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Energy Efficient Approaches for Dynamic Cluster Head Selection Using Optimized Genetic Algorithm in Cluster Networks of WSN

Sunny Sall[1], Dr. Rajesh Bansode[2]

[1]Assistant professor, Computer Engineering Department of Computer Engineering, St. John College of Engineering and Management Palghar, India.

[2]Professor, Department of Information Technology, Thakur College of Engineering and Technology, Mumbai, India.

Abstract: Expanding the duration and reliability of wireless sensor networks (WSNs) via energy efficiency is challenging. Clustering has increased energy efficiency by selecting Cluster Head (CH), but its deployment is still tricky. The areas where cluster-heads are desired are initially explored in current cluster-head selection techniques. The cluster heads are then chosen from the nodes nearest to these sites. This location-based method has several drawbacks, including dynamic load, low selection precision, and repeated component selection. It proposes the weight-based Genetic Algorithm (GA) methods for dynamic cluster head selection (DCHS) in a cluster network to solve these problems. The current work proposed is based on multiple cluster generation for effective and lightweight data transmission from Cluster Member (CM) to Base Station (BS) via CH. The fundamental objective behind this research is to reduce the cut generation in-network and reduce communication cost and network overhead. When it generates the multiple clusters with n number of nodes, each node has some energy used for communication and data transmission. The optimized GA-based function is used for selection of best CH in specific cluster region. Moreover, we also define a logic backup cluster head when extra overhead is generated on the CH. It receives additional benefits such as eliminating data collision problems, data leakage, and single-point bottleneck attacks. In the current experimental analysis, this demonstrates the CH selection efficiency with different NS2 protocols such as DSR, DSDV, AODV, and LEACH, etc. It also determines that the experiment automatically extends the network lifetime. In comparative analysis our method has evolute with state-of-art such as ACO, LEACH and dynamic CH selection techniques. It required low computation for transmission and enhance the network lifetime due effective utilization of nodes and energy. The GA provides around 9% high throughput and reduce the 60% packet overhead with exiting methods during the communication.

Keywords: Cluster network, cluster head selection, data transmission, energy consumption, Genetic algorithm, AODV, DSR, Leach.

INTRODUCTION

In Wireless Sensor Network (WSN) settings, energy-efficient, low-cost sensor nodes effectively communicate sensed data with the base station (BS) [1,2]. When robots, people, and the environment are autonomously integrated, WSNs are now considered a new technological problem. As a result of advancements in memory, processors, and microelectronics devices, various programmed activities may now be performed, enabling identifying and calculating components to be combined into small strategies [3]. Temperature, pressure, precision agriculture, sound, device surveillance, smart buildings, facility management, habitat monitoring, preventative maintenance, logistics, and transportation are just a few of the environmental or physical conditions that WSNs [4,5] can measure. Consequently, their data is skipped by the network and sent directly to the central site [6]. Military applications such as battlefield surveillance are driving the progress of wireless sensor networks. Those networks are being utilised in various industries, including consumer applications, including control and process monitoring, healthcare, and pharmaceuticals [7–9]. However, the significant difficulties of WSN are energy, distance, and time delay.

In most WSNs, a non-rechargeable battery serves as a sensor power source. As a consequence, the distance within nodes has a large influence on energy consumption. Consequently, to minimise distances between nodes, eliminate service redundancy, and produce a balanced energy distribution, the cluster-head approach, which is at the core of most clustering algorithms, is used. The network energy is often lost early when the cluster head is selected wrongly [10]. Attackers who get control of all cluster heads may take entire control of the network without gaining control of any other nodes. On the other hand, proper cluster head selection may lower energy consumption, ensure constant data flow, increase data integrity, and prolong network lifetime [10]. The time delay increases as the distance between nodes & base stations increases, as is well known.

Similarly, the CH must be chosen so that it is geographically near to both the base station and the sensor nodes. Consequently, the time delay may be effectively decreased, and data transmission speed can be improved as a result [1]. Excessive computations for measurement techniques, before-mentioned as the distance between nodes, including a base station, signal strength, hop count, and node frequency, are required to guarantee CH election correctness and used by most prior research — especially in stationary networks— have been purposefully disregarded. The emphasis on each degree of precision in selecting the cluster head by conducting complicated mathematical operations, including evaluating numerous variables, planning delays, and depleting the network power intended to remain supplied, are disadvantages of such protocols.

Based on prior research, it's possible to infer that WSNs are still immature in many ways. Power consumption is still a significant issue with WSNs. Clustering is also a common method for reducing delays, loss ratios, & power consumption. Though, it does not provide a system for selecting the best cluster start to improve data aggregation performance. Moreover, inefficient cluster ruler selection results in excessive sensor node power consumption. Furthermore, the complex calculations used in the cluster head selection rule, such as node centrality measure, hop sum, and density, rapidly deplete energy, reducing the network's lifespan. Finally, improper energy-based route selection is to blame for the excessive delays in WSNs.

The suggested protocol DCHS builds future goals to address these shortcomings in current routing protocols for WSNs. It presents a basic, lightweight, and straightforward-to-implement algorithm. It lowers power consumption in WSNs by utilising a clustering method with efficient cluster head election, and therefore the WSNs' lifespan is extended. In addition, the DCHS protocol determines the best way to deliver a data packet to the sink node with the least amount of latency and routing overhead.

It also adds to the safety of the CH election process. This study seeks to decrease power consumption, improve network latency, and improve security in this regard. As a result, the following are the study's significant contributions:

1. Dynamic Cluster Head selection with backup CH in each cluster using DCHS approach.
2. Dynamic energy assigning to each sensor node when network has initialized
3. To proposed a method dynamic location-based movement for selected CH in network.
4. To implement a proposed system with various protocols such as AODV, DSDV, DSR and LEACH etc. and measured the QoS parameters.

Furthermore, the remainder of the work is separated into the following sections: In part II, prior researchers explain several known strategies for CH selection in WSN. Section III illustrates the material and techniques used in the proposed system's implementation, whereas section IV represents the algorithm specification for the proposed implementation. An experimental setup for assessing the proposed work and findings gained with our technique and comparative analysis with several state-of-the-art methodologies is described in section V. The conclusion and so its future scope is discussed in Section VI.

LITERATURE SURVEY

The sensor network is divided into numerous groups by the clustering procedure. Each group elects a cluster head, who leads the cluster throughout the data transmission process. The network designer or sensor nodes may choose the cluster head. By authorizing the sensor's design differently, clustering methods may overcome various limitations in wireless sensor networks. It is accomplished by grouping sensors into clusters, assigning each sensor a specific task, and then transferring data to higher levels. Clustering methods are used to achieve excellent energy effectiveness, reprocess bandwidth, monitor targets, gather data, besides ensure a extensive network lifetime. Clustering is also one of the greatest widespread procedures for dealing with power ingesting and severance issues arise throughout the service admittance and communication progression. As a result, efficient Clustering lowers network redundancy and saves considerable energy [11]. In conclusion, clustering [12] is the essential direction-finding technology for reducing energy ingesting. It depicts the most basic and standard energy-saving schemes, counting the cluster-oriented construction beneath investigation.

The genetic algorithm (GA) [13] is a randomized search and optimization method frequently used to solve optimization problems with many potential solutions. The survival of the fittest theory underpins GA. GA begins with a randomly generated collection of possible solutions known as the starting population. Each solution is referred to as a chromosome. Each chromosome must have the same length. Each chromosome's fitness value is calculated using a fitness function. The optimum solution is closer to a chromosome with a high fitness value. To produce two offspring, two-parent chromosomes are chosen for crossover. To achieve a better answer, the mutation is applied to a randomly chosen chromosome. The subsequent population is created through crossbreeding and transformation. To guarantee that the next generation is at least as fit as the previous, a few of the best fitness value chromosomes of the prior population are chosen in the new people. Elitism is the term for this procedure. This procedure is continued until one or more halting conditions are not met.

All monitoring nodes in LEACH-C [14] transmit their location and electricity content to the access point, providing the required data to determine the average transmission power. Sensor networks with less than this amount of residual energy is barred from becoming cluster heads in the current round. The ground station locates a predetermined number of criteria provided and splits the network into multiple to reduce the energy needed for cluster members to send data to the collection of services. This method, however, does not ensure the creation of clusters with an equal network node in each.

LEACH-F uses a stable cluster with a rotating cluster head paradigm to avoid re-clustering, in which a collection that has been created stays stable throughout the network's lifetime. Only the responsibility for gathering cluster data is rotated across cluster nodes. The LEACH-C technique is used to build clusters once the cluster heads have been selected. A Controlled Density Aware Clustering Protocol (CBCDACP) [15], which makes the base station handle the cluster formation process centrally, and the Two-Tier Clustering Protocol [16] are two further base station-assisted techniques.

FZ-LEACH [17] that shaping Far-Zone which is a gathering of sensor hubs that are put at areas where their energies are not exactly an edge, Data Dissemination approach [16] that furnishes versatile and proficient information conveyance with area mindful, FZ-LEACH [16] that framing Far-Zone which is a gathering of sensor hubs that are put at areas where their energies are not exactly an edge, According to the distances to the BS, hubs are named as close hubs or far off hubs in the Adaptive Cluster Head Election and Two-jump LEACH convention (ACHTHLEACH) [18]. The Greedy K-means method divides the remote nodes into clusters, while the close nodes belong to one collection. The cluster head is moved, and the node in each group with the highest residual energy is chosen.

In a report [19], a bunch head radical race called grid sectoring was introduced, based on the circulation of load adjusting and energy utilisation over both uniform and non-uniform sending, and in the Optimal Placement of Cluster-heads (OPC) calculation, a key future is taking care of the heap close to the sink is to change the thickness and transmission scope of the group heads dependent on the distance between bunch heads and also the sink.

By reducing the number of nodes in the root tree, the EAMC [20] may decrease the number of relays required for data transmission. The Unsatisfactory Cluster-based Direction-finding protocol [21] divides nodes to groups of varying dimensions. Cluster heads closest to the BS have slighter cluster dimensions than those further away, allowing them to save energy for inter-cluster data furtherance and selecting the best node as a cluster head using the decision tree method.

Even in the 6G era, the wireless ad hoc network remains an important research topic due to its role in the internet of things (IoT) or autonomous driving [22]. In a wireless ad hoc network with limited resources, it is advantageous to create a hierarchical network architecture using Clustering [23]. Cluster heads are situated at the centres of clusters in hierarchical network architecture and perform critical roles in communication between nodes. As a result, cluster heads with excellent energy-consumption efficiency are preferred in terms of communication quality and network lifespan. Energy consumption concerns are critical in many kinds of real-world wireless ad hoc networks.

Compared to similar studies such as theory-based game clustering, this MWIS-based Clustering through QAOA offers many features. In terms of goal, Soorki et al. [24] introduced theory-based game clustering, which focuses on decreasing system failure & energy consumption by considering energy consumption or access request queue time as payoffs. MWIS-based Clustering through QAOA, on the other hand, is mainly concerned with energy efficiency. As a result, MWIS-based Clustering through QAOA favours fully separated clusters (nonoverlapping clusters), while theory-based game clustering does not. In terms of structure, theory-based game clustering eliminates the requirement to explore all partitions or transmit information about changes to a centralized controller. MWIS-based Clustering using QAOA, on the other hand, is better at exploring all divisions and delivering change data to a centralised controller or an arbitrary node. Fast quantum operations in one quantum revolution may simultaneously refresh the data of all nodes due to the notions of superposition and entanglement.

According to [24] WSN dealing with many issues due to implementation in susceptible environments. Various researchers have already defined systems for data transmission with WSN, still such gadget has high information loss issues, maximum packet postpone as well as packet overhead at some stage in the information transmission. Different parameters had been taken into consideration to improve such losses like cluster network generation, records aggregation, relaxed statistics encryption, and facts transmission the use of distribution approach that produces powerful final results and eliminates such troubles. Furthermore, implementation with cluster network and selection of a cluster head (CH) based totally on believe, which produces a lot effective consequences and provides flexibility to gadget. On this research, we suggest a secure information transmission in cluster network and inspect the nice of service (QoS) parameters the use of numerous experimental evaluations. First of all, we create unique clusters with collaboration of multisensory nodes even as every node consists of person battery power as strength. We calculate the agree with of each node and define a CH based totally on the highest energy, records aggregation and broadcast tree production (BTC) are the two distinct techniques that have been used to remove network lifetime or cut technology inside the community in the course of facts transmission. In partial test, analysis device shows advanced QoS parameters like throughput, put off, packet overhead, etc., respectively. It also complements the community lifestyles due to proposed power conservation approach.

Even though energy-efficient Clustering is an ancient issue, it continues to be studied because of its significance. Various clustering techniques have been suggested, with game theory-based clustering mechanisms being convenient and efficient [25]. In wireless ad hoc networks, however, more fundamental and flexible clustering techniques are needed. As a result, using QAOA, this article offers an energy-efficient cluster head selection technique that is more intuitive and adaptable than current methods. First, the weight of each node in the network is given based on its energy consumption efficiency. The greatest weight independent set formulation describes the cluster head selection approach. MWIS-based Clustering provides some advantages over the minimal id and full degree clustering, including improved energy efficiency [26]. The issue Hamiltonian is translated to the policy represented as an MWIS formulation using Boolean functions. The case Hamiltonian is used to construct the QAOA circuit. The stochastic gradient descent technique is used to find the optimum parameter of the proposed QAOA circuit. An estimated explanation of the strategy represented by the MWIS construction is achieved by finding the anticipation cost of the problematic Hamiltonian in the optimal parameterized national. The CH are chosen based on a rough solution.

PROPSOEDSYSTEMDESIGN

The cluster formation procedure and data transfer between the source and destination nodes are shown in Figure 1. Each network node validates sensed data at the end of the network and sends cluster-creation signals to nodes within a specified Cluster Distance (CD). Sensor Node (SN) and Cluster Node (CD) are used to organise sensors into clusters. Each node checks the value of RN after receiving the broadcasted message. If its value is inside SN, it saves it to memory and compares CD to the distance between each node. When the distance between nodes is equal to or less than CD and the detected value falls within a specified RN, the nodes form a cluster.

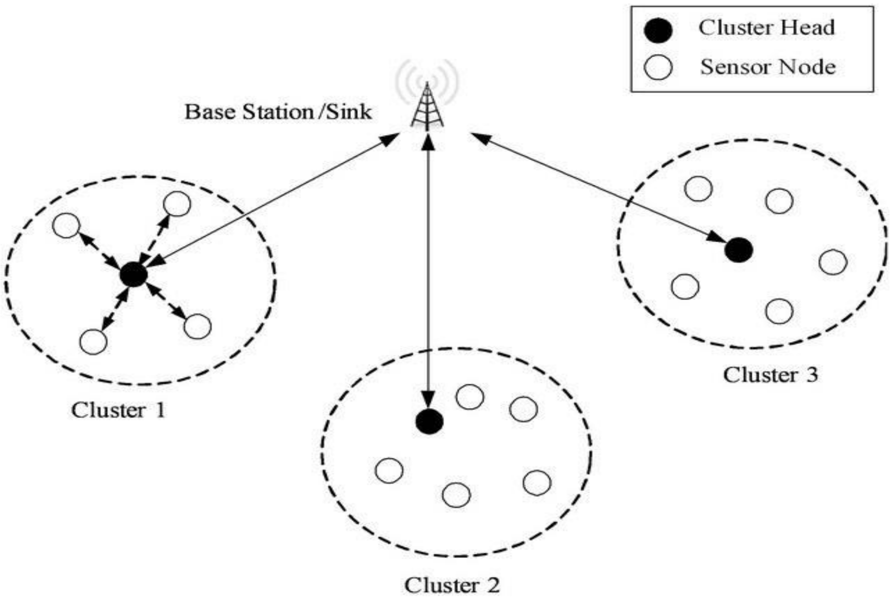

Figure 1: Proposed System Architecture for dynamic cluster head selection

Nodes will not transmit cluster formation messages with the same NID. Non-participating nodes in the SN & CD-based cluster creation procedures. Once the cluster assembly procedure is complete, each node stores its cluster member's NID, Node Location (NL), NTE, & Sink Location (SL), as well as battery power data, in its memory. Each node with the most energy calculates the minimum distance between each node within range, referred to as Cluster Head (CH), and transmits the CHID to the rest of the network. It also finds the Cluster Head Transmission (CHT) node with the shortest distance to the sink and provides CHTID. They will use this node (CHT) to deliver data to the sink if the remaining CH energy is inadequate for data transformation after measurement. When a node detects the CH, it transfers data to it. The cluster head provides processed data to the sink through a one-hop connection, meaning it talks with the sink directly.

When the target approaches the borders of several clusters, a dynamically cluster will be formed. How the system determines the situation when the target is nearing the limits, particularly in a completely dispersed manner, is a difficult job. To address this problem in a completely distributed manner, we utilise border nodes.

A CH node sends data to the BS by passing it to its neighbours, who then send the data to the BS. For hierarchically clustered WSNs, we presented an energy-efficient routing algorithm that is compatible with the proposed secure data transmission protocols. The network is divided into clustered layers, and data packets are routed from a lower cluster head to a higher cluster head, and then to the BS.

Despite the fact that the proposed research covers energy efficient and reliable routing, it fails to address the fundamental security problems that arise in wireless sensor networks. The security mechanism may be used to improve the suggested system. When a sensor node detects data from the environment, it may encrypt it and send the cypher text to the base station through the cluster head. The original data may be decrypted and retrieved by the base station.

ALGORITHM DESIGN

In this section, the working mechanism of GA-based cluster selection algorithm is proposed for generating the Cluster head and backup cluster head. This algorithm applied on all clusters exists in-network, before execution and communication. This also validates our four different protocols with algorithms such as DSDV, DSR, LEAC, and AODV, respectively.

Algorithm for generation of CH

Input: set of sensor node in individual network Sen_Node[] called as initial population, $mutation_{Rate}$.

Output: Cluster Head CH and backup Cluster Head CH'.

Step 1: Initialized all population as all nodes in cluster Sen_Nodes[].

Step 2: Generate random energy to all generated nodes in cluster.

Step 3: Read each node and its feature such as node id, position, energy, distance from base station, number of neighbours nodes etc.

$$Pop\_Sizenode(m) = \sum_{m=1}^{n} (feature\_Set[A[i] \; \ldots\ldots.. A[n] \leftarrow \text{Sen\_Nodes[]})$$

Step 4: Apply crossover by using below formula on selected random population

$$cross\_res[] = \sum_{m=1}^{n} (pop\_Sizenode[i] \;\; € \; pop\_Sizenode[i+1] \;\;)$$

Step 5: Apply Mutation function on entire crossover results, which may content combination of old and new population

$$mutate\_res[] = \sum_{m=1}^{n} \left(cross_{res[i]} \;\; random(val) > mutation_{Rate} \;\; \right) update(cross_{res[i]} ? 0 : 1)$$

Step 6: Calculate fitness of each node using below fitness function

Tot_{Nodes} : Total nodes in network

nd_{eng} : Current available energy with node

Tot_{CH} : Total cluster heads in network

$NDtoCH_{dist}$: Total distance from node to cluster head

$CHtoBS_{dist}$: Total distance from cluster head to base station

CH': Backup cluster Head

$$\boldsymbol{Fitness} = nd_{eng} + (Tot_{Nodes} - Tot_{CH}) + \frac{NDtoCH_{dist}}{Tot_{Nodes}} + \frac{CHtoBS_{dist}}{Tot_{Nodes}}$$

Step 7: Rank all nodes according to Fitness values with descending order

Step 8: return $CH = Fitness[0]\ , CH' = Fitness[1]$

This algorithm generates dynamic CH and CH' after network initialization; this algorithm provides assurance the CH having sufficient energy for communication and is the best node from his cluster. The CH' generation another extra option when CH is down or overheated, but such condition not infrequently occurs in network.

RESULTS AND DISCUSSION

In this section, the proposed system assesses both the intended and present systems. After detailing our experimental design and the many factors used, such as throughput, packet delivery ratio, cost, & time, it quantitatively evaluates the research. Vector and scalar data may be filtered, processed, and presented in a variety of ways. The results directory in the project folder contains the us. tr file, which contains the simulation's performance data. We display the outcome parameters against the x - axis and y parameters based on the us.tr file using the graph tool. Graph files with awk extensions may be plotted with the graph software.

Table 1: Parameters and Values

No.	Parameter	Values
1	Simulation environment	NS-allinone 2.35
2	Time for simulation	25 sec
3	Type of Channel	Wireless channel
4	Model of Propagation	2 ray grounds
5	Network standard	MAC/802.11
6	Simulation area size	1000*1500 cm
7	Packet length limit	1000 bytes
8	Ad hoc routing	DSR, AODV, DSDV, SAODV
9	Traffic	CBR
10	No. of nodes	100
11	Initial energy of nodes	10 Jules
12	No. of clusters	5
13	Hoping techniques	Single hop

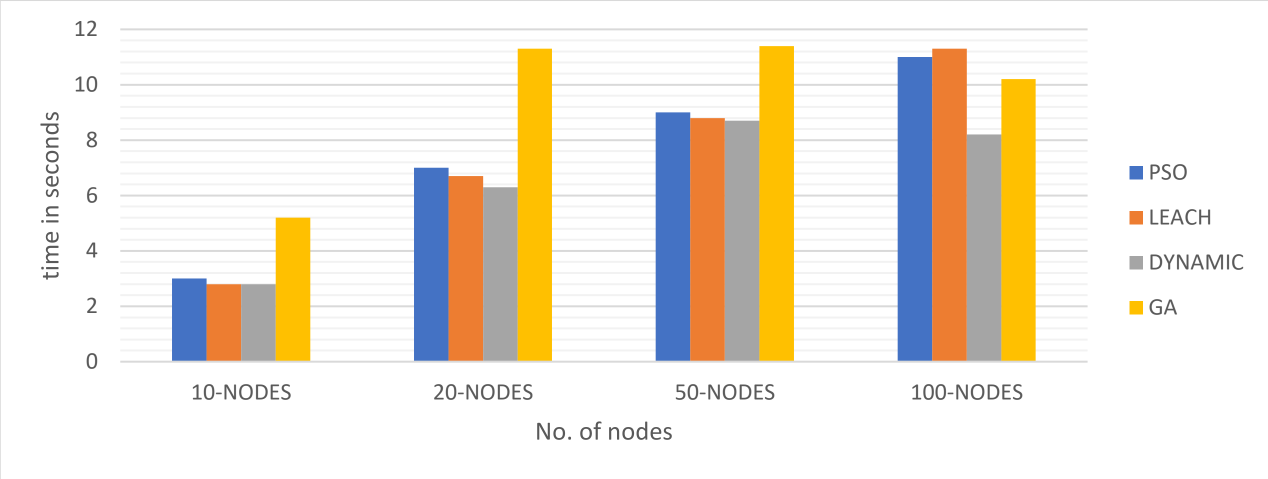

Figure 2: Time required for Proposed CH selection technique (GA) versus existing mechanisms PSO, LEACH, DYNAMIC with 10, 20, 50, 100 Nodes

The above Figure 2 demonstrates, time required for Cluster Head (CH) selection in cluster region. The evaluated of proposed simulation results with PSO-CH [4], LEACH [5] and Dynamic CH [6]. The CH selection evaluation has done with different node size such as 10, 20,50 and 100 nodes respectively.

Table 2: Performance evaluation of proposed system CH selection technique (GA)

Details of technical parameters	**Output achieved**	**Outcome inferred from output**	**Impact**		**Improvement difference**	**Percentage Improvement**
			Without GA	With GA		
Throughput	3.6 bit/s	Achieve high throughput than other protocols	3.3 bit/s	3.6 bit/s	0.3 bit/sec	[(3.6-3.3)/3.3] *100=9.09%
End to End delay	0.022 sec	Increased delay only when input data is large or massive	0.031 sec	0.022 sec	0.09 bit/sec	[(0.022-0.031)/0.031] *100= -29.03%
Packet Drop	1.12	Low packet drop and it arises due to energy consumption	2.87	1.12	1.75	[(1.12-2.87)/2.87] *100=-60.97%
Packet Delivery	97.5	High packet	96.1	97.5	1.4	[(97.5-96.1)/96.1]

		delivery rate, pockets should loss when closing the simulation				*100=1.45%
Overhead	0.25	Overhead can be generated only when sensed data is high or large packet generation by source node	0.97	0.25-0.26	0.74-0.75	[(0.25-0.97)/0.97] *100=-74.22% [(0.26-0.97)/0.97] *100=-73.19%

Validation: The above table demonstrates the performance evaluation of the proposed simulation with a genetic algorithm and without a genetic algorithm. As a result, all parameters have been improved by the proposed cluster head selection technique using a genetic algorithm. Current work presented above already validated our suggested results with three existing systems, which are produced better results. This evaluation also demonstrates the improvement in terms of percentage with genetic algorithm.

CONCLUSION

The clustering method relies heavily on cluster formation. The article proposes a centralised, hierarchical clustering method based on a genetic algorithm to optimise the selection, which chooses heads depending on their remaining energy and considers the trade-off between inter-and intra-cluster transmission distance. In addition, the proposed method maximises the number of clusters heads each round. Compared to existing state-of-the-art methods, simulation findings showed that the suggested way has a longer network lifespan. In the future, a comparable system with a homogenous cluster network and priority-based packet sequencing in WSN should be developed.

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