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A Review on Cluster Head Selection in Wireless Sensor Networks

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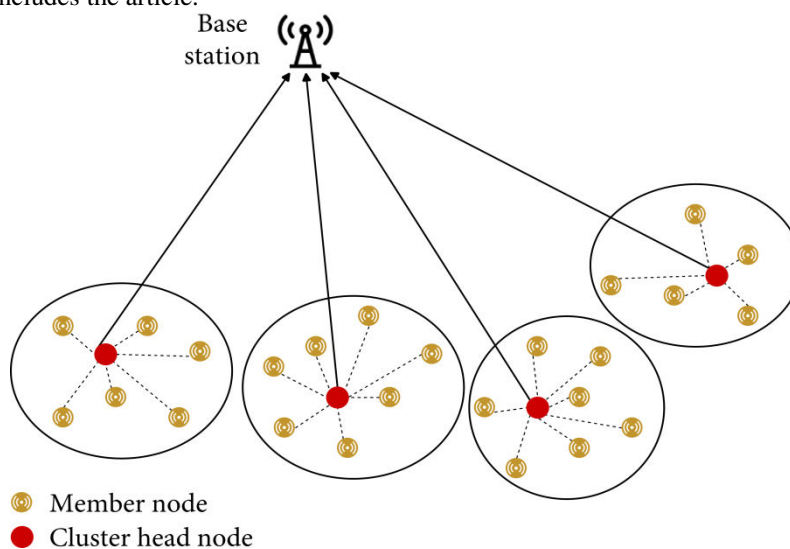
ABSTRACT: Wireless Sensor Networks (WSNs) typically consist of thousands of resource-constrained sensors that monitor their surroundings, collect data, and send it to remote servers for processing. Although WSNs are considered highly flexible ad-hoc networks, network management has been a major challenge in these networks due to the large deployment size and associated quality concerns such as resource management, scalability, and reliability. Topology management is regarded as a viable method for addressing these concerns. The most well-known topology management method in WSNs is clustering, which groups nodes to manage them and/or executes various tasks in a distributed manner, such as resource management. Although clustering techniques are most commonly used to reduce energy consumption, they can also be used to achieve a variety of quality-driven goals. We review existing WSN clustering techniques, their objectives, and the network properties supported by those techniques in this paper. We extract about 215 of the most important clustering techniques after refining over 500 of them, which we then review, categorise, and classify based on clustering objectives as well as network properties such as mobility and heterogeneity. Furthermore, statistics based on the chosen metrics are provided, providing highly useful insights into the design of clustering techniques in WSNs.

KEYWORDS: Wireless sensors networks; backpropagation; cluster head; LEACH; energy consumption

I. INTRODUCTION

The rising of wireless sensor networks (WSNs) has contributed to their wide usage in many applications like disaster management [1], RFID networks [2], drone application [3], and medical applications [4]. Since WSNs are made of low cost and small-sized sensor nodes, they face some limitations like limited battery capacity, small memory size, and shorter communication ranges. The energy usage in WSNs is continuous, because it is employed during data sensing, data collection, and within the data transmitting phase. The info transmitting phase uses the foremost amount of energy on the average, where to transmit one little bit of data over 100 m by radio costs the identical amount of energy as executing 3000 instructions [5]. In recent years, the energy efficiency problem has received more focus because changing or recharging the battery supply can not be done easily for networks in large scale or remote areas [6]. Furthermore, efficient data transfer is another problem faced in WSNs. This can be because of a mismanagement of WSNs which will increase the packet payload size, which directly increases the probability of dropping data packets. As such, retransmission of information packets will consume more energy yet [7]. In early 2000s, Heinzelman et al. [8] introduced an energy-efficient communication protocol which is termed as LEACH (low-energy adaptive clustering hierarchy). LEACH helps in optimizing the ability consumption through a clustering technique, where some CHs are selected supported cluster rotation, and other nodes join these cluster heads to create clusters. The sensed data are sent to the respective CH to be aggregated, and also the data is then transmitted to the BS by the CH [8]. Back then, this was a really successful method, where LEACH helped enhance the network lifetime by saving the energy usage within the transmission phase. Although, the strategy enhanced the energy efficiency, there have been some challenges faced within the long term. The foremost common problems faced were the network hole problem and also the isolated node problem. The network hole problem is additionally called as a hotspot problem, where the CH near the BS depletes energy faster as compared to the nodes far from the BS during a multihop environment, as most of the info reaches to the CH near the BS for aggregation and data transfer to the BS [9–13]. On the opposite hand, the isolated node problem

is where nodes don't join any cluster and don't have a path to send data to the BS [14–16]. These problems are tackled by proposing some techniques and methods like unequal clustering, mobile BS, and efficient CH selection method. Unequal cluster formation is where clusters near the BS have a lower number of sensors compared to the clusters isolated from the BS. Therefore, a CH near the BS uses lesser energy to speak with its cluster members, and it can communicate with other CHs that are removed from the BS, making the load balanced [4, 17, 18]. A mobile BS is where the sink is moved from time to time to gather the sensed data from the cluster heads [19]. Both methods take more effort and consume more energy in terms of cluster formation and memory usage to stay track of the placement of the mobile BS. This leaves us with the acceptable CH selection method, which has been widely researched and discussed in recent years. CH selection is finished by setting some selection criteria like residual energy of the node and therefore the distance between cluster members (CM), CH, and BS. In some research, the choice criteria are inserted into a metaheuristic method for faster convergence and better accuracy of choosing CHs moreover as ensuring a more robust QoS of the network. From the reviews done of the past decade, it's observed that almost all of the survey articles don't discuss the inclusion of metaheuristic algorithms in clustering. Most of the surveys cover topics regarding clustering objectives and therefore the forms of clustering models in terms of probabilistic and deterministic models, which can be explained and discussed further in Section 2. Moreover, most of the surveys don't discuss the recently researched clustering methods and techniques. during this article, a comprehensive survey on the nonmetaheuristic and metaheuristic methods in clustering the WSNs is presented. The contributions of this work are as follows: (i) Detailed concepts of cluster head selection techniques in nonmetaheuristic and metaheuristic methods are presented (ii) Detailed concepts of cluster formation techniques in nonmetaheuristic and metaheuristic methods are presented (iii) All the presented techniques are analyzed in terms of assorted environment settings (iv) Various kinds of nonhybrid and hybrid metaheuristic techniques, including their overall parameters, setting, evaluation, advantages, and drawbacks are presented (v) Usage of varied methods in certain applications in terms of medical applications, drone applications, and disaster management also are discussed (vi) Multiple comparative analysis tables are presented for a clearer and better understanding of the differences and similarities (vii) The open issues and future directions of cluster head selection techniques and cluster formation techniques are discussed At the tip of this survey, readers would be able to differentiate the methods in nonmetaheuristic and metaheuristic cluster head selection and cluster formation phases in terms of their limitations and advantages. Readers will be ready to know the performance of certain methods in several environment settings like mobile nodes, multihop and single-hop data transfer, heterogeneity of sensor nodes, and other parameters involved. The challenges and future direction may help in further research during this field of study, as having a correct CH selection or cluster formation technique may help to scale back energy consumption in various applications. The remainder of the paper is organized as follows: Section 2 presents some related reviews on clustering in WSNs. Section 3 presents the overview of LEACH, with an overall taxonomy of clustering in WSNs supported nonmetaheuristic and metaheuristic methods. Section 4 presents a discussion on the assorted methods in nonmetaheuristic techniques. Section 5 discusses the varied methods in metaheuristic techniques. Section 6 presents comparative analysis, the method's performance discussion, open issues, and future directions of the clustering-based research. Section 7 concludes the article.



1.1 Cluster formation

After the sensor nodes are deployed, the distance between any two sensor nodes have to be computed. For this, our proposed approach employs a mechanism in which a beacon signal is transmitted from the sink to the rest of the sensor nodes. Based on the received signal strength, a sensor node can calculate its distance from the sink. Then a group of tentative cluster heads (TCHs) are elected from the sensor network for aspecific fraction of the entire network as follows. A threshold “T” is calculated and forwarded to all the sensor nodes. Every sensor node generates a random number and compares the same against the received threshold value. Suppose the generated value is more than the threshold, then the sensor node declares itself as a cluster head. Otherwise, it becomes an ordinary sensor node.

1.2 Benefits of Clustering

Clustering enhances the lifespan of WSNs by providing high energy efficiency. The benefits of WSN clustering are listed as follows:

1. Extremely energy efficient.
2. To reduce the number of broadcast nodes connecting BS, cumulative data or condensed information is transmitted directly across CH and BS.
3. SNs aggregate data and send it to CH, which combines it into packets and sends it to the BS. Individual sensor node energy consumption is reduced because only CH communicates with the BS and no other non-CH sensor nodes.
4. Redundant messages are eliminated because SNs are only required to relay messages or information to the CH.
5. It is not necessary to preserve the topology in a sequence because SNs only communicate with one cluster.
6. By using a TDMA schedule to connect the clusters, the CH sends messages to the BS at predetermined timeslots, effectively reducing packet crashing.
7. Battery life is extended due to TDMA scheduling.
8. The network becomes highly scalable, as opposed to a traditional network with no clustering.

II. LITERATURE SURVEY

The past work of researchers is outlined here in this section. The goal of this survey is to research different techniques for selecting the head of the cluster. The study contains the study of classical based routing where the cluster head is selected randomly. Which in turn create uneven traffic. There are some challenges which should be focused like load balancing, node converges etc. The researchers are responsible for several robust routing protocols focused on optimization algorithms such as ABC (Artificial Bee Colony), PSO (Particle Swarm Optimization), GA (Genetic Algorithm), FL (Fuzzy Logic).

Researcher Heinzelman, et. al.[1] introduce the clustering algorithm called LEACH (Low Energy Adaptive Clustering Hierarchy). LEACH algorithm is based on clustering. The whole network area is separated into the small region and anyone node is arbitrarily selected from the cluster as head of cluster (CH).The cluster head choice is done on rotation bases to equally dispense the energy in the network. Cluster heads duty to accumulate the data from its cluster and aggregate it and promote it to the BS(Base station) or the sink node. Because of this, it reduces the long communication which was happened between the base station and normal sensor node. LEACH uses the TDMA to avoid the collision while transmitting the data. After some time the role of cluster head is given to any random node to obtain the uniform distribution of node in the network. Setup phase and steady phase are the two phases of LEACH. In the first phase (steady phase)clusters are formed and a cluster head is chosen. In a steady phase, actual data transfer takes place between the base station and cluster head. After selecting as a head the node broadcast the message to the remaining normal sensor node. The normal sensor node will connect one cluster depending upon the signal strength. The normal sensor node informs to cluster head about joining of the cluster. TDMA slot is used by the cluster head for each node for data communication to avoid the collision. In a steady phase, actual data get transferred. This protocol is a LEACH enhancement for PEGASIS (Power-Efficient Gathering in Sensor Information Systems). In PEGASIS every node is communicating with the nearest neighbor and turn to the base station. This method distributes a load of energy evenly. The sensor nodes in PEGASIS are positioned randomly in the region. The node will create a chain structure either by them or by applying a greedy algorithm which starts with any node. Eventually,the base station will found the chain to broadcasting to the entire sensor. If a node dies, the chain again constructed by excluding the dead node. PEGASIS does not build a cluster that uses a single chain node to send the data collected to BS[2]. The researchers have came up with various clustering approaches to solve the issue of energy consumption.

Author Bilal Muhammad Khan et.al[3] talked about the Fuzzy-TOPSIS technique, where the decision is based on multicriteria. To make best use of the lifetime of the WSN choose CH proficiently and successfully. The parameters of the criterion consist of the outstanding energy of the node; the rate of consumption of node energy; the number of

neighbour nodes present; the average distance between neighbouring nodes; and the distance from the sink. It includes various phases. In phase 1 the sink node broadcast hello packet which contains the location of the sink. In phase 2-Sensor nodes broadcast one packet called HELLO in their transmission range, by using (CSMA) technique. After receiving the broadcast control packet from neighbouring sensor nodes, all the nodes present update their corresponding neighbourhood table. The Rank Index (R.I.) is determined in step 3 of cluster head selection using the Fuzzy-TOPSIS method (Technique for Order Preference by Similarity to Ideal Situation).. The node which contains the highest R.I.value in its transmission range will be selected as a cluster head. In phase 4 clusters formed. When cluster head announces him as a cluster head its transmission range other nodes will be joining to that cluster. Then CH uses TDMA for transmitting the data. Cluster head not changed in every round to overcome the overhead.

Researchers, VinithChauhanet.al[4] proposed cluster head selection using mobile sink based on an energy-efficient strategy for WSN(wireless sensor networks). The network is alienated into a rectangle area. each one area consists of a cluster head. The author proposed firefly optimization for selection of cluster head. The multi-criteria include an average node to node distance, distance from the node to sink and residual energy, considered. In the initial phase,the cluster head is arbitrarily selected for an early population for optimization technique. Following this fitness function is calculated. After calculating the fitness values firefly algorithm is applied. The maximum fitness value of node act as cluster head. Cluster head sends its location to sink. Sink calculate its location. Cluster head eventually gathers the sense data from a cluster member. The Cluster head sends the aggregated data to the sink directly or may send to another cluster head. Here TDMA is used to avoid the collision when data transfer takes place. When any one of the cluster members sends the data to cluster head other cluster members turnoff theirradio until there turn comes for data transfer. This method utilizes the energy efficiently.

Author Jin Wang, et.al[5]proposed method where it selects the CH by using new fuzzz method which considersthreeparameter like the centrality of the cluster,remaining energy of the node, and space between the node and the sink(mobile). Ultimately the cluster which is having maximum energy, which is in center of the cluster and the one which is near to the mobile sink, is nominated as a cluster head. Choice of cluster head is based on the fuzzy method called Mamdani. In thesesmethods, these three parameters are taken as an input and will get the output priority opportunity a fuzzy variable. The Mamdani inference system consists of three steps first is fuzzzification, second is rule generation and evaluation and last is defuzzzification.

Researchers P. T. Karthick et.al suggested optimised cluster head choice for the wireless sensor network in [6] krill herd. Initially, arbitrary population is developed, the GA-based method is suggested. To measure the fitness of any node, the fitness function is used. The whole distance from the cluster head to the base station, number of cluster heads, remaining energy, total intra-cluster distance, is the parameter considered for calculating it. The cluster head is the node with the maximal fitness score. Another strategy is the krill approach, where the node sends its position and residual energy to the base station in the early set-up process. Calculate the maximum average energy of that node at the specified time base station. The node with the most energy will serve as a cluster head for that round during this round. For the next base station iterations, run the krill algorithm for the cluster head calculation. The cost function is determined by using the function of the highest average Euclidean distance between the nodes and their corresponding cluster head and the function of the ratio of the total initial energy of all the nodes in the network to the total current energy of the nominee cluster head in the respective round. If an optimal number of nodes and energy is given, then the node is selected as the head of the cluster.

Author AmitSarkar et.al [7] talked about Cluster head selection based on delay-less routing in a wireless sensor network. As have known,the delay is directly proportional to distance. The cluster head selection is based on if it is closer to the base station and closer to the sensor node. Firefly algorithm is implemented to make the best use of the energy of the network and living time of the node. First, it selects randomly eligible cluster head and then cost function is calculated. While calculating the cost function parameters like distance, energy and delay. After calculating the cost function, the maximum value is taken. If the updated values aregrater then the previous value then-new firefly is updated with a new one. This is repeated until the maximum count is reached.

Researcher Muhammad Arshad et.al suggested in [8] a system focused on residual energy and randomised node selection. In the next round, the node that was the cluster head in the previous round will not be considered. In this, all network nodes make the option to become a cluster head based on the likelihood and outstanding energy of the node with the help of the LEACH algorithm during cluster forming. In this case, the network is alienated into k clusters with the total number of nodes in the network N. After N / k , this means each node gets a chance. For the next round, the nodes that are selected will not be considered. The cluster is formed and then TDMA is used to prevent a collision between the cluster member and the cluster head for data communication.

Researcher De-gan Zhang et.al[9] talked about a new clustering method for WSN. Here during cluster formation node density, relative distance and remaining energy of the node is considered. As it considering node density selected

cluster head gives better coverage with a short distance from a cluster member. It eventually reduces the cost of communication. During cluster formation, all nodes broadcast its ID. It counts its neighbour, number and distance between a node and its neighbour. Every node then calculates regular time t . Starts timing after it receives information from the base station. If a node, didn't get the information then that node itself declares as a cluster head and notify this to neighbour nodes. And if receive the information then that node will be the cluster member for that cluster. If it receives the data from multiple cluster head then the one who sends last that cluster will be considered.

III. COMPARISON WITH THE NUMBER OF PARAMETERS CONSIDERED

Author	Method used	Parameter Considered	Compared with	Advantages	Limitations
Bilal Muhammad Khan et.al[3]	Fuzzy-TOPSIS and a Multi-Criteria Decision Making (MCDM) technique	- Remaining energy - Rate of Energy consumption 3. - Amount of neighbour nodes - space between neighbouring nodes - Distance from the sink.	- LEACH I - The conventional Fuzzy	it allows the attribution weights according to the level of importance of each criterion and considers the complexity, subjectivity, and uncertainty of the decision process.	It can cause the phenomenon known as rank reversal
VinithChauhan et.al[4]	Firefly optimization algorithm	- Remaining energy - Node to node distance - Distance from the node to sink	- LEACH, - LEACH-GA - A-LEACH - MIEEPB, - MSIEEP	It have good efficiency for certain problems and require only a small number of iterations.	It have high probability of being trapped in local optima
Jin Wang,et.al[5]	Fuzzy cluster head Selection Algorithm	- Remaining energy - Centrality of a cluster, - Distance between node	- LEACH - CHEF - EAUCF	It is a robust system where no precise inputs are required.	Fuzzy logic is not always accurate, so the results are perceived based on assumption.
P.T. Karthicket.al[6]	Krill Herd Algorithm based clustering	- Average Euclidean distance of nodes to related CHs - Number of nodes fit to cluster - Ratio of the total initial energy of nodes with the total current energy of the CHs	- LEACH - GA optimization	It requires few control variables to regulate, the search space effectively and efficiently.	It may not escape some local optima.
AmitSarkar et.al [7]	Firefly with cyclic randomization	- Energy - Distance - Delay	-----	It is efficient and easy to implement	it is a local search algorithms.

	is proposed			algorithm and also suitable for parallel implementation	
Muhammad Arshad et.al[8]	Multi-hop energy efficient cluster head selection in mWSN	- Residual energy of node - Node has elected as a cluster head after N/k rounds	- LEACH (Hybrid Multi-hop LEACH)	Improving energy efficiency can lower individual utility bills, creat jobs, and hel stabilize electricity prices	The sensor nodes close to the sink must forward much more packets than sensor nodes further away from the sink
De-gan Zhang et.al[9]	Predictive energy consumption efficiency (PECE)	- Neighbour nodes - Shorter relative distance away from neighbour nodes	- LEACH - PEGASIS	Provide useful information to make decisions on energy generation and purchase	It can be affected directly or indirectly by many different factors

IV. CONCLUSION

In Wireless Sensor Networks, how much power they use is very important. Power isn't something that can be replaced with something else. It takes only a small amount of energy to run nodes that are equipped with sensors (batteries). To make the network run better, you can use less power when you talk to each other. People who read this paper will learn about a new way to group things in the LEACH routing protocol that makes use of the Neural Networks method. There were more network sensors that lasted longer when they used less electricity, which made them last a long time.

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