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A Review on Energy Efficient Clustering and Routing Protocol for Wireless Sensor Networks

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ABSTRACT *Wireless Sensor Networks (WSNs) are a collection of battery-powered, small sensor nodes with a wide range of applications in everyday life. Because sensor nodes consist of limited energy resources, energy efficiency while routing is a significant requirement in WSNs. The fundamental difficulty with wireless sensor networks is efficient energy use. Many academics have previously worked on determining the best route among a member node and a drain node with the purpose of prevent energy consumption of the network and improve lifetime of network. WSNs have a variety of obstacles, but one of the most difficult is determining how to decrease energy consumption. The existing literature on clustering and routing approaches was examined and categorized based on their Optimization strategies. The procedures were characterized as metaheuristic-based, fuzzy logic-based, or hybrid method-based depending on the technique characteristic and operating approach. Efficiency, clustering, optimization variables, and factors that influenced protocol efficacy were used to compare the different types of protocols. A detailed survey of Optimization technique-based routing and clustering is offered in this research. This thorough evaluation provides an in-depth overview of previous research in the field of WSNs.*

Keywords : *Energy Efficient, Clustering, Optimization, and metaheuristic.*

I. Introduction

In general, a WSN is made up of a number of small sensors known as nodes. A sensor subunits for data collecting from the physical outdoor landscape, a processing device for local data storage and processing, and a wireless communication subsystem for data transfer are the three essential components of this node [1], [2]. The sensor nodes can gather and transport data to other sensors or back to a base station. We should utilize the energy efficient routing protocol to consume the least amount of energy. Sensor nodes have limited power sources that are often irreplaceable [3]. Because there are so many nodes deployed in key terrain, it's impossible to replace or recharge the batteries. The lifespan of a sensor network is determined by the amount of energy available. As a result, an energy-efficient routing protocol is required [4]. Many technologies for routing, transmission power, and data dissemination have been developed expressly for wireless sensor networks. Due to the intrinsic properties of wireless sensor networks, routing is extremely difficult. The development and maintenance of WSNs are complicated by these limits, which are compounded by the normal deployment of a high number of sensor nodes [5].In this research, we looked at some of the most important routing difficulties that affect sensor network architecture [6]. Although numerous routing strategies for WSNs have been developed. In terms of energy efficiency, we looked at a few alternative procedures [7]. It is obvious from the review protocols that the performance of the protocols is optimistic in terms of energy efficiency. However, it is impossible to create a routing system that can solve all WSN design challenges while also providing adequate efficiency for all wireless sensor network applications [8], [9]. Making an energy-efficient routing mechanism in a WSN is currently the most difficult task. The major goal is to have the sensor last a long period while using minimal energy. Data transmission and reception account for the majority of energy use [10]. As a result, a slew of new security procedures and techniques have emerged to tackle the problem.

II. Energy Efficient Clustering and Routing

First, Clustering is the division of sensor nodes into groups depending on certain characteristics. Clusters of remaining residual energy quality are generated in general based on geographical location. There are a plethora of clustering methods available now, with more on the way. These algorithms can be categorized in a number of ways, including whether or not they require location information, whether they are distributed or centralized, cluster head selection, and cluster formation. The algorithms are initially categorized according to the type of WSN that is being used. It is possible for a WSN to be diverse. In terms of resources, a WSN is one in which the network has a variety of nodes. Some node will usually have greater resources accessible than the rest of the system, such as processing power and energy. In a homogeneous WSN, all nodes have the same set of resources available [11].

Sensor network routing is difficult due to various characteristics that set them apart from conventional methods and wireless ad-hoc networks. Many protocols for communication and security in wireless networks, such as infrastructure-based networks, ad-hoc networks, and mobile networks, have been developed by researchers. In recent years, a great deal of research has been done on low-power protocols, network setups, routing protocols, coverage issues, and the construction of reliable wireless sensor networks. A number of methods have been proposed to prolong the life of WSN and ensure that the proper data is routed to the base station. However, each protocol has drawbacks and is not appropriate for use in area monitoring applications. Due to sensor node resource limits, such as low power devices, communication capability, and processing speed, certain protocols cannot be used directly. Even after a lot of work, there are still a lot of design possibilities open for improvement, and more study focused on specific applications is needed. As a result, alternate and/or innovative protocols that enable more efficient use of restricted resources at mobile nodes for an application are needed to be investigated [12].

III. Recent Advancements in Optimization Algorithms

WSNs use clustering and routing to meet performance criteria such as low energy consumption. Clustering protocols must consider more than just energy efficiency; they must also ensure quality of service (QoS) and strike a balance amongst the number of competing concerns, such as operational lifetime, coverage, and bandwidth [13]. In recent decades, a slew of bioinspired, meta-heuristic, and AI-based optimization strategies have been created to discuss these issues. Several researchers used different optimization strategies to achieve energy efficiency in WSNs by integrating optimization techniques with clustering procedures. The majority of currently utilized optimization techniques in the WSN clustering and routing process are categorized in this study which are presented in Fig. 1

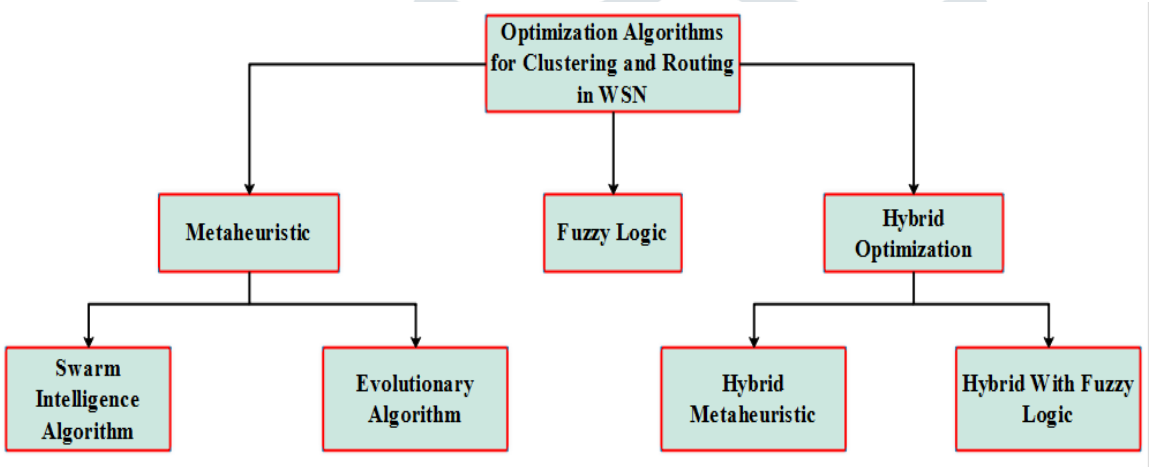

Fig. 1. Classification of Optimization Algorithm.

A. Maintaining the Integrity of the Specifications

The goal of creating optimization methods is to deliver remedies to NP-hard tasks that can be performed in a reasonable amount of time using existing approaches. Even though they don't always prove the optimal answer, meta-heuristics include a comprehensive explanation to NP-hard problems. Clustering techniques and meta-heuristics are utilized in WSNs to obtain optimum energy utilization since they work together to find the best solutions [14]. Swarm intelligence, analyzing problems, and evolutionary algorithm-based methodologies have all been applied by the researchers.

B. Evolutionary Algorithms

Genetic Algorithm (GA) is the most widely utilized evolutionary procedure for routing and clustering in WSNs. To enhance the network life and efficiency, the GA is utilized to extend the lifetime of CHs. Several research has shown that combining GA and Artificial Bee Colony (ABC) approaches can improve clustering, optimal routing, and QoS [15]. Despite the GA's capacity to handle multidimensional issues, since it has high execution times and is unable to generate consistent optimization system performance in large populations. Various factors were used to investigate the methods of clustering evolutionary algorithms-based techniques.

C. Swarm Intelligence Algorithms

This group's algorithms are based on the natural life rhythms of a variety of animals and insects. ABC, PSO and firefly algorithms are also some of the methods in this category [16]. As an optimization tool, the swarm intelligence subcategory shares two characteristics with evolutionary algorithm. The following section presents swarm intelligence and gives the background information needed to grasp its fundamental concepts. Analysis is used to build unconventional optimization approaches in evolutionary computation. As previously said, an evolutionary algorithm imitates the theory of evolution by Swarm Intelligence techniques which are discussed and contrasted in this paper. These variables are intended to provide a broad overview and evaluation of these regimens.

D. Fuzzy Logic

Fuzzy logic is a quantitative subject that was created to represent approximate human reasoning. It gives a level of uncertainty or inaccuracy related with the use of language variables [17] through rules within a fuzzy set. In this section,

fuzzy logic procedures were described and analyzed using fuzzy logic standard parameters and an optimization methodology.

E. Hybrid Techniques

Hybrid optimization is a method of selecting an optimization technique from a set of techniques that all perform the same task. It is assumed that for the same optimization, two or even more methods have been developed [18]. As a result, hybrid optimizations rely on current optimization procedures to identify the proper method to use in any case.

F. Hybrid Meta-Heuristics

In order to obtain optimal range, decreased data redundancy and identifying the smallest number of sensors necessary, a hybrid approach based on an upgraded GA and a binary ACO was used. The ABC's work was to improve the WSN's performance by allowing for more search and utilization throughout CH selection. The purpose of the modified ABC was to determine the shortest route discovery and produce optimal CHs for WSNs [19]. The ideal explanation is the one that has the highest fitness parameter evaluated for sensor activation in the Fractional-GOA.

G. Hybrid Fuzzy

Fuzzy-based and meta-heuristic-based techniques are two types of hybrid optimization methodologies [20]. Since only one CH can be picked across their transmission range, certain nodes do not adopt CH status. When a timer expires, each node chooses one CH depending on the intensity of the received signals from possible CHs. Following the CHs' data aggregation and cluster construction, the data is transferred to the BS according to predefined rules. The approaches and features of fuzzy hybrid techniques from diverse studies were examined and appraised in this part.

IV. Literature Survey

Many existing strategies for energy-efficient clustering and routing in WSN have been developed for diverse purposes up till now. Table 1 below provides a brief assessment of some significant contribution to the existing research.

Author & Year	Methodology	Advantage	Disadvantage
G. Rajeswarappa, S. Vasundra [21] (2021)	RDSAOAEECP is projected in this article for enhancing lifetime probability and energy constancy in WSNs.	This technique is useful for balancing exploration and exploitation under CH assortment to maintain energy stability. The features of SA and RDOA were also employed to achieve the necessary CH, as well as the best base station position for maximizing energy efficiency.	This repetitive process is repeated until the temperature reaches the target value. Still, there is still potential for expansion in terms of exploration and exploitation capabilities.
Ushus Elizebeth Zachariah, · Lakshmanan Kuppusamy [22] (2021)	HOCK and HECK are two new energy-efficient clustering algorithms proposed in this paper to extend lifetime of network in homogeneous and heterogeneous environments, respectively.	This protocol was used to decrease energy consumption and increase lifetime of network in WSNs in both homogeneous and heterogeneous situations.	However, because of the increased number of clusters, it is not suited for big networks. It was also only appropriate for a single base station..
D. Laxma Reddy, Puttamadappa C, H.N. Suresh [23] (2021)	This research proposes a new hybrid algorithm for optimal CH selection called ACO included Glowworm Swarm Optimization (GSO) approach (ACI-GSO), which is a hybridization of GSO and ACO techniques.	WSN's lifespan is extended using this way. The choice of CH in every cluster is regarded as the proficient tactic for energy-efficient routing in the clustering model, which reduces the transmission delay in WSN.	Conversely, when compared to other common schemes in the 80th round, the provided model displays a high network energy usage..

R.M. Alamelu and K. Prabu [24] (2021)	The (PIOA-DS) Protocol for WSN is an optimistic strategy for energy-efficient Pigeon Optimization Algorithm based Clustering and Dempster-Shafer (DS) for Routing to enhance network lifetime.	In comparison to existing approaches, the PIOA-DS method has postponed the Half Node Dies (HND) to the greatest extent possible. The proper CH election is made with standard potentials, ensuring that the network's power efficiency is maintained.	However, because of the high convergence rate of a vast network, this strategy was not appropriate..
Tanima Bhowmik, Indrajit Banerjee [25] (2020)	For clustering and routing in WSN, this work proposes an improved PSO Gravitational Search Algorithm (GSA). The goal of this study is to balance the energy of the clustering nodes and transport data from the cluster head to the sink.	The proposed paper attempts to reduce energy usage while also extending the life of the network. Clustering and routing are used in an effective system to decrease energy usage and increase the network's lifespan.	The remaining energy is not efficiently utilized during cluster formation. The key issue is scalability, which is difficult to assess as the network grows..
Nitin Mittal et al [26] (2020)	his research developed a Trust-aware energy-efficient stable clustering strategy for wireless sensor networks utilizing a fuzzy type-2 Cuckoo search optimization algorithm to solve the problem of WSN data exchange reliability and efficient communication with the data collection center.	In terms of successful eradication of malicious nodes, energy depletion, constancy length, and system longevity, the suggested strategy beats previous communication techniques.	For the reselection of CH, it results in high network overheads due to the non-optimized CH election. Furthermore, intra-cluster communication is direct which resulting in inconsistent energy use.
P. C. Srinivasa Rao et al [27] (2021)	CSO based techniques have been proposed in this research to address the hot-spot problem, and these algorithms are together referred to as CSO-UCRA By taking into account of remaining energy and numerous distance aspects, the proposed method has been built with well-organized fitness parameters.	The PSO-UCRA algorithm converges quicker than the EBUC algorithm, which is based on PSO. Because crucial parameters were taken into account in PSO-UCRA, an enhanced fitness function was applied.	But this solution necessitates a strategy for incorporating mobility into the network and overcoming the hot spot problem, but it ignores QoS factors..
Aparajita Chowdhury, Debashis De [28] (2021)	The Voronoi-Glowworm Swarm Optimization-K-means method is used in this article to propose an energy-efficient coverage optimization technique. Glowworm Swarm Optimization, the K-means algorithm, and the Voronoi cell structure are used in this method to increase coverage while using the fewest amount of active nodes possible.	By means of multi-hop transmission and the sleep-wake device, the suggested solution extends the lifespan of the arranged system by reducing the amount of energy spent by the deployed sensor nodes.	However, in the suggested approach, the sleep-wake process is exploited to reduce energy usage, resulting in a very modest drop in the number of living nodes. Therefore, the proportion of coverage progressively drops, allowing coverage to be maintained for a longer period of time.
Piyush Rawat, Siddhartha Chauhan [29] (2021)	To improve network lifetime and performance, a PSO-EEC is suggested in this research. The recommended procedure chooses the relay nodes and CH via the PSO method. Selection of CH is done by fitness function based on particle swarm optimization, which takes into account the energy ratio, distance amongst the CH & node, and degree of	The suggested PSO method was utilized to pick the maximum ideal node as CH to manage the progression of cluster. The energy and distance to the BS are utilized as parameters in this protocol's routing technique to calculate the fitness function and identify the ideal route to BS for sending the packets. Also, it	However, this strategy does not take into account the various levels of heterogeneity and does not use other appropriate factors to create the fitness parameter for the selection of relay and CH.

	nodes to determine the most suitable node for CH.	exploits fault tolerance in the progression to eliminate performance deprivation in the event of gateway miscarriage.	
S.T. Sheriba, D. Hevin Rajesh [30] (2021)	The IHCBW with interval type 2 fuzzy logic system-based HEED (IIT2FLS-HEED) method is proposed in this paper. For the selection of appropriate residual energy, we employed a combination of cuckoo search (CS) and improved black widow optimization (IBWO) algorithms (IHCBW). The interval type 2 fuzzy logic system is used to select the best cluster heads (CHs) (IT2FLS).	With less energy usage, this protocol enabled ideal scalability and network longevity. According to this study, the suggested procedure takes less time and has less computational complication over the conventional techniques.	As a consequence, decent performance is gained with minimal energy usage, but data link is poor.

V. CONCLUSION

Here, a current state-of-the-art analysis of the obtainable optimization approaches, principles of clustering and progressing through optimization to classifying existing WSN protocols are analyzed. Depends on the administration and network organization strategies, modern clustering systems are classified as fuzzy logic, meta-heuristic and hybrid methods. To establish the competency of clustering and routing protocols, researchers looked at the clustering's features and parameters, goals, benefits, and essential features of various optimization strategies. Based on their methodology, this comparison intended to assess the performance of existing clustering and routing systems. Protocol design, energy consumption, bandwidth, stability duration, and system lifetime were all considered in the performance-based evaluation of the protocols. This overview of Optimization based clustering and routing approaches is meant to pave the way for future WSN research.

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