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# Energy Aware Clustering Routing Protocol for WSN Using Grey Wolf Optimization Algorithm

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**Abstract:** *Wireless Sensor Networks have gained significant attention due to their ability to connect the physical and digital worlds in applications such as environmental monitoring, healthcare, industrial automation, and military surveillance. However, sensor nodes in WSNs are battery-powered and often deployed in hazardous or inaccessible environments, making energy efficiency and network lifetime major challenges. This study focuses on improving the lifetime and energy efficiency of WSNs using fuzzy logic-based clustering and cluster head selection techniques. The proposed work utilizes a fuzzy logic controller integrated with intelligent optimization algorithms for efficient cluster head selection and energy management. The study compares the performance of Grey Wolf Optimization (GWO) and Artificial Bee Colony (ABC) optimization techniques under different network sizes and scenarios. The fuzzy logic-based GWO approach is designed to reduce computational complexity while improving clustering efficiency and remaining energy utilization. Simulation results indicate that the GWO-tuned fuzzy logic controller performs better than the modified ABC optimization technique in terms of network lifetime, energy conservation, and clustering performance. The proposed approach provides faster convergence, efficient routing, and improved energy balancing among sensor nodes. The study concludes that the GWO-based fuzzy clustering technique significantly enhances network longevity in WSNs. Additionally, future work may focus on integrating multi-layer authentication and advanced security mechanisms to improve the reliability and protection of WSN environments against external threats*

**Keywords:** WSN, IDS, PSO, GA, Fuzzy Logic System

## I. INTRODUCTION

Wireless Sensor Networks (WSNs) have emerged as one of the most important technologies in modern communication and monitoring systems due to their wide range of applications in military surveillance, healthcare monitoring, environmental sensing, industrial automation, smart agriculture, and intelligent transportation systems. A WSN consists of a large number of small sensor nodes that are deployed in a sensing environment to collect and transmit data to a base station. These sensor nodes are generally battery-powered and have limited energy, processing capability, memory, and communication range. Therefore, energy efficiency becomes one of the most critical challenges in the design and operation of WSNs.

Routing protocols play a significant role in improving network performance and extending the lifetime of sensor networks. Among various routing techniques, clustering-based routing protocols are widely preferred because they reduce communication overhead, improve scalability, and conserve energy. In clustering approaches, sensor nodes are grouped into clusters, and a cluster head is selected to collect and forward data from member nodes to the base station. Efficient cluster head selection is essential for minimizing energy consumption and balancing network load.

Recently, optimization algorithms inspired by nature have gained significant attention for solving complex routing and clustering problems in WSNs. One such intelligent optimization technique is Grey Wolf Optimization (GWO), which is based on the leadership hierarchy and hunting behavior of grey wolves in nature. The GWO algorithm provides


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efficient exploration and exploitation capabilities, making it highly suitable for cluster head selection and routing optimization in wireless sensor networks.

This review paper focuses on energy-aware clustering routing protocols for WSNs using the Grey Wolf Optimization algorithm. The study examines different clustering and routing approaches proposed by researchers to improve network lifetime, reduce energy consumption, enhance packet delivery ratio, and increase throughput. The review also analyzes the advantages, limitations, and performance of GWO-based routing protocols in comparison with traditional routing methods.

Although GWO-based protocols show promising results in enhancing energy efficiency and network stability, several challenges still exist, including scalability issues, computational complexity, node mobility, and security vulnerabilities. Therefore, further research is required to develop adaptive, secure, and lightweight energy-aware routing mechanisms for next-generation wireless sensor networks.

## II. PROPOSED METHODOLOGY

The proposed research methodology focuses on improving energy efficiency and extending the lifetime of Wireless Sensor Networks using clustering and intelligent optimization techniques. The study implements a routing protocol based on the Grey Wolf Optimization (GWO) algorithm integrated with a Sugeno Fuzzy Inference System (FIS). The methodology is designed to optimize cluster head selection and reduce energy consumption in Wireless Sensor Networks. Initially, a network consisting of multiple sensor nodes is deployed randomly within the sensing area. Since clustering improves communication efficiency and reduces energy usage, the K-means clustering algorithm is applied to organize sensor nodes into balanced clusters. K-means is selected because of its simplicity, fast execution, and efficient clustering capability. After cluster formation, the centroid of each cluster is calculated for effective cluster management. The next stage involves the selection of Cluster Heads (CHs). In cluster-based routing protocols, CHs are responsible for collecting, aggregating, and transmitting data to the base station. Improper CH distribution may reduce network performance and increase energy consumption. Therefore, a Sugeno fuzzy inference system is designed with three membership functions and twenty-seven fuzzy rules for selecting optimal CHs.

An objective function is developed to evaluate important parameters such as residual energy of sensor nodes, distance between nodes and sink, and distance between nodes and cluster centroids. Based on these parameters, the fuzzy inference system determines the most suitable cluster heads.

Finally, the Grey Wolf Optimization algorithm is employed to optimize the fuzzy rule parameters and improve routing efficiency. The GWO algorithm enhances energy balancing, prolongs network lifetime, and provides faster convergence compared to traditional optimization techniques. The overall methodology aims to achieve efficient clustering, reduced energy consumption, and improved performance in WSN environments.

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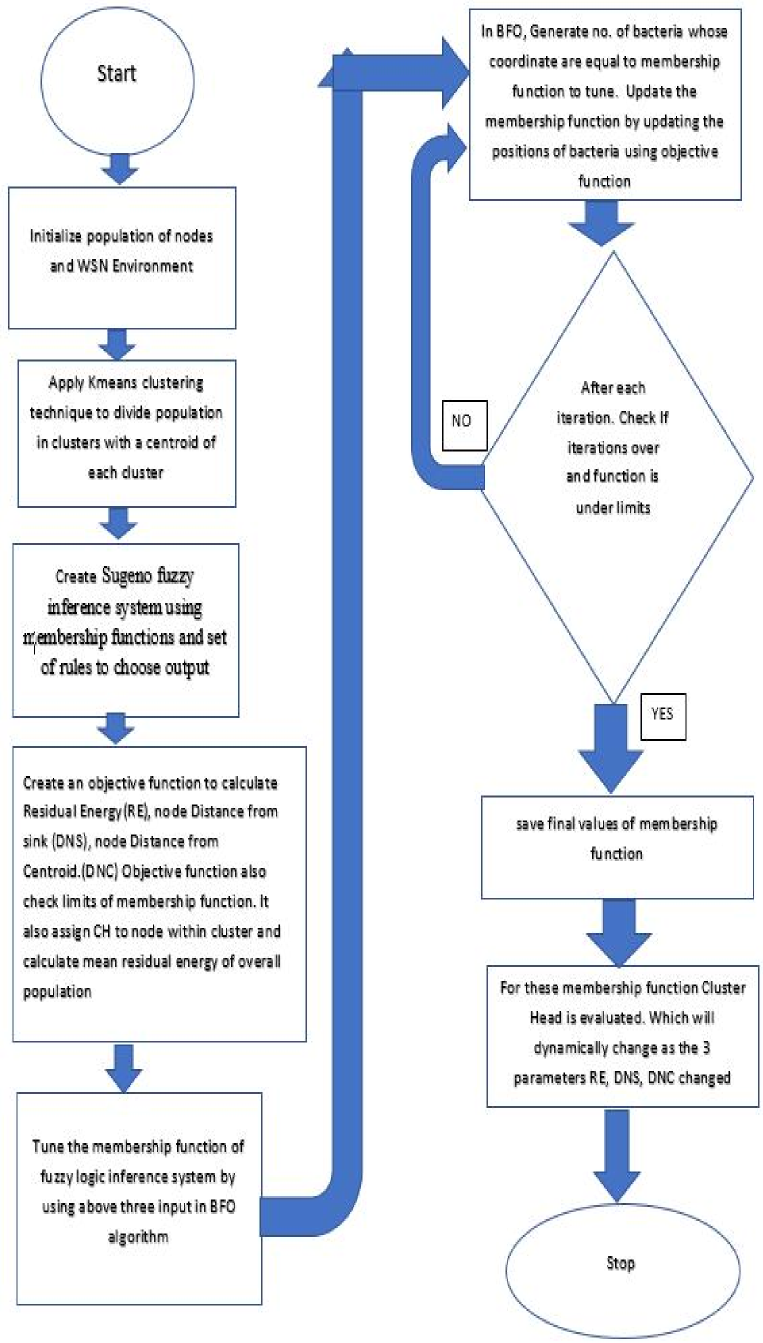


**Fig 1 Proposed Methodology**

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## III. RESULT ANALYSIS

Although the geographical area is 200.00 m², we assessed and observed the impact of GWO &ABC calculations on enhancing the WSN lifetime characteristic.

The output is computed as

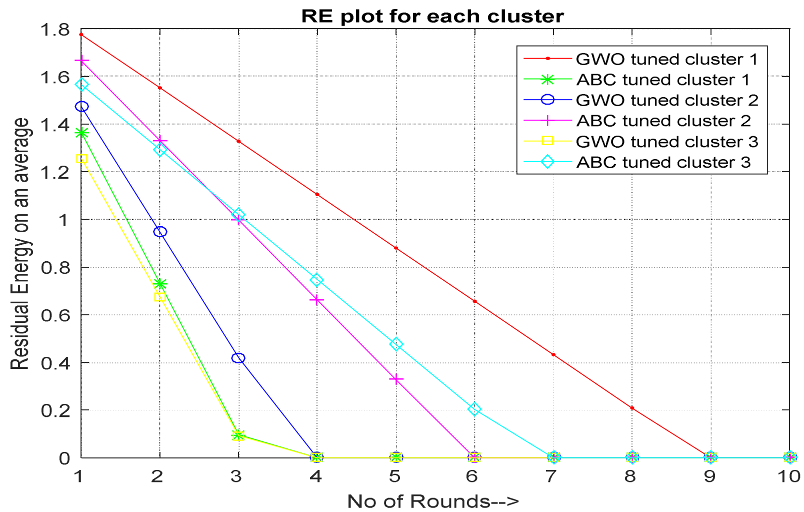


Figure 2 R.E ploting of G.W.O & A.B.C

A consolidated list of 3 distinct examples has been created for enhanced comparing and analysis. GWO is perceived to provide superior implementation compared to the suggested algorithm for the continuous layout of governing and WSN conditions. Furthermore, observation indicates that whenever the mineral area is extensive, the outcomes of BFO & ABC are comparable; however, for a smaller geographical location, GWO surpasses ABC in the ongoing dominance of the WSN situation.

## IV. CONCLUSION

Wireless Sensor Networks require energy-efficient routing mechanisms to improve network lifetime and communication reliability. This study proposed a clustering-based routing approach using Grey Wolf Optimization integrated with a Sugeno Fuzzy Inference System for optimal cluster head selection in WSNs. The methodology utilized K-means clustering and fuzzy logic to reduce energy consumption and balance network load effectively. Simulation results demonstrated that the GWO-based approach outperformed the ABC optimization technique in terms of residual energy, network lifetime, and routing efficiency. The proposed model provides faster convergence, better energy management, and improved performance for next-generation WSN applications.

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