Here, index modelling determines the cluster head by considering inputs such as starting energy, residual energy, and the relative distance between each node in the zone (network section). Zone nodes must notify the base station of their available conditions, and the base station will relay this information to the respective cluster heads, who inform the zone nodes. When choosing a Cluster Head (CH), each zone will consider the node's prior experience with the role. Subsequently, selected nodes from each zone will report to the final designated CH. As stated in the protocol specifications, the proposed protocol uses multi-hop communication techniques instead of single-hop. Despite the network's three or four layers, this guarantees an equitable distribution of its energy. Energy efficiency is improved through these novel tactics, resulting in a tenfold increase in all performance parameters compared to the well-known published approach.

The CH role is rotated based on historical periods to maintain a balanced burden. Node reusability (if it previously served as a CH) and intra-distance from the sink node are tracked to decrease energy costs for various energy nodes. A well-known protocol is simulated across 11000-16000 cluster rounds with a sampling frequency of 500 to validate the proposed MOP protocol, which attempts to extend the lifespan of HWSN. According to the investigation, the disclosed system outperforms the published one more than 1.95 times.

2. Literature Review

In Industrial Wireless Sensor Networks (IWSN), addressing optimal routing and energy efficiency is crucial for advancing Industry 4.0, with limited battery resources posing a significant challenge. Challenges in energy-efficient clustering within IWSN stem from anonymous acts affecting energy use and frequent changes in inter-cluster routing. Energy efficiency is given top priority when developing Wireless Sensor Networks (WSNs), and this is achieved by employing metaheuristic optimization techniques for multi-hop routing and clustering. The Metaheuristics Cluster-based Routing Technique for Energy-Efficient WSN (MHCRT-EEWSN) primarily focuses on improving energy efficiency and WSN longevity by cluster construction utilizing the Whale Moth Flame Optimization technique.

The Improved African Buffalo Optimization (IABO) method considers residual energy and distance factors to determine the optimal paths. Compared to other contemporary techniques, MHCRT-EEWSN performs promisingly, according to simulation validation. Notable pieces of work include the "PD-MAC," "GWO-LPWSN," and the self-paced contention window-based adjustment method. "Hybrid Firefly Variants Algorithm," "Guidelines for addressing the Strong Generalized Minimum Label Spanning Tree Problem using heuristic methods," "Identification of outliers in both temporal and spatial dimensions, as well as the strategic positioning of relay nodes for optimization" have been essential in addressing a variety of problems in the context of energy-efficient clustering and routing in Wireless Sensor Networks (WSNs), from node location to Quality of Service (QoS) optimization [8]. Numerous similar research highlight the necessity of these fixes. Industrial Wireless Sensor Network (IWSN) optimization proposes fixes, including optimizing a supervision-based fault diagnostic technique and putting the hybrid ANFIS-based Reptile optimization algorithm into practice for effective routing. Evaluation with multiple nodes and a pair of distinct sinks helps in reducing energy consumption. The broader context of real-time activity research emphasizes the importance of energy-efficient clustering, fault diagnostics, routing algorithms, and energy-aware clustering. Highlighted achievements include a hierarchical routing protocol based on trust management to enhance network behaviour and optimize energy utilization.

A clustering solution based on dynamic fuzzy-based optimization (Particle Swarm Optimization) prioritizes efficient routing. This is complemented by a combination of the Moth-Flame Cuttlefish optimization algorithm that improves fault detection and recovery within the WSN environment [9]. It indicates that remote event monitoring necessitates more energy-efficient design techniques. Cluster-based routing is suitable for increasing energy efficiency and extending performance parameters. This improves network reliability, control, and connectivity. One of the clustered approach's key successes is increased capacity to scale.

Routes based on clusters can be classified based on the type of node, how they are grouped, and the type of communication (single-hop or multi-hop). Clustering can also be classified as single, multilevel, or multistage. WSN clustering might be static or dynamic. Extending the network's life by reducing the energy consumption of relaying obtained data is possible. [10-14] presents a list of energy-saving measures. In the era of effective clustering, a critical approach to cluster hierarchies using adaptive clustering techniques is also reported in the literature. However, several assumptions require confirmation. Clustering methods include random CH selection, residual energy selection, residual to network energy ratio selection, and average node energy selection. Some authors suggest multifeatured heterogeneous clustering can be used.

However, this comes at the expense of a lack of awareness of real-world applications for multivariate data. Data cleansing and processing with redundant data have received less attention. Some writers use an analysis strategy that uses relative distance with the given data elements to produce better clustering results. These accomplishments come at the expense of undiscovered blind spots during data processing. Some writers explored biological aspects such as ant colony schemes and K-medoid to improve performance factors.

As a result, cluster formation is constrained, and there are fewer supports for scalable networks. It hurts network survival time when there are a lot of data points. Historical techniques of thresholds can be applied to real-time communication systems. It communicates data using soft and hard criteria. However, residual energy and relative distance are given less weight [12-18]. It is occasionally necessary to have anthropology that can regulate CH selection and enhance energy efficiency with repeated operation. That combines a balanced clustering technique with a changed fusion rate for communication to boost lifetime enhancement even further. Avoiding CH at close range and minimal energy on the same platform may boost stability and longevity. The deployed network's performance can be enhanced by assembling a circle of nodes (layers) with different residual energies and relative distances.

According to some researchers, utilizing heterogeneity-aware clustering can help increase network stability. Other authors suggest combining stability with an energy-efficient clustering technique could increase performance attributes. The lifetime of the clustering protocol can be extended by an organized network deployment methodology favouring high-energy nodes in sparse fields over congested fields. At the same time, the network's stability can be maximized by segmenting it into small clusters based on each cluster's capabilities. However, this causes an imbalance in the amount of energy used. Regional clustering based on energy supplied by isolated nodes can compensate for clustering process shortcomings such as internal overheads and recurrent CH selection [16-20].

The ratio of residual to the average energy of its close neighbours' nodes within the cluster range is used to calculate the Cluster Height (CH) in clustering. This heterogeneity-aware clustering approach employs Spanning Tree approach between CH families and sink nodes via direct communication. The network's longevity increased as the energy consumed for internal network communication decreased. This strategy offers scalability features and raises the performance thresholds of the designed application. The employment of sensor nodes necessitates specific consideration for boosting the general energy savings of the network because energy constraints limit their lifespan. The multi-hop technique reduces the energy required by each node along the communication line in a scalable network. However, figuring out the best routing plan is a challenging issue.

To overcome this issue, the authors offer the approach of well-balanced, energy-efficient cluster routing. The communication line must use the least energy or be the shortest (less lossy). Dijkstra, link states, and Destination Sequence Routing (DSR) are all approaches for determining the shortest path. Only the price of internal costs connected with CH selection is considered. Nodes are unaffected by their location, and hop count and energy are utilized to establish how tightly clusters are linked. Clusters are frequently built using a specific probability value. During the runtime, nodes of up to three types may be employed [19-24]. In summary, the reviewed articles contribute to the foundational understanding, development, and optimization of energy savings in WSN. From early contributions emphasizing energy efficiency to recent studies addressing multidisciplinary challenges, this work reflects the ongoing evolution of clustering protocols to meet the diverse needs of WSN applications. These papers also offer a thorough basis for practitioners and researchers working to push the boundaries of environmentally friendly clustering for heterogeneous WSNs.

This rich history of research in WSNs, marked by seminal contributions and contemporary advancements, provides a solid motivational foundation. Designing the novel clustering method to boost the efficiency of heterogeneous networks through clustering multilevel nodes becomes not only a necessity in overcoming existing challenges but also a pursuit inspired by the continuous evolution of the field. This motivation drives researchers to push the boundaries of clustering protocols, ensuring they remain adaptive, energy-efficient, and capable of addressing the diverse needs of modern WSN applications.

3. Method

The primary objective of the suggested architecture is to leverage 3 and 4-level node heterogeneity to test the proposed protocol, concurrently validating the improvements in energy enhancement and assessing various performance indicators. Energy consumption during data relay to the sink node is regulated while aiming to determine diverse performance metrics.

The CH role is dynamically rotated, varying the epoch value when selecting CH based on the remaining network energy. CH rotation is executed, enabling other nodes to participate according to the energy-based era period. The epoch is changed to guarantee that every node in the network becomes idle at the exact moment.

Nodes are selected for CH activity using the Node Quality Index (NQI) and the established criteria of the value function based on a regression formula. Nodes with a higher NQI value than the network average (filtering criteria) and satisfying the boundary condition are chosen as potential CH nodes. To ensure the suggested CH nodes do not face the network boundary, they are verified against boundary criteria. Nodes farther away from the central station (BS) node use more energy than those closer. According to the location of the BS node, the network is first divided across four identical sections in the proposed protocol design.

The most appropriate CH node can be chosen more easily by mean NQI or NI number for every zone node as a limit for filtering criteria. In this concept, the BS calculates the NQI value of each individual and selects a high-value NI node, referred to as the "temporary CH". The primary CH or ultimate CH has the most significant NQI number within the network nodes that are reachable in each zone. It is a relay element for data communication to assist the temporary CH. In this scheme, nodes near the layout territory do not receive additional weight for the CH role.

3.1. Energy Consumption Model

The presentation of data communication between two sensor nodes is based on specific communicational properties. Depending on the transmission length limit, there are two categories for the transmission model: either direct or multipath propagation. Normally, the transmitter node uses more energy while transmitting collected data. This is due to the modulator's predicted energy consumption, energy depletion in the environment, and energy dissipation at the antenna's transmitting amplifying portion.

Alternatively, the receiver expends energy in its radio electronics (separated by the threshold distance 'd_0' or more). If the separation of communication entities by a distance 'd' during data transfer is shorter than a crossover or threshold distance, then it follows a direct communication model, energy expenses can be computed based on the same, and if the condition reverses energy consumption will be calculated with a multipath propagation model.

Data transmission is initiated nearby for a packet of length 'L' (in bits). The radio connection characteristics used here are comparable to [18, 20, 21]. The energy model details are derived based on several communicational parameters, such as 'E_{TX}', the energy that carries a data packet. 'E_{RX}' is the cost for the receiver. 'E_{elec}' expense by radio electronics; 'E_{mp}' is for a multipath model communication; and 'E_{fs}' is for direct propagation.

Similarly, 'E_{DA}' is the total amount of energy consumed for aggregate data for the summer. Finally, 'E_{Relay}' indicates the power to send a data packet with the length 'L'. The details are given below in subsections. Now, the calculations for the various attributes employed in the energy model are provided [18, 20].

$$d_o = \sqrt{\frac{E_{fs}}{E_{mp}}} \tag{1}$$

Energy expenses over distance 'd' for a packet of length 'L',

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

$$E_{TX}(L,d) = L\cdot E_{elec} + L\cdot E_{mp}\cdot d^4;\ \text{if } d > d_0 \tag{3}$$

Energy expenses borne by the receiving node are,

$$E_{RX}(L,d) = L.E_{elec} + L\cdot E_{DA} \tag{4}$$

One-hop communication relay node computation can be possible same as [18, 21]:

$$E_{Relay}(L,d)=E_{RX}(L)+E_{TX}(L,d) \quad (5)$$

$$E_{Relay}(L,d)=2\cdot L\cdot E_{elec}+L\cdot E_{DA}+L\cdot E_{fs}\cdot d^2, \text{ if } d > d_0 \quad (6)$$

$$E_{Relay}(L,d)=2\cdot L\cdot E_{elec}+L\cdot E_{DA}+L\cdot E_{mp}\cdot d^4; \text{ if } d > d_0 \quad (7)$$

3.2. Network Model

Detailed network structures are presented in this subsection as several combinations of energy nodes with different population percentages. Some assumptions are mentioned here for convenience.

- Nodes are scattered randomly.
- After deployment, all nodes remain stationary and always have data to transfer.
- When nodes lose their ability to perceive, they are deemed dead.
- All Nodes are location unaware.

The network model shown here is the same as in [18, 20, 21]. The proposed model relies on several node populations. Subsequently, Three or four variations in nodes utilized apart from the average are advanced, super node, and ultra node. It is anticipated that there will be "N" nodes in total. Advanced nodes have population value a with 'N' nodes; each is endowed with 'A_e' (fractional value) more energy than standard nodes.

Normal node the percentage population factor 'n_n' with starting energy 'N_e'. Supernodes, which have a population value of 's' and an energy value of 'S_e' times that of a standard node, are used. Finally, an ultra-node is a node with a higher energy, 'U_e', than a normal one. Whose energy is 'Ne', with a population factor of 'n_n ' times of 'N'. Details of energy for each node are as follows.

3.2.1. 3-Type Node Model

Normal node energy is presented as follows;

$$En_n=n_n.N_e.N;\ n_n=(1-a- s) \quad (8)$$

$$E_{AN}=a.(1+A_e).N_e.N \quad (9)$$

Energy contributed by Super node,

$$E_{SN}=s.(1+S_e).N_e.N \quad (10)$$

Thus, the network model complete energy is calculated as;

$$E_{Network}=En_n+E_{AN}+E_{SN} \quad (11)$$

Individual node details contributed to the total energy is presented as;

$$E_{Network}=(N_e(n_n+a(1+A_e)+s(1+S_e))).N \quad (12)$$

If energy increments by a factor of 2, the network's total energy availability is broken down into the details as (for three type nodes);

$$E_{Network}=(n_n.N_e(1+3a+5s)).N \quad (13)$$

Hence, a generalized equation for a multilevel node heterogeneity can be presented in the form of the following equation for 4,5, etc.

$$E_{Network}=N_e(1+2a.\ldots+(2m-1)t).N;\ m=3\ldots x \quad (14)$$

Where x is any integer value, and t is the percentage of the population factor at that respective level.

3.3. Proposed Protocol

Through load balancing and selecting appropriate nodes for the CH role, the recommended protocol and its implementation increase the overall energy effectiveness of the network's model being tested. These days, the energy-consuming characteristics, relative position, and reusability value are considered when choosing a CH. The suggested design distributes load uniformly throughout the network and achieves a higher node degree at each head level. As a result, cluster size is controlled rather than arbitrary. Therefore, cost management eventually raises the network's residual energy. Compared to other activities, sensor nodes typically have pretty high power when transmitting.

Consequently, an effort is made to use multi-hop communication with remote nodes to minimize effort. The strain placed on CH on deck is decreased by organizing interim CH on behalf of the zone (based on node index value) and main CH (for the benefit of the network) according to the higher number of the corresponding node index among the available nodes.

Every zone has a temporary CH node that transmits data collection to the main CH and relays it to the central station (BS). Based on the node index value, any node whose communication distance exceeds the BS sends the collected data to a nearby node. Alternatively, data can be transferred straight to the BS (the same approach is utilized by CM in relaying data to CH or the main CH).

Several performance features of wireless sensor nodes in clustering are evaluated in the proposed study, such as the necessity that selected relay nodes waste the least amount of energy to transfer sensed events. At this point, the CH chosen must have an NQI value more significant than the average NQI value (after filtering out the other nodes). Selected CHs are less likely to be located beyond the network border and are available to play the role of CH. Initially, it is feasible that many nodes have a better NQI value than the ideal cluster head value in some of the first few rounds. As a result, the LEACH technique is used for the first 100 cluster cycles. The focus is on a query-based technique for agricultural applications at this stage. Each zone's temporary CH node passes collected data to the main CH, which then communicates it to the BS. In this case, any node whose communication distance exceeds the BS transfers the collected data to a nearby node depending on the node index value. Alternatively, data can be transferred straight to the BS (the same approach is utilized by CM in relaying data to CH or the main CH). The clustering process's supporting parameters are calculated similarly to [18, 21].

3.4. Performance Parameter Overview

In this section, an effort is made to highlight the details of simulation parameters and performance parameters. A set of standard parameters is used to verify and validate the simulation of the implemented protocol. The following are some specifics of the performance parameters used in validation, with a practical limit of 0 to 99999. The experimental set limit for the following parameters is between 0 and 99999. Some details of the performance parameters used in validation are presented as follows;

3.4.1. Stability

The interval of cluster rounds before the demise of the network under examination's initial node.

3.4.2. Number of Alive Nodes per Cluster Round

A node's survival rate after varying energy excursions during operation is measured as the number of alive nodes in each cluster round.

3.4.3. Number of Dead Nodes per Cluster Round

Conversely, the quantity of deceased nodes following specific rounds is additionally significant in determining the remaining energy within the node population.

3.4.4. Throughput

After the cluster round, throughput is indicated by the amount of information packets the receiver collects concerning the total number of messages communicated over the network.

3.4.5. Lifetime

How many cluster rounds did the last live node serve before being removed from the network?

3.4.6. Energy Remain in the Network per Cluster Round

This shows how much energy the network leaves after each cluster round. This suggests success in load balancing with the proposed protocol across the deployed network.

A well-presented findings section combined with a convincing explanation will undoubtedly demonstrate the novelty and importance of the work. It would provide a succinct and precise description of the experimental data, their interpretation, and the experimental conclusions that may be reached for the developed system.

4. Result and Discussion

The suggested solution is tested and validated using the standard simulating parameters (data set) listed in Table 1. The network configuration has 200 randomly distributed nodes. The network layout here is 200 x 200, with BS at 100 X 100. In this case, the percentage population factor is a = 0.1 and s = 0.2, roughly 200 nodes per the 3-level system model.

On the other hand, the 4-type node, or 4-level model, u = 0.4 and subsequently for the higher level. The energy value is increased by 1.2 times for the following node types. Towards lower energy nodes, the energy-wise nodes are termed ultra, super, advanced, and regular. In the case of five type nodes, the 5th node is an ultra-super node (a master node).

Table 1. Simulation parameters used

Symbol	Parameters Details	Values
M X M	Network area (in meters)	200 X 200
N	Total number of nodes	200
N_e	Normal node energy	0.5–1.5J
L	Data packet length	4000bits
E_{elec}	Radio energy	50 nJ/bit
E_{fs}	Free path energy	10 pJ/bit/m^2
Emp	Multipath energy	0.0013 pJ/bit/m4
E_{DA}	Data aggregation energy	5 nJ/bit/signal
d_0	Threshold distance	87-87.7 m

4.1. Validation Using the Published Protocol

The proposed solution is being tested at various stages, including utilising Contrib1's position-aware, fixed-epoch nodes. Altering the epoch value does not affect nodes based on position (refer to Contrib2). Using the Base Station's (BS) highly efficient computational power and energy, the Received Signal Strength Indicator (RSSI) makes it easier to calculate node locations in location-insensitive applications.

As per [1, 2], the protocol, Low Energy Adaptive Clustering Hierarchy (LEACH), was the first clustering idea. In the proposed method, BS selects the CH randomly using a random number-generating mechanism. Clusters of any size can form here, putting additional strain on CH and leading the node to die sooner. The chosen CH may occasionally come from the network's service region. The burden was thus dispersed unevenly among the nodes. This may result in excessive energy costs. However, this severely reduces the network's stability and life. Throughput will rapidly drop as long as energy is present. Importantly, LEACH is unable to investigate the capabilities of heterogeneous WSNs. LEACH's capabilities are uniform because it treats each node as an equal capability node. Second, as mentioned in [4], compared to the preceding LEACH, SEP's idea of heterogeneity with the inclusion of advanced nodes in homogeneous WSNs can provide more excellent performance.

The proposed method chooses CH primarily based on initial energy, with less weight given to location, measured RSSI, and residual energy. The SEP approach frequently penalizes advanced nodes in the configuration above. The SEP protocol is usually more dependable than the LEACH protocol. Because CH selection is not a systematic procedure, it affects the aliveness of nodes in each cluster round. The technique mentioned above hurts the network's residual energy and throughput. However, Design Energy Efficient Clustering (DEEC) aims to compensate for energy balancing across the network [5]. In this system, the node's power determines the epoch. Depending on how close the two locations are and how directly CH delivers data to BS, this can require more energy. The decrease in network stability results in an imbalance in the network's power, consequently reducing its lifespan. Nonetheless, the approach outperforms LEACH and SEP.

Compared to earlier versions, the proposal yields numerous improvements in performance parameters through appropriate CH. Thus, there is an additional decrease in energy use. This context considers various factors, including the node's position, energy availability, and whether the chosen CH node is beyond the network boundary. The burden of data exchange with BS does not apply to CH regarding zones. Since zonal CH nodes transfer collected data to the network's main CH for data packet relaying to BS, the recommended stage one technique performs better regarding stability and lifetime than LEACH, the SEP, and the DEEC.

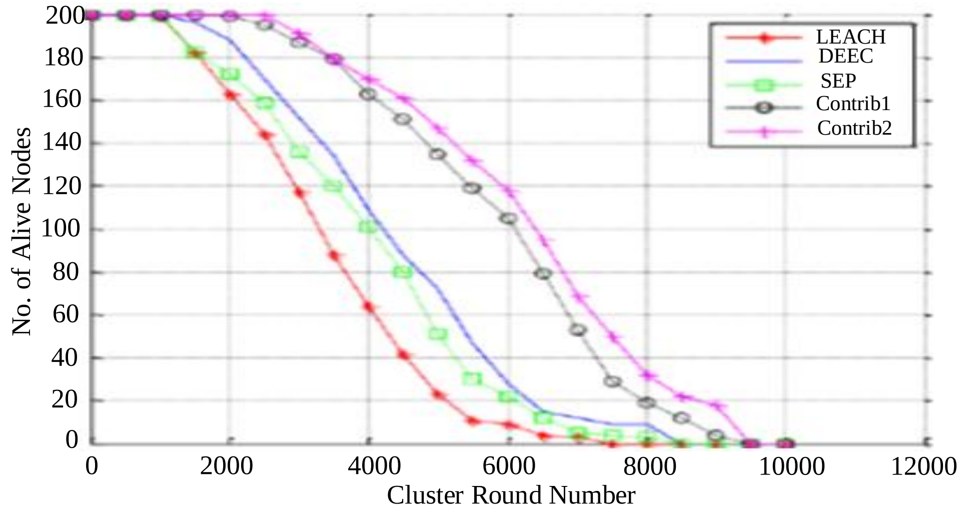

Fig. 1 Alive node Vs Cluster rounds of MOP with well-known published protocol

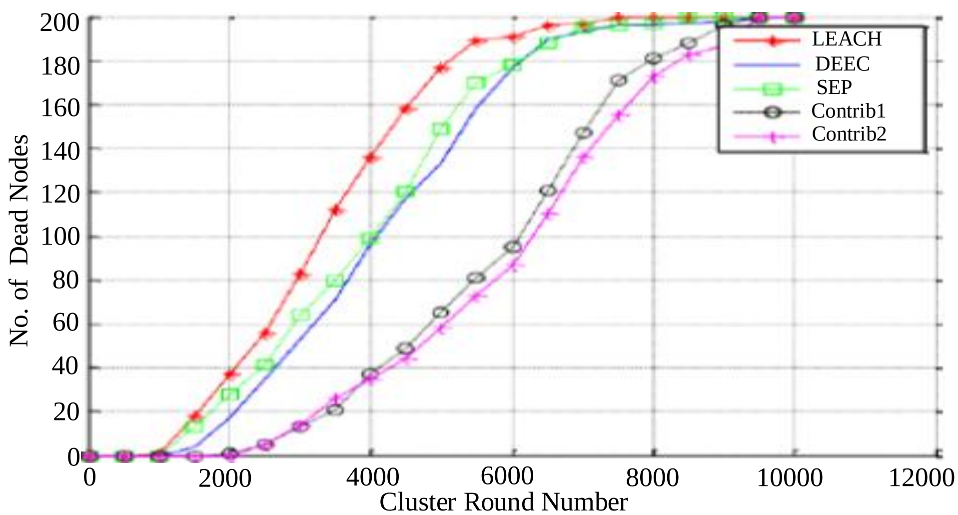

Fig. 2 Dead nodes Vs Cluster round of MOP with the well-known published protocol

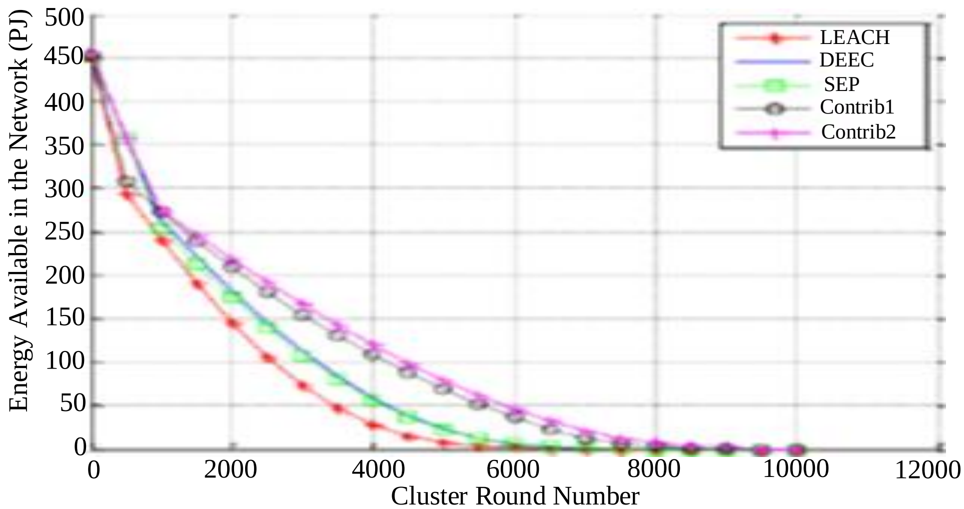

Fig. 3 The network's remaining energy compared to cluster rounds by MOP with well-known published protocol

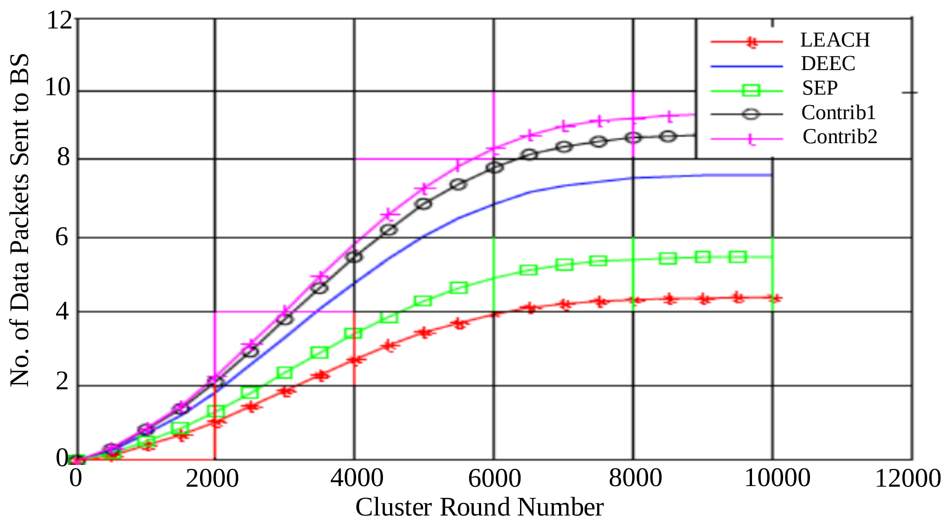

Fig. 4 Data packets are transferred to the Base Station (BS) over a cluster round by the MOP with a well-known protocol

The newly generated cluster appears more evenly spread than the previous clustering process. The reusability of any node in the CH role is checked before it is finalized. The suggested design's nodes are not location-sensitive and consume less energy than the first-stage method. This method of data communication is the same as it was in Contrib1. As a result, nodes die slower than in the previous design. As a result, the network's connectivity improves. Produces a minimal level of energy excursion proportionally. Instead of being random, cluster sizes are controlled by network division.

These low cluster numbers increase network survival time to a greater extent over the network's lifetime. As a result, the final proposed design's stability time, lifetime, residual energy, and throughput outperformed the stated approach. The validation plots discovered on the simulation ground are currently presented in Figures 1 to 4. The figures depict node aliveness, dead nodes, remaining energy, and network speed during cluster rounds using the published protocol. In the readings collected for the 10% boundary condition (from the border towards inside the field), the probability of cluster formation is considered to be 0.1 or 10%. Finally, various levels of node heterogeneity will be taken into consideration for experimentation is displayed in a table as follows:

Table 2. Record for various level network models with contrib1

Parameter	LEACH	SEP	DEEC	Contrib1
Record for Three-Level Network				
Stability	1060	1406	1787	1987
Lifetime	7106	8840	9090	9115
Record for Four-Level Network				
Stability	1782	1978	2378	2612
Lifetime	8439	10421	10611	11108
Record for Five-Level Network				
Stability	3030	2800	3190	3460
Lifetime	10045	13005	12402	13565

Table 3. Record for various level network models with contrib2

Parameter	LEACH	SEP	DEEC	Contrib2
Record for Three-Level Network				
Stability	1060	1406	1787	2177
Lifetime	7106	8840	9090	9209
Record for Four-Level Network				
Stability	1782	1978	2378	2781
Lifetime	8439	10421	10611	11928
Record for Five-Level Network				
Stability	3030	2800	3190	3580
Lifetime	10045	13005	12402	15478

4.2. Improved Result Achievement

As the proposed design incorporates the following features, the proposed technique seems more effective than the published one.

- Reduction in internal control messages and ease of network management while operating by the strategy of network division and distance-based data communication by an individual node.
- A distributing the available energy around the network evenly and preventing the load-carrying capacity from being overloaded while allowing everyone to play the part of CH.
- To further balance the energy inside the network, keep track of the epoch based on energy value.

Because it strategically incorporates features like minimized internal control messages, efficient network management, lower data packet prices, and balanced energy distribution, the suggested technique is judged to be more successful than well-known published protocols. These attributes collectively position the proposed design as a superior solution for multilevel node networks, contributing to enhanced overall performance compared to existing methodologies.

5. Conclusion

Regarding stability and longevity, the suggested architecture outperformed the 3-level network model by 71.52% and 92.21%, respectively. On the other hand, the stability and durability of the proposed 4-level network model are 78.51% and 86.50% better than those of the previously published protocol, respectively. As a result, the suggested design improves stability and longevity overall by 75.02% and 89.35%, respectively.

Hence, a multilayer node network's whole parameter set is improved when stability and energy efficiency are combined. The suggested approach selects the best node for the CH job and makes network management easier. The node's life will be extended further by lowering the communication energy required to transfer data from CH to the sink station. This proposed design achieves better load balancing and well-assured cluster connectivity. Hence, the proposed MOP works better for multilevel clustering approaches for various dimensions of networks. Overall, CH's node connectivity, load balancing, and energy efficiency indirectly improve the residual energy and network throughput.

In the coming period, incorporating the convex hull algorithm for the proposed scheme and integrating a genetic algorithm for optimizing the CH energy will be pursued.

Funding Statement

Gratitude is also expressed to Matoshri Research Centre for providing access to laboratory facilities as needed during holidays and day and night.

Acknowledgments

Sincere appreciation is extended to the respected journal committee and reviewers for their valuable guidance and cooperation, dedicating precious time to publication.

References

[1] W.R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-Efficient Communication Protocol for Wireless Microsensor Networks," *Proceedings of the 33rd Annual Hawaii International Conference on System Sciences*, Maui, USA, vol. 2, pp. 10-19, 2000. [CrossRef] [Google Scholar] [Publisher Link]

[2] M. Perillo, Z. Cheng, and W. Heinzelman, "On the Problem of Unbalanced Load Distribution in Wireless Sensor Networks," *IEEE Global Telecommunications Conference Workshops - GlobeCom Workshops*, Dallas, TX, USA, pp. 74-79, 2004. [CrossRef] [Google Scholar] [Publisher Link]

[3] Ankita Srivastava, and Pramod Kumar Mishra, "Energy Efficient Clustering Using Modified Promethee-II and AHP Approach in Wireless Sensor Networks," *Multimedia Tools and Applications*, vol. 82, pp. 47049-47080, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[4] Georgios Smaragdakis, Ibrahim Matta, and Azer Bestavros, "*SEP: A Stable Election Protocol for Clustered Heterogeneous Wireless Sensor Network*," CAS: Computer Science: Technical Reports, pp. 1-11, 2004. [Google Scholar] [Publisher Link]

[5] Li Qing, Qingxin Zhu, and Mingwen Wang, "Design of a Distributed Energy-Efficient Clustering Algorithm for Heterogeneous Wireless Sensor Networks," *Computer Communications*, vol. 29, no. 12, pp. 2230-2237, 2006. [CrossRef] [Google Scholar] [Publisher Link]

[6] A. Kashaf et al., "TSEP: Threshold-Sensitive Stable Election Protocol for WSNs," *2012 10th International Conference on Frontiers of Information Technology*, Islamabad, Pakistan, pp. 164-168, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[7] Carolina Del-Valle-Soto, Alma Rodríguez, and Cesar Rodolfo Ascencio-Piña, "A Survey of Energy-Efficient Clustering Routing Protocols for Wireless Sensor Networks Based on Metaheuristic Approaches," *Artificial Intelligence Review*, vol. 56, pp. 9699-9770, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[8] Sweta Kumari Barnwal, Amit Prakash, and Dilip Kumar Yadav, "Improved African Buffalo Optimization-Based Energy Efficient Clustering Wireless Sensor Networks Using Metaheuristic Routing Technique," *Wireless Personal Communications*, vol. 130, pp. 1575-1596, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[9] P. Paruthi Ilam Vazhuthi et al., "A Hybrid ANFIS Reptile Optimization Algorithm for Energy-Efficient Inter-Cluster Routing in Internet of Things-Enabled Wireless Sensor Networks," *Peer-to-Peer Networking and Applications*, vol. 16, pp. 1049-1068, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[10] Bryar A. Hassan, and Tarik A. Rashid, "A Multidisciplinary Ensemble Algorithm for Clustering Heterogeneous Datasets," *Neural Computing and Applications*, vol. 33, no. 17, pp. 10987-11010, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[11] Bryar A. Hassan, Tarik A. Rashid, and Hozan K. Hamarashid, "A Novel Cluster Detection of COVID-19 Patients and Medical Disease Conditions Using Improved Evolutionary Clustering Algorithm Star," *Computers in Biology and Medicine*, vol. 138, pp. 1-16, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[12] Zhezhuang Xu et al., "Balancing Energy Consumption with Hybrid Clustering and Routing Strategy in Wireless Sensor Networks," *Sensors*, vol. 15, no. 10, pp. 26583-26605, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[13] Bryar A. Hassan, Tarik A. Rashid, and Seyedali Mirjalili, "Formal Context Reduction in Deriving Concept Hierarchies from Corpora Using Adaptive Evolutionary Clustering Algorithm Star," *Complex & Intelligent Systems*, vol. 7, pp. 2383-2398, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[14] Bryar A. Hassan, Tarik A. Rashid, and Seyedali Mirjalili, "Performance Evaluation Results of Evolutionary Clustering Algorithm Star for Clustering Heterogeneous Datasets," *Data in Brief*, vol. 36, pp. 1-12, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[15] Bryar A. Hassan, and Tarik A. Rashid, "Artificial Intelligence Algorithms for Natural Language Processing and the Semantic Web Ontology Learning," *arXiv*, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[16] Absalom E. Ezugwu et al., "Automatic Clustering Algorithms: A Systematic Review and Bibliometric Analysis of Relevant Literature," *Neural Computing and Applications*, vol. 33, pp. 6247-6306, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[17] Edy Umargono, Jatmiko Endro Suseno, and S.K. Vincensius Gunawan, "K-Means Clustering Optimization Using the Elbow Method and Early Centroid Determination Based on Mean and Median Formula," *Proceedings of the 2nd International Seminar on Science and Technology (ISSTEC 2019)*, Atlantis Press, pp. 121-129, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[18] Ishita Banerjee, and P. Madhumathy, "QoS Enhanced Energy Efficient Cluster-Based Routing Protocol Realized Using Stochastic Modeling to Increase Lifetime of Green Wireless Sensor Network," *Wireless Networks*, vol. 29, pp. 489-507, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[19] Nevine Makram Labib et al., "Design of an Enhanced Threshold Sensitive Distributed Energy Efficient Clustering Routing Protocol for WSN-Based IoT," vol. 110, no. 8, pp. 1373-1392, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[20] Chaoming Wang et al., "Hybrid Multi-Hop Partition-Based Clustering Routing Protocol for WSNs," *IEEE Sensors Letters*, vol. 2, no. 1, pp. 1-4, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[21] Fifi Farouk, Rawya Rizk, and Fayez W. Zaki, "Multi-Level Stable and Energy-Efficient Clustering Protocol in Heterogeneous Wireless Sensor Networks," *IET Wireles Sensor Systems*, vol. 4, no. 4, pp. 159-169, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[22] Dilip Kumar, Trilok C. Aseri, and R.B. Patel, "EEHC: Energy Efficient Heterogeneous Cluster Scheme for Wireless Sensor Networks," *Computer Communications*, vol. 32, no. 4, pp. 662-667, 2009. [CrossRef] [Google Scholar] [Publisher Link]

[23] Nadeem Javaid et al., "An Energy-Efficient Distributed Clustering Algorithm for Heterogeneous WSNs," *EURASIP Journal on Wireless Communications and Networking*, vol. 2015, no. 151, pp. 3-11, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[24] Brahim Elbhiri et al., "Developed Distributed Energy- Efficient Clustering (DDEEC) for Heterogeneous Wireless Sensor," *2010 5th International Symposium on I/V Communications and Mobile Network*, Rabat, Morocco, pp. 1-4, 2010. [CrossRef] [Google Scholar] [Publisher Link]