

Novel Approach for Energy Efficient Routing and Clustering in WSN using FCM-IDEO with EC²-SRP

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Abstract— Wireless Sensor Networks have become increasingly significant in the 21st century, enabling a wide spectrum of critical applications. However, energy efficiency remains a fundamental limitation affecting their scalability, reliability, and sustainability. This study introduces a novel framework that integrates Intelligent Dolphin Echolocation Optimization (IDEO) with Fuzzy C-Means clustering for adaptive Cluster Head (CH) selection. The proposed method employs a multi-criteria strategy considering residual energy, transmission distance to the Base Station (BS), and latency minimization, thereby ensuring efficient data aggregation in dynamic environments. Furthermore, an Energy-Conscious Cognitive Smart Routing Protocol (EC²-SRP) is developed to establish both energy-efficient and shortest routing paths, reducing communication overhead and extending network longevity. The novelty of this work lies in (i) the hybrid integration of IDEO with FCM for adaptive clustering, (ii) multi-criteria CH selection for enhanced energy efficiency (iii) the design of a cognitive routing protocol balancing energy awareness with path optimality, and (iv) a comprehensive QoS-based evaluation. Simulation results demonstrate superiority over existing methods in terms of energy consumption, network lifetime, packet delivery ratio (PDR), throughput, latency, and routing overhead, thereby achieving higher energy efficiency, reliability, and sustainability in Wireless Sensor Networks.

Keywords—Clustering; Cross-layer routing; Fuzzy-C Means; Optimization; Wireless Sensor Network; Optimization

I. INTRODUCTION

The 21st century have witnessed wireless sensor networks (WSNs) as one of the most transformative technology, enabling critical applications in environmental monitoring, smart agriculture (Chand et al., 2014), healthcare, industrial automation (Mittal et al., 2019), disaster management, and military surveillance (Maraiya et al., 2011). A WSN typically consists of spatially distributed nodes that sense, process, and transmit information to a Base Station (BS). Despite their promise, WSNs are severely constrained by limited battery resources, communication bandwidth, and processing capabilities (Rani et al., 2024). Energy efficiency is considered as the foremost challenge, since battery replacement is infeasible due to deployment of sensor nodes in remote or inaccessible areas (Wang et al., 2018). Node energy depletion leads to coverage gaps, diminished reliability, and premature network failure underscores the energy-aware clustering and

routing mechanism to ensure network longevity and scalability.

Clustering is an effective method to reduce redundant transmissions and balance node energy, wherein sensor nodes transmit data to a Cluster Head (CH) that subsequently forwards aggregated information to the BS. Nonetheless, CH selection process remains a non-trivial task as it depends upon certain factors like residual energy, communication distance, and network dynamics (Soleymani et al., 2020).

To improve WSN performance, various approaches have been proposed with emphasis on latency reduction, energy efficiency, and effective cluster head selection. The Latency-Aware Heterogeneous Cluster-based Data Acquisition (LA-HCDA) (Tandon et al., 2021) technique was developed to lower end-to-end delay and improves coverage. When integrated with quartile aggregation, it further enhances data collection and extends network lifetime. In addressing energy related challenges, the Bionic Cross-Layer Routing (BiCLR) protocol (Latha et al., 2019) operates across multiple layers—physical, data, and transport—employs an optimized CH selection method to achieve energy-efficient communication, and performance evaluated using Quality-of-Service (QoS) indicators like transmission mobility and latency. Further, the Energy-aware Adaptive Fuzzy Neural Clustering (EAANFC-MR) algorithm (Ramachandran & Perumal, 2018) chooses CHs based on residual energy, node proximity, and centrality while leveraging Quantum Optimized Bacterial Foraging Optimization (QOBFO) for efficient multi-hop routing. Similarly, the MOFIS-BFO model (Daniel et al., 2021), integrates with Bacterial Foraging Optimization with a Multi-Objective Fuzzy Inference System, incorporates parameters energy, hop-count, and flexibility for CH selection, improving network longevity. In addition, the Nature-Inspired Cross-layer Clustering (NICC) method (Mahajan & Badarla, 2021) also exhibited superior energy management. The Improved Sunflower Optimization (ISFO) algorithm (Venkatesan et al., 2022) further diminished energy use and prolonged node activity. Some other metaheuristic algorithms like WOA, GA etc. were evaluated in (Raslan et al., 2021), confirming their effectiveness in energy use, latency, and overall WSN efficiency.

The existing routing protocols discussed above were unable to concurrently achieve energy efficiency and path reliability, particularly in large-scale or highly dynamic deployments. These shortcomings have driven the adoption of intelligent

bio-inspired optimization techniques to address challenges in both clustering and routing.

This study proposes a novel framework that integrates Intelligent Dolphin Echolocation Optimization (IDEO) with Fuzzy C-Means clustering for adaptive CH selection and introduces Energy-Conscious Cognitive Smart Routing Protocol (EC²-SRP) for efficient data communication. The IDEO-FCM hybrid improves CH selection by jointly considering residual energy, minimal transmission distance to the BS, and latency reduction, while EC²-SRP dynamically identifies energy-efficient and shortest routing paths to reduce overhead and extend lifetime. The novelty of this work lies in hybrid IDEO-FCM clustering, multi-criteria CH selection, and cross-layer routing design. Performance is rigorously evaluated across average energy consumption, residual energy, network lifetime, packet delivery ratio (PDR). Simulation results confirm that the proposed framework significantly outperforms existing techniques, delivering superior energy efficiency, reliability, and sustainability for WSNs.

The organization of this paper is done as follows: Section 2 describes the model behaviour of clustering and routing. Section 3 details the proposed hybrid methodology, including the design and implementation of the Intelligent Dolphin Echolocation Optimization (IDEO) algorithm for cluster head selection and Energy-Conscious Cognitive Smart Routing Protocol (EC²-SRP) for efficient data transmission. Section 4 offers an in-depth analysis of the proposed framework through simulations, highlighting performance metrics such as energy consumption, residual energy, packet delivery ratio and network lifetime. Last section describes conclusion in terms of outlining future directions for sustainable and intelligent routing solutions for WSN.

II. SYSTEM MODEL

In WSNs, multiple sensor nodes continuously monitor and record environmental parameters within their surroundings, forwarding the aggregated data to BS. To comprehensively analyze this process, the system model is categorized into two components: the network model, which defines the spatial deployment and communication structure of the nodes, and the energy model, which characterizes the power consumption associated with data transmission, reception, and processing.

A. Network Model

Energy consumption in WSN is optimized by organizing sensor nodes into distinct clusters. Normal sensor nodes monitor the environment, collect the data and forward it to designated CH. Only CHs are authorized to aggregate data from cluster members and transmit it to BS. Various factors are included in the selection of CHs like residual energy, node proximity and sensing range etc. So, energy is conserved by clustering mechanism as direct communication is not required between sensors and BS. The WSN structural representation is discussed in Figure 1.

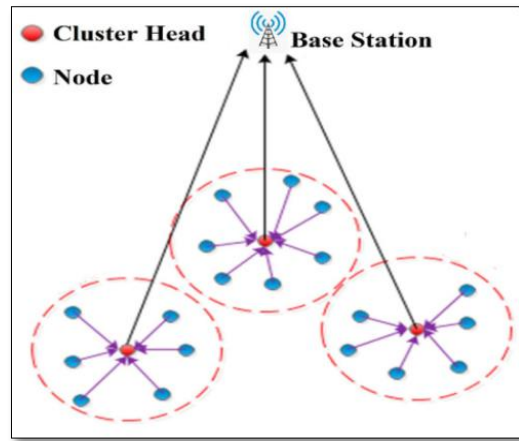


Fig 1. Framework scenario of a WSN

B. Radio Energy Model

Let

$$\begin{aligned} E_{elec} &= \text{Electronic energy/bit,} \\ \epsilon_{fs} &= \text{Amplifier coefficient for free-space} \\ \epsilon_{mp} &= \text{Amplifier coefficient for multipath} \\ d &= \text{link distance,} \\ d_0 &= \sqrt{\epsilon_{fs}/\epsilon_{mp}} = \text{threshold distance} \end{aligned}$$

Then the transmit energy to send an N -bit packet over distance ' d ' is

$$E_{tx}(N, d) = \begin{cases} N E_{elec} + N \epsilon_{fs} d^2, & d < d_0 \\ N E_{elec} + N \epsilon_{mp} d^4, & d \geq d_0 \end{cases} \quad (1)$$

The reception energy is

$$E_{rx}(N) = N E_{elec} \quad (2)$$

III. PROPOSED ALGORITHM

The proposed work presents a hybrid, intelligent framework for sustainable WSNs by incorporating **Intelligent Dolphin Echolocation Optimization (IDEO)** with an Energy-Conscious Cognitive Smart Routing Protocol (EC²-SRP). The framework exploits the echolocation-inspired behaviour of dolphins to develop a dynamic and adaptive clustering mechanism, enabling optimal CH selection based on multi-objective criteria such as residual energy, node centrality, and communication cost. Through efficient exploration and exploitation of the solution space, IDEO algorithm addresses the inherent limitations of conventional meta-heuristics approaches. In parallel, the EC²-SRP protocol leverages cross-layer information—encompassing the physical, MAC, and network layers—to enable real-time, energy-aware routing decisions that adapt to network dynamics and traffic conditions. Collectively, the IDEO and EC²-SRP modules establish a unified system that enhances network lifetime, balances energy consumption, and improves data reliability. This synergistic integration effectively addresses the critical need for sustainability, adaptability, and scalability in WSNs,

particularly within energy-constrained and heterogeneous deployment scenarios.

A. Fuzzy C-Means Intelligent Dolphin Echolocation Optimization (FCM-IDEO) for Cluster Head Selection

Efficient energy utilization is possible in WSNs with clustering by placing sensor nodes in clusters or groups and revealing one node as CH which will be responsible for all activities of that group from collection of data to transmit data to BS. In this study, to optimize CH selection, IDEO algorithm is integrated with FCM clustering by dividing sensor nodes into fuzzy clusters. Each node is not restricted to belong to one cluster only, but nodes with membership degree variance can belong to multiple clusters. FCM also offers a probabilistic approach in cluster formation to upgrade efficiency and flexibility. Dynamic adjustment of cluster centroid is performed to reduce the gap within the cluster, influencing the energy-efficient communication. Further advancement in CH selection is performed by IDEO algorithm. By taking the motivation from dolphins' echolocation experience used for object detection, navigation and path experience, IDEO algorithm setup this behaviour to make optimal CH selection by determining factors like consumption rate, communication range and stability of network. Although applied in a hybrid manner, the integration of FCM clustering with IDEO not only optimizes CH selection, but also balance energy consumption, reduces packet delays and prolongs network lifetime. The FCM-IDEO-based integration for clustering encompasses the following steps:

1. Input: Initialize the number of clusters and fuzzy membership matrix for each sensor node.
2. Cluster Centroids Estimation: Based on the weighted membership of nodes, upgrade the cluster centroid.
3. Membership Value Modification: Iteratively adjust node memberships to clusters to reduce intra-cluster variance.
4. IDEO Optimization: Employ dolphins' echolocation-inspired intelligence to extend CH selection by assessing node energy levels, hop-count to the BS, and overall network stability.
5. Convergence Confirmation: Continue repeating steps 2 through 4 until the cluster centers and CH selections reach stability.

The proposed algorithm integrates FCM clustering with IDEO algorithm to attain optimal CH selection. To determine the absolute number of clusters (N), two factors are taken into account. One is area of deployment (A) and other is sensing range (R) of the sensor nodes. The total clusters are estimated using the equation $C = A/\pi R^2$, where A represents the network's coverage area, and R is the communication radius of a sensor node. This calculation ensures that sensor nodes are adequately divided into clusters, optimizing both network connectivity and energy conservation.

The FCM clustering algorithm assigns all sensor nodes to clusters with respect to a fuzzy membership function. For

every node i , a membership degree (μ_{ij}) to cluster j is estimated as follows:

$$\mu_{ij} = \frac{1}{\left(\frac{d_{ij}}{d_{ik}}\right)^{\frac{2}{m-1}}} \quad (3)$$

Where d_{ij} denotes gap between node i and cluster centroid j which is called Euclidean distance, and m represents fuzziness factor, ranging between 1.5 and 3. The repetitive process refines the cluster centroids using (4):

$$V_j = \frac{\sum_{i=1}^n \mu_{ij}^m X_i}{\sum_{i=1}^n \mu_{ij}^m} \quad (4)$$

Where X_i denotes spatial coordinates of sensor node i . In this way, clusters are dynamically modified to express the spatial adjustment of nodes, thereby upgrading clustering precision and diminish energy usage. After finishing the process of clustering, it is the time to select CHs and which are refined through IDEO algorithm and assess sensor nodes on the basis of their remaining energy, hop-count to the base station (BS), and intra-cluster communication range. The fitness function for CH selection is defined by (5):

$$F_{CH}(i) = w1 \cdot \frac{E_i}{E_{max}} - w2 \cdot \frac{d_{i,BS}}{d_{max}} - w3 \cdot \frac{d_{ij}}{d_{max}} \quad (5)$$

Where E_i denotes the residual energy of node i , hop-count from node i to BS is denoted by $d_{i,BS}$, BS and d_{ij} is intra-cluster distance. The coefficients $w1$, $w2$ and $w3$ are weighting factors set to balance energy efficiency, network lifetime, and communication overhead. The highest fitness score sensor node is chosen as the initial cluster head (CH). The step-by-step procedure of clustering with FCM and optimal cluster head selection using Dolphin Echolocation Optimizer is given in Algorithm 1.

Algorithm 1: Clustering using FCM and CH selection with Dolphin Echolocation Optimizer

1. Initialize the WSN parameters.
2. Position the Base Station (BS) at random coordinates.
3. Deploy all Sensor Nodes (SNs) randomly within the network region.
4. Partition the total number of nodes into multiple clusters using the FCM clustering approach.
5. Assign every node to a cluster based on the highest membership value determined by the FCM algorithm.
6. Select the initial CH within each cluster using FCM's centroid-based clustering methodology.
7. Generate three-dimensional coordinates (p, q, r) for each node in relation to its CH.
8. Compute the Euclidean distance between each node and its CH using the FCM algorithm.
9. Apply the IDEO algorithm for CH selection optimization based on energy efficiency, distance, and node density criteria.

10. Iterate steps 7 to 9 until convergence and an optimal CH is identified at the centre of each cluster.

B. Energy-Conscious Cognitive Smart Routing Protocol (EC²-SRP)

Energy conservation and scalability are critical challenges in determining the most efficient data transmission paths from source to destination. These objectives can be achieved through the proposed Energy-Conscious Cognitive Smart Routing Protocol (EC²-SRP), which enhances communication reliability and reduces packet delays.

In contrast, the existing Cross-Layer Opportunistic Routing Protocol (CLORP) (Liu et al., 2024) encounters several limitations:

- As the number of constraints increases, the processing capability of WSNs limits the complexity of data transmission.
- Difficulties in integrating with other network protocols.
- Excessive energy consumption, packet loss, reduced delivery rate, and considerable communication delays, all of which impair overall network efficiency.

The proposed EC²-SRP framework effectively mitigates these issues by optimizing routing strategies and leveraging residual energy in the network. This approach maximizes node transmission power, minimizes energy wastage, and improves overall network performance.

Initially, all nodes are deployed with a given energy level, and each maintains its residual energy. Nodes first discover neighbors within their transmission range to build a candidate set for forwarding. To select the next-hop node, EC²-SRP introduces a **fitness function** that integrates residual energy, distance, link quality, and delay tolerance. Nodes with higher residual energy and better link quality are prioritized, while nodes with longer delays or excessive distance are penalized. Weighting factors (α , β , γ , δ) allow the protocol to adapt dynamically depending on network requirements, such as favoring energy conservation in dense deployments or reducing delay in real-time applications.

The node with the maximum fitness value is selected for data forwarding. During transmission, the energy consumption is calculated using a radio model that accounts for electronic circuitry (E_{elec}) and amplifier cost (ϵ_{mp}) relative to distance. After each transmission, the sender's residual energy is updated, ensuring fair load distribution across nodes. If a node's energy drops below a defined threshold, it is excluded from routing decisions to prolong network lifetime. This cognitive and adaptive process minimizes packet loss, reduces communication delays, and optimizes energy utilization. Unlike CLORP, which suffers from integration complexity and high energy overhead, EC²-SRP dynamically balances energy conservation with communication reliability. As a

result, the protocol significantly enhances scalability and prolongs the network's operational lifetime while maintaining a high packet delivery ratio with minimal delay as described in Algorithm 2.

Algorithm 2: Energy-Conscious Cognitive Smart Routing Protocol (EC²-SRP)

Input:

- Sensor nodes N , initial energy E_0 , packet size k , transmission range R .
- Radio parameters: E_{elec} , ϵ_{amp} , n .
- Weight factors (α , β , γ , δ).
- Energy threshold E_{th} .

1. Initialization

- Deploy sensor nodes with initial energy E_0
- Each node discovers neighbors within transmission range R .

2. Fitness Calculation

- For each candidate neighbor j , compute fitness value:

$$F_j = \alpha \cdot \frac{E_j^{res}}{E_0} + \beta \cdot \frac{1}{d_{ij}} + \gamma \cdot LQ_{ij} - \delta \cdot D_{ij} \quad (6)$$

- Select next-hop node as:

$$Next - Hop(i) = \arg \max_{j \in C_i} F_j \quad (7)$$

3. Energy Update

- Transmission energy:

$$E_{tx}(k, d) = k \cdot E_{elec} + k \cdot \epsilon_{amp} \cdot d^n \quad (8)$$

- Reception energy:

$$E_{rx}(k) = k \cdot E_{elec} \quad (9)$$

- Update residual energies for sender and receiver nodes.

4. Threshold Check

- If $E_j^{res} < E_{th}$, exclude node j from forwarding set.

5. Adaptive Routing

- Adjust weighting factors dynamically:
 - Increase α to prioritize energy efficiency in dense networks.
 - Increase δ to prioritize delay minimization in real-time applications.

6. Repeat

- Continue Steps 2–5 until data reaches the BS.

7. Termination

IV. SCENARIO GENERATION

To assess the performance of the proposed Bio-Inspired Clustering and Multi-Objective Routing Framework—combining FCM-IDEO with EC²-SRP—a detailed simulation was conducted using a custom-built script in programming language Python. The simulation environment covers a 1 km × 1 km area with 100 randomly placed wireless sensor nodes, each initialized with 0.5 joules of energy. A base station is positioned outside the sensing area at coordinates (60, 190), mimicking real-world remote communication challenges. Initial node grouping is performed using FCM algorithm based

on spatial and data similarity. IDEO then optimizes CH selection by considering residual energy, intra-cluster distance, and node centrality. The number of CHs dynamically ranges from 2 to 10, adapting to energy and network conditions. EC²-SRP performs multi-hop routing using cross-layer parameters. Simulation uses realistic data from the Energy Efficiency Detection Dataset. Metrics include packet rate, node availability, energy, coverage, and network lifetime. The transmission of data packets from Start node to Destination via CHs is shown in Fig.2 in which six cluster heads supervise all sensor nodes within their respective clusters while conserving energy and provides efficient data collection and transmission.

The efficiency of proposed FCM-IDEO clustering approach in terms of network performance is evaluated against K-means (Wand et al., 2018) and FCM clustering on metrics like energy consumption, packet delivery and network lifetime.

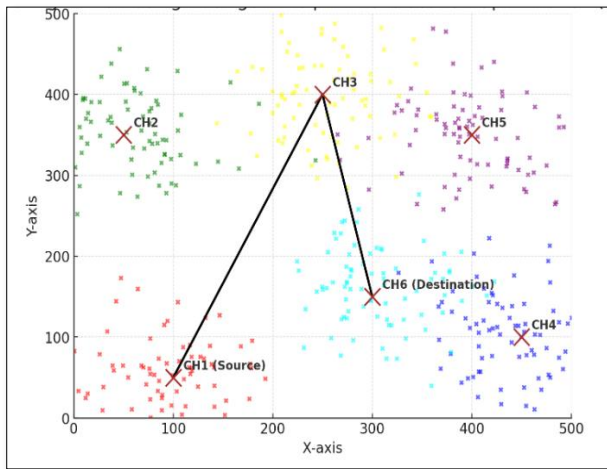


Fig.2. Data packet transmission from Source (CH1) to Destination (CH6)

A. Evaluation of Clustering and Routing Performance

A WSN comprises of multiple sensor nodes, which can either be active or inactive. The proposed clustering technique continuously monitors the nodes to determine their distances and form clusters accordingly. Instead of utilizing the K-means algorithm, this method applies FCM clustering to group neighboring nodes into clusters. An energy-efficient SN is dynamically selected as CH on the basis of energy consumption levels of all SNs and CH is periodically updated in every subsequent round gives adaptability.

1) Performance Evaluation of Clustering

A crucial technique for guaranteeing effective data transfer is clustering. Based on the average energy usage of each node, the suggested work clustered similar data into a single group using the FCM technique. The efficiency of proposed FCM-IDEO clustering approach in terms of average energy consumption is evaluated against K-means (Iwendi et al., 2021) and FCM clustering and shown statistically in Table I. At the start when cluster size is 2, almost all algorithms in context are almost same energy consumption. At cluster size of

5 there are some hiccups in proposed scheme, which may be due the reason that some burst of data may come and calculation part takes toll of energy a bit. In all other cases proposed scheme outperforms the other two by a defined margin in all cases.

In Fig.3, comparison of proposed clustering approach with existing approaches like K-means and Fuzzy C-means clustering approaches in terms of average energy consumption has been displayed. Therefore, for different cluster sizes, the proposed methodology consumed less power on average in comparison with K-means and Fuzzy C-Means method.

TABLE I
AVERAGE ENERGY CONSUMPTION COMPARISON OF THE PROPOSED ALGORITHM WITH EXISTING ALGORITHMS

Cluster size	Average energy consumption (J)		
	K-Means	Fuzzy-C Means	Proposed FCM-IDEO
2	0.023	0.028	0.019
3	0.030	0.040	0.023
4	0.035	0.042	0.028
5	0.039	0.047	0.025
6	0.042	0.053	0.033
7	0.046	0.057	0.035
8	0.050	0.062	0.037
9	0.060	0.070	0.039
10	0.0648	0.075	0.0423

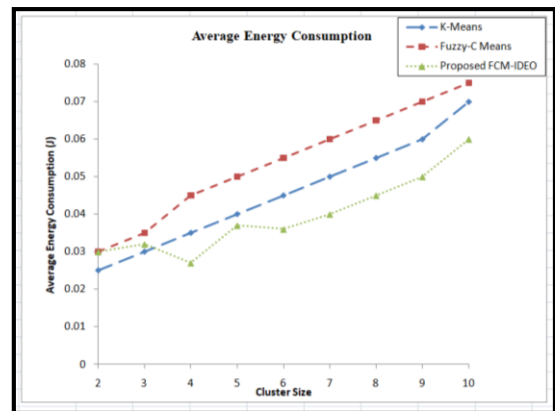


Fig. 3. Performance evaluation of the average energy consumption of the proposed FCM-IDEO algorithm

In addition, the comparison of the FCM-IDEO optimization algorithm is performed with an existing bio-inspired optimization algorithm to estimate the efficiency on metrics like packet delivery, throughput, and network lifetime (Tam et al., 2018; Singh et al., 2017). The obtained results are further benchmarked against cross-layer-based adaptive thresholding (CLAT) (Messaudi et al., 2017) and cross-layer-based fuzzy logic (CLFL) (Samara et al., 2021) to highlight the superiority of the proposed approach.

The statistical data in Table II shows CH selection comparison of the proposed FCM-IDEO method using two traditional techniques as Improved Vertical Clustering - Low Energy Adaptive Clustering Hierarchy (IVC-LEACH) (Echoukairi et al., 2017) and the Whale Optimization Algorithm (WOA). The CH selection in 200 rounds by the proposed method based on the average residual energy is 42.23 J, whereas the existing

methods, IVC-LEACH algorithm and the WOA, have 37.33 J and 32.37 J, respectively.

TABLE II
RESIDUAL ENERGY COMPARISON OF THE PROPOSED ALGORITHM WITH EXISTING ALGORITHMS

Rounds	Residual energy (J)		
	IVC-LEACH	WOA	Proposed FCM-IDEO
200	37.33	32.37	42.23
400	32.43	27.46	37.33
600	19.62	14.72	24.53
800	12.76	4.91	14.72
1000	2.95	0.98	4.91
1200	2.94	0.98	4.9
1400	0.49	0.02	0.98
1600	0	0	0

Fig.4 is interpretation of several rounds show with residual energy as a parameter. Here too it can be referred that proposed scheme has more energy left as compared to others. It can be seen that when rounds are above 1000, the performance is almost same for all.

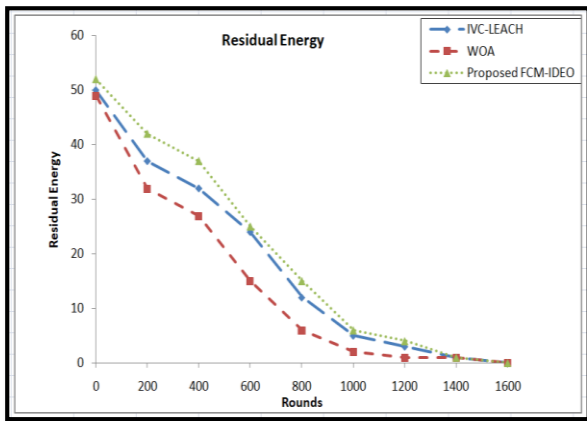


Fig.4. Comparison of the proposed method FCM-IDEO for CH selection

2) Performance Evaluation of Routing

The efficiency of the proposed routing protocol EC²-SRP is evaluated in terms of routing performance on metrics like Energy consumption, Network Lifetime, Packet Delivery Ratio in comparison with existing techniques EC-Fuzzy (Energy Aware Cross Layer based Fuzzy Logic) and EC-adaptive threshold (Energy Aware cross-layer-based adaptive threshold technique).

a) Energy Consumption

The energy consumption of the proposed methodology is shown in Table III, along with two existing approaches EC-Fuzzy (Energy Aware Cross Layer based Fuzzy Logic) and EC-adaptive threshold (Energy Aware cross-layer-based adaptive threshold technique).

TABLE III
COMPARISON OF ENERGY CONSUMPTION OF PROPOSED TECHNIQUE WITH EXISTING ROUTING TECHNIQUES

Techniques	Energy consumption (mJ) vs. Number of nodes					
	100	200	300	400	500	600
Proposed EC ² -SRP	1.77	1.01	4.13	3.8	3.19	2.0
EC-Fuzzy	7.95	9.36	9.87	11.75	10.56	10.67
EC-adaptive threshold	7.25	7.89	7.21	7.95	7.43	7.74

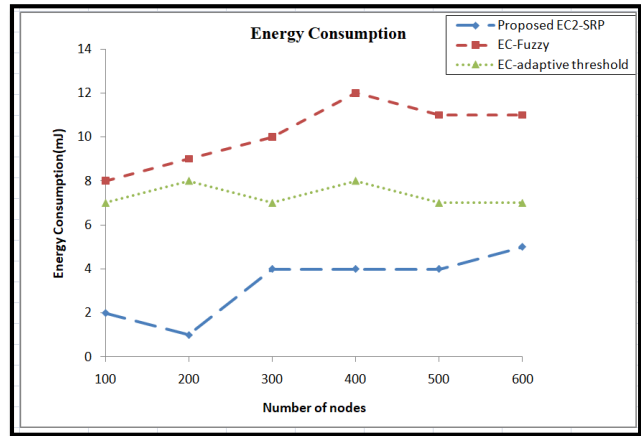


Fig.5. Energy Consumption Comparison of EC²-SRP Technique

The comparison of proposed routing approach in terms of energy consumption with two existing approaches like EC-Fuzzy and EC-adaptive threshold is shown in Fig.5 and proposed methodology energy consumption rate is lower than existing techniques for any number of nodes. For example, for 400 nodes, proposed methodology consumes power 3.8mJ whereas EC-Fuzzy and EC-adaptive threshold consumes 11.75mJ and 7.95mJ respectively. When number of nodes increase the performance decreases a bit which may be because of excessive mathematical computations.

b) Network Lifetime

The network lifetime of the proposed EC²-SRP is evaluated against conventional algorithms, as illustrated in Fig.6. The results indicate that the proposed method achieves a significantly longer network lifetime compared to other approaches according to data given in Table IV.

TABLE IV
COMPARISON OF NETWORK LIFETIME OF PROPOSED TECHNIQUE EC²-SRP

Techniques	Network Lifetime (Rounds) vs. Number of nodes					
	100	200	300	400	500	600
Proposed EC ² -SRP	5808	5611	5414	5118	4922	4710

EC-Fuzzy	4804	4608	4510	4118	3921	3618
EC-adaptive threshold	5295	5000	4804	4608	4510	4404

adaptive threshold					
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The simulation results clearly demonstrate that the proposed method extends the network lifetime to 5808 rounds for 100 nodes. In comparison, the existing cross-layer-based adaptive threshold technique and cross-layer fuzzy logic approach achieve 5295 and 4804 rounds, respectively. Additionally, network lifetime gradually decreases as the number of nodes increases shown in Fig.6. Therefore, data transmission efficiency is directly influenced by the extended network lifetime. Denser medium makes network lifetime at decline and this is as per the theory suggested that more nodes will call for more calculations.

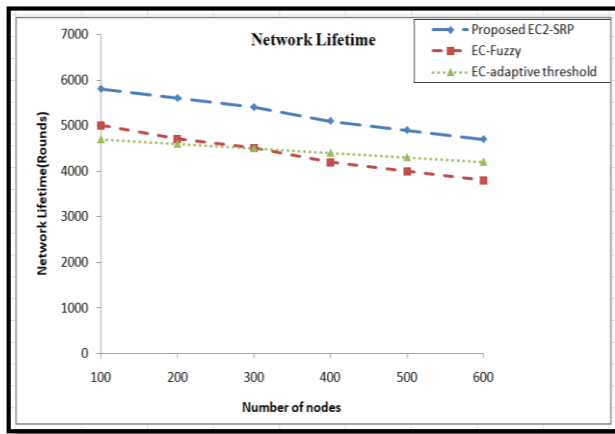


Fig.6. Network Lifetime Comparison of EC²-SRP Technique

c) Packet Delivery Ratio (PDR)

The comparative evaluation data of the proposed technique with the conventional algorithms cross-layer-based adaptive threshold and cross-layer fuzzy logic with respect to Packet Delivery Ratio is shown in Table 5. The EC²-SRP approach's packet delivery ratio was high (100%) in 100 nodes as compared to the conventional algorithms.

Packet delivery ratio is most important criterion for routing performance. It touches 100 percent mark when nodes are sizeable of the order of 100 or 200. Then there is sudden fall around 400, which may be because of route adjustments based on energy calculations. There is abrupt down around 400 which may be due to the same cited reason as a burst may come sometimes as shown in Fig.7.

TABLE V
COMPARATIVE EVALUATION OF PACKET DELIVERY RATIO OF PROPOSED TECHNIQUE EC²-SRP

Techniques	PDR(%) vs. Number of nodes				
	100	200	300	400	500
Proposed EC ² -SRP	100	100	98	96	96
EC-Fuzzy	97	96	96	95	94
EC-	95	91	90	90	88

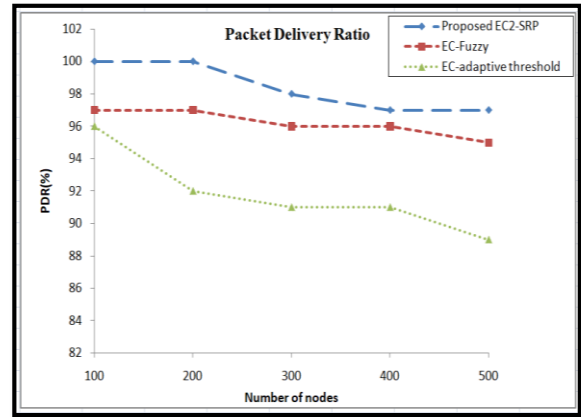


Fig.7. Packet Delivery Ratio Comparison of EC²-SRP Technique

V. CONCLUSION

A new scheme, in essence a hybrid scheme has been proposed. The scheme performs in two major steps as, (i) promotes CH selection using FCM Clustering with IDEO and (ii) effective routing in WSNs via Energy-aware cross-layer smart routing protocol (EC²-SRP). The IDEO-FCM method can be applied for the best CH selection from appropriate nodes. The common metrics—Average Energy Consumption, Packet Delivery Ratio, Residual power, —were used to compare the results. Lastly, for effective data transmission, the EC²-SRP algorithm routing protocol is employed. On established node-to-node paths, the routing procedure is allowed. The suggested system works better than other methods, as shown by the simulation results. The suggested methodology's performance compared with that of the current optimization-based routing techniques. The optimal route from the CH to the BS is selected by EC²-SRP.

The proposed method results outperformed those of the current approaches in evaluating PDR, energy consumption, network lifetime. Performance results for QoS criteria include PDR (100%), power consumption (1.77 mJ), network lifespan (5908 cycles) for 100 nodes. The overall accuracy of the suggested approach is 93.19%. Consequently, the proposed approach performs more efficiently than current strategies. In all scenario and metrics, the suggested approach yielded superior outcomes. A static sensor node WSN was used to test, implement, and idealize the suggested work. This study can be extended to networks of sensors with real-time mobile sensor nodes.

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