Improved cluster to normal ratio protocol for increasing the lifetime of wireless sensor networks

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ABSTRACT

The wireless sensor network (WSN) is a decentralized network that allows sensor nodes to freely join and quit the network, making it a unique network type that varies from centralized systems in which the fusion center decides on entry and exit. However, one of the key drawbacks of these networks is that the sensor nodes are small and located in remote areas. As a result, energy usage must be efficiently managed. In order to limit energy consumption, an efficient clustering protocol approach is necessary, which may be performed by dividing the networks into clusters and selecting cluster heads depending on the remaining energy and sensor distance. The energy hole problem has an impact on the performance of an energy-efficient technique. As a result, this work aims to extend the lifespan of WSNs, the goal of this research is to make the cluster to normal ratio (CTNR) Protocol better. Data forwarding nodes are added to the CTNR protocol hierarchy to enable hopping and avoid consuming nodes in order to solve the energy hole problem (sink). The proposed method is implemented in Matlab, and the results are compared to literature on energy usage and the amount of dead and living nodes. In terms of the performance indicators given, the results reveal that our proposed scheme beat others.

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1. INTRODUCTION

A self-configuring decentralized network in which the sensor nodes are deployed for monitoring the surrounding ecological scenarios is known as a wireless sensor network [1], [2]. The collected information is then transmitted to a specific destination by careful coordination [1]. The interrelated sensor nodes are combined such that it can observe, enumerate, and interact with each other across the wireless medium in WSN [1]. Reliant on the kind of application, the number of sensor nodes deployed can vary [1], [3]. The wireless sensor devices aim to resolve the objections forwarded by the "control site" [3]. The objections are the type of data that needs to be sensed by the sensor node and forwarded to the base station. Either continuously or occasionally, the sensor nodes can transmit its information [3]. Global positioning systems (GPS) or Local Positioning methods are used to localize the information from networks [3]. To perform in specific conditions, the actuators are implemented along with WSNs. Since energy efficiency is paramount in WSN, optimal base station location is crucial for management of the system and other functionality like data sensing and transmission which are also key tasks of WSNs [4]-[6].

To perform communication with each other, these deployed sensor nodes use radio signals [3]. The networks however face certain constraints since the sensor nodes are of limited size and have limited resources [7]. The functionality of a sensor network framework is designed once the sensor nodes are deployed [8], [9]. Thus, it can also be commonly known as “wireless sensor and actuator networks” [10]. Since the sensor nodes need to operate in various environmental surroundings, it must include a source of power or energy like batteries in it [6], [11].

However, due to limited available power, the effectiveness of sensor nodes is reduced once all the power of its battery is consumed [12]-[14]. Energy utilization is consistent among the normal nodes and cluster heads of a cluster. The cluster heads consume high energy when data is transmitted to the station at the base as compared to normal sensor nodes [15]-[18]. This is because information needs to be collected and forwarded by the nodes from other nodes deployed in the network. Single or multi-hop communication is needed to transfer the data to the base station. When transmitting or receiving the information, the sensor nodes consume additional amounts of energy. Since the normal nodes need to sense the data, it consumes less energy. Uneven power is consumed by cluster head nodes in different clusters. The nodes consuming higher amounts of energy die before the other nodes since the energy utilization is different for each node [15]-[17]. When consistency and frameworks of wireless sensor networks get affected, it directly increases the energy consumption of WSN.

To intensify the lifetime of WSNs, it is important to balance energy usage among various sensor nodes [19], [20]. There are small-sized batteries included in the sensor nodes deployed in WSNs which help in executing the tasks in applications [21]-[23]. Sensing, calculation, and execution of radio operations are the three important tasks in which most power of the network gets consumed. Replacement of batteries is important once the power is consumed and this is not always possible since the nodes might be deployed over regions that are not easily accessible to humans [24]. Wireless sensor networks face major issues to reduce the energy consumption. For resolving the energy-based problems in WSNs, several techniques and protocols have been designed [21]-[23], [25]-[27]. The following are some of the commonly used protocols.

The low-energy adaptive clustering hierarchy (LEACH) protocol is a two-step technique that is extensively used in WSNs. It develops a hierarchy in the first stage and conveys information to the set-up and steady phases in the second [28]-[30]. The network is partitioned in clusters, and the head of a cluster is chosen for each cluster [18]. The cluster head is chosen reliant on the amount of energy left in the cluster and the distance between nodes in other clusters. All data collected from nodes in their clusters is delivered to the cluster chiefs [31]. This information is subsequently transferred to the network's base station [31]. Figures 1 and 2 depict the LEACH protocol's architecture and flowchart, respectively.

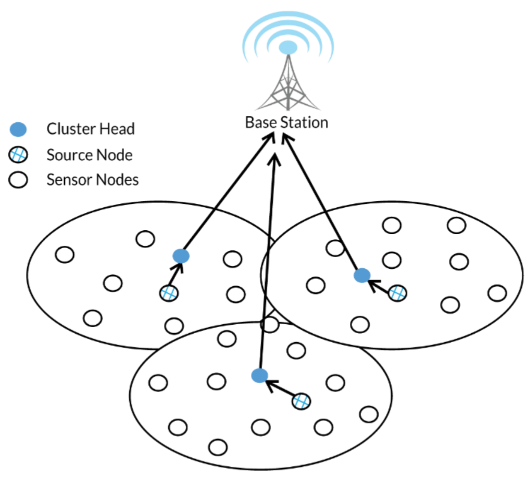

Figure 1. LEACH protocol architecture

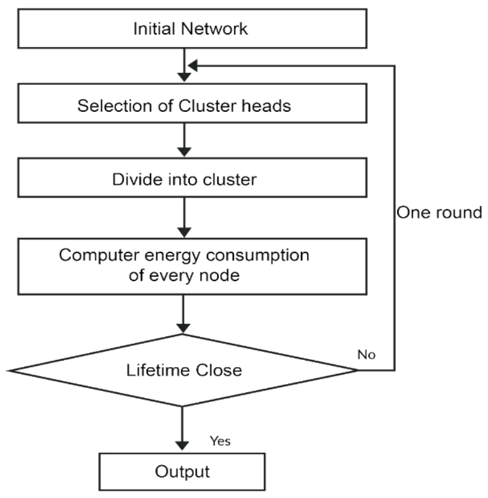

Figure 2. LEACH protocol flowchart

The hybrid energy efficient distribution (HEED) protocol was designed to remove the limitation of LEACH, which is to select the cluster head randomly [29], [32], [33]. The architecture and flowchart for the HEED protocol are shown in Figures 3 and 4, respectively. The amount of energy consumption is reduced by this protocol to increase the network’s lifetime. It also helps in selecting the cluster heads in the network using the least amount of energy possible. As shown in Figure 4, the chprob represents the probability value for any node. To calculate the cluster head probability of all nodes (Chprob), Chprob = (E_residual/E_max) + Tr , where E_residual is the estimated current residual energy in the node, E_max is a reference maximum energy (equivalent to a completely charged battery) that is normally the same for all nodes, and Tr is the transmission range.

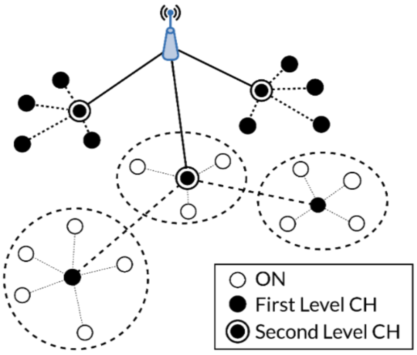

Figure 3. HEED protocol architecture

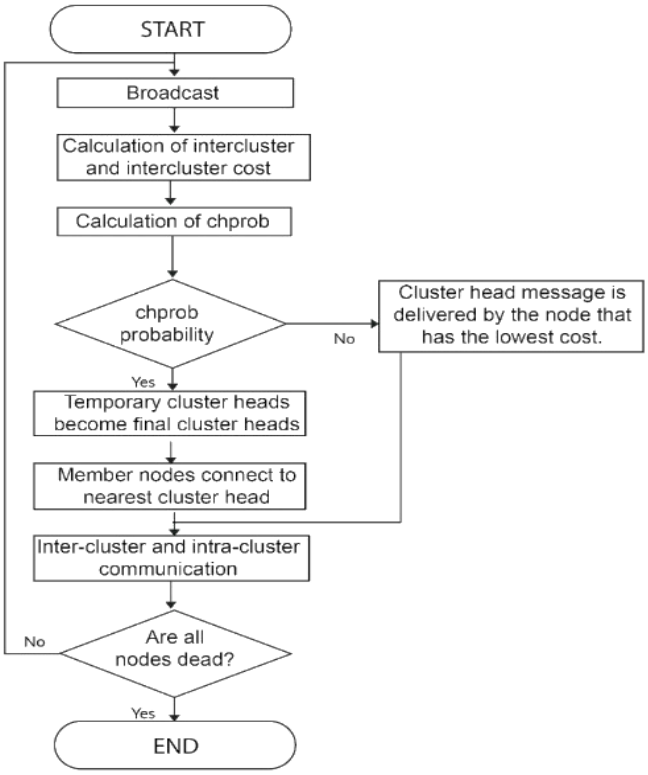

Figure 4. HEED protocol flowchart

The stable election system (SEP) is a two-level cluster heterogeneous routing protocol that helps pick advanced nodes as cluster heads rather than normal nodes [34]-[36]. In this protocol, each node has its own energy level. When choosing cluster heads, the node's leftover energy is taken into account. Advanced nodes have been shown to have more energy than standard nodes. As a result, they are more likely to be chosen as cluster heads, as indicated in the SEP flowchart, where G': Node does not become CH, T (S') is the regular node threshold, G'': Node does not become CH, and T(S'') is the advanced node threshold. The flowchart and architecture of the SEP are shown in Figures 5 and 6 respectively.

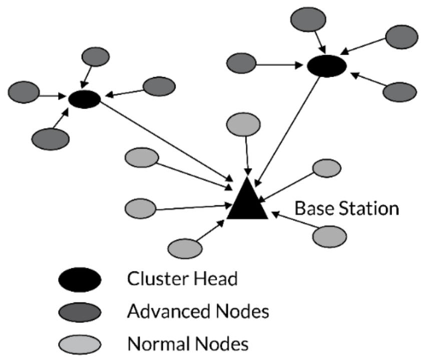

Figure 5. SEP architecture

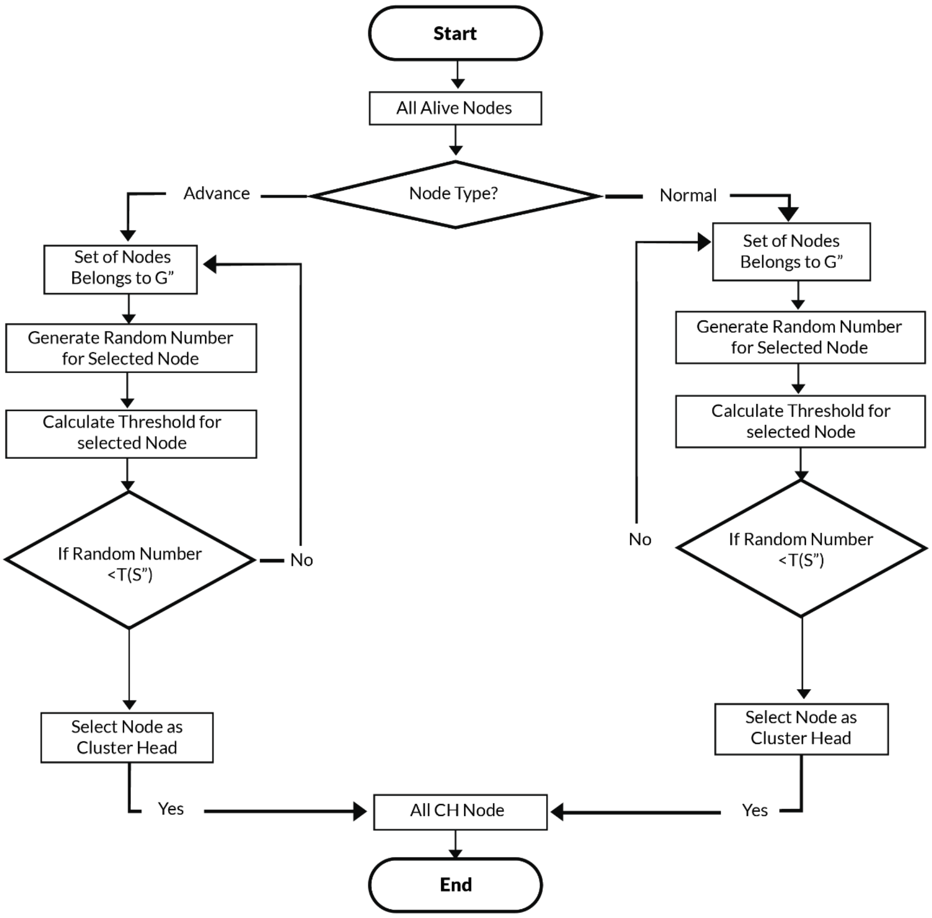

Figure 6. SEP flowchart

2. METHOD

The novel proposed energy-efficient clustering algorithm is a simple and capable algorithm used to monitor topological areas [37]. The cluster heads were selected based on the remaining power and average distance between the base station and sensor nodes. A new system called cluster head to normal ratio was employed to rotate the functions of cluster heads among sensor nodes. Some metrics, such as total advantageous information proportion, load matching, measurability, reproduction time, and main node inactive, were utilized to evaluate the proposed scheme. The strength of the proposed algorithm was revealed by performing various tests. A new scheme called aerial supported clustering (ASC), based on data integration set-up of data degeneration and clustering applying double cluster heads was proposed in [38].

Two stages of divided cluster heads were employed to boost the life span of WSN. The cluster heads applied data degeneration for the classification purpose, which in turn achieves more accurate and efficient information delivery results. The suggested technique demonstrated consistent performance in balancing energy dissipation among WSN sensor nodes while also extending the wireless sensor network's life.

Dragana *et al.* [39] was suitable for complete region surveillance and developed for an incorporated unmanned aerial vehicles-WSN (UAV-WSN) system. In this scheme, the cluster design system was evaluated based on different sizes of wireless sensor networks. The tested results depicted the viability and growth of the proposed algorithm. This algorithm was based on efficient cluster head selection. Synchronized interchanging of different energy stages in [40] was applied in another modified algorithm and the obtained results demonstrated the efficacy of the modified approach. This modified routing algorithm could be applied to the internet of things (IoT) in WSNs to provide these networks with the necessary energy used to process big data. The modified algorithm enhanced the life period of the WSN. This algorithm successfully minimized energy consumption in a distributed manner. The traffic and energy-aware routing (TEAR) protocols select cluster heads based on the energy level and congestion assortment of the sensor nodes [41]. The TEAR algorithm performed better in terms of stability than existing algorithms. The power balance was applied among all sensor nodes in the cluster's communication network to reduce power expenditure [21]. The experimental results showed that the proposed strategy performed better in terms of many criteria. These parameters included power consumption, packet transfer, network life duration, and cluster head count. The obtained results indicated the efficiency of the proposed algorithm. The proposed algorithm improved the life span of the network by up to 73% and reduced power expenditure by up to 60% [21]. However, in this case, the deployment of a wireless sensor network was done by focusing on smart farming [21].

The energy consumption of the wireless sensor network is consumed due to active mode and radio elements of the network. It was also analyzed that the residual physical elements of a sensor node used less power in a significant manner [22]. The results of the executed analysis also recognized the duty cycle system as a major factor to reduce power utilization in a WSN node. This network was designed to simplify the control of the central network. In another study, the operation and competence of the software-defined networks (SDN) to handle different issues in wireless sensor networks were described in detail [25]. To identify the help provided by the SDN toward various networks in terms of power reduction utilization, a lot of comparisons were carried out. The design of the proposed algorithm was based on distance and power expended predicated on multipath principles [42]. The two major factors considered in this investigation were identified as restriction of the power expended and the distance amid all nodes. The different tests depicted that the proposed multipath algorithm gave a better performance in terms of several factors which are accuracy, latency, and power competence [42].

In the hybrid energy-efficient power (HEEP), manager scheduling was proposed [43]. The main aim of this approach was to save power. To decrease the overall power expenditure, two energy-efficient schemes were used mutually [43]. The schemes are the dynamic power management system (DPMS) and dynamic voltage and frequency scaling (DVFS) [43]. The purpose of these methods was to make the scheduling strategy to use globally available resources [43]. Hence, the hardware models and original network traces were used to perform the test [43]. The generally limited behavior of the sensor node in the proposed system provided an appropriate power approach and ensured the performance as well. The collaboration between energy and time constraints was developed by using scheduling policies along with power lessening, thus the HEEP algorithm provided maximal reliability and scalability [43]. Also, the proposed approach in [44] broke down the wireless sensor networks into several clusters, which is a fundamental component. In each cluster, a supporter cluster head node, a cluster management node, a primary cluster head node, and a few more ordinary nodes were explored.

According to Huang [44], the supporter cluster head node was utilized to integrate information from the network. In multi-single hop, the main cluster node was used to transfer data available in the cluster of the sink node, or some other cluster node. The primary cluster head node, the assistant cluster head node, and other ordinary nodes in the cluster were implemented using the cluster management nodes. In order to find the best pathways and place them in the routing table, a balanced multipath routing method was suggested [45]. The proposed method was based on each node's remaining power and hop count [45]. Therefore, various factors such as choice of an optimum path with a minimum number of hops, accessibility of weighted power, and maximum power amongst candidate nodes, affect the performance of the proposed approach [45]. These features were essential to enhance the life span of the network. The obtained test results were based on the Fi-function and n-cloud function [45].

Several tests were performed based on power consumption [46]. Their study explains that the life span of a node was generally based on its power competence. The investigational outcomes revealed that these protocols could be utilized in different applications. Due to its adaptive containment window, the intense secure medium access control protocol was used to handle excess traffic within the network [46]. The dynamic medium access control (D-MAC) protocol adjusted the duty cycles adaptively according to the traffic load in the network, all in a bid to efficiently minimize excessive energy consumption [46]. Various factors affected the energy consumption of wireless sensor networks. The D-MAC protocol have various factors like standard protocols, the range of communication networks, network standards, cluster nodes, and sensor devices stack protocols which affect energy consumption of wireless sensor networks. The wireless sensor networks mainly considered data transactions [47]. In these networks, the measurement of power utilized by the sensor nodes was a fundamental task [47]. The energy consumed by the ad-hoc nodes played a decisive role in prolonging the lifetime of a WSN [47]. The life span of nodes and the techniques to detect power expenditure were dependent on the clustering algorithm to a large extent [47]. In WSN, a symbolic node includes an inbuilt sensor system [47]. This system is used for various applications, such as sensor application, node application, and sensor network application [47].

The main objective of clustering was to organize a network for reducing the expenditure of power [48], [49]. The intra-cluster communication contributed significantly to decreasing the power expenditure within a network [48], [49]. Therefore, the plans implemented in the intra-cluster communication network were of high importance. The proposed approach was flexible and power saved in terms of design [49]. The importance of duty cycle protocol to reduce energy consumption was also explained in this work [49]. The different experimental outcomes revealed that the MAC protocol was able to conserve energy efficiently [49]. The main aim of the proposed protocol was to increase the energy efficiency of the nodes deployed in the network [49]. In WSN, power efficiency was an important designing issue. A new connection was represented in this research by using a novel methodology based on the adaptation of the Dijkstra algorithm [50]. Sertbas [50], certain factors including the distance of adjacent nodes, the overall nodes, and residual power were considered to compute link weight. The different parameters are considered while considering certain assumptions. The performance of the proposed routing algorithm was evaluated with different metrics such as unlike thresholds, unlike sensing levels, different network dimensions, and different quantity of nodes [50]. In the new algorithm, the deployed sensor nodes sent sub-images achieved from the layered coding system [51]. The used channel state gave information related to the minimization of consumed power [51]. The experimental outcomes depicted that the proposed approach increased the lifetime of a wireless sensor network in all channel conditions [51]. The better class of reception in insensitive channel condition was attained despite the presence of a transaction amid the achieved image quality and the lifetime of the network [51]. The access management directly shows improvement in the proposed algorithm.

To agument the life of wireless sensor networks, Shemim *et al*. [52] was presented with energy heterogeneity. A different cluster head selection scheme was employed to boost the lifetime of wireless sensor networks [52]. The proposed approach utilized awake and efficient sleep schedule to overcome the issue related to an energy hole for improving the stability period [52]. The tested outcomes revealed that the proposed approach outperformed the other current algorithms in terms of different factors [52]. These factors included power efficiency, trustworthiness, and efficacy. The proposed algorithm improved the life span of WSNs. In various network architectures, this approach employed open-loop coding [53]. This work also used the electronic data capture (eDC-NC) approach to enable the quick revival from wireless connections or sensor node failures [53]. This approach performed well in terms of different factors such as energy efficiency and network overhead [53]. To make wireless sensor networks perform better, these factors were quite imperative. The use of the EDC-NC approach improved the consistency of WSNs. This scheme not only reduced power expenditure but also improved network competence by enabling fault recovery [53].

The network's dependability is determined by the quantity of energy it consumes. A agglomeration approach is applied for rising the energy potency of WSNs relying upon the similarities, detector nodes square measure sorted along once clusters square measure shaped. A cluster head is chosen for every of the clusters supported the remaining energy of nodes. The cluster head to traditional magnitude relation (CTNR) is calculated as adopted for rising the period of WSNs [37]. The CTNR protocol helps in choosing cluster heads supported the space and residual energy of a node. Reckoning on the residual energy, a cluster is elective directly for each spherical. However, the CTNR protocol potency gets reduced because of the existence of the energy hole drawback. To unravel this drawback, the entryway nodes square measure deployed optimally almost the bottom station in our projected model with a finite variety of detector nodes. The deployed network is split into a hard and fast variety of clusters exploitation location-based agglomeration. In every cluster, cluster heads square measure selected supported the two parameters that square measure energy and distance. The detector nodes that have the utmost energy and least distance to the bottom station is chosen because the cluster head whereas the second level of nodes is that the leader nodes. The detector nodes that have the utmost energy and least distance to the bottom station is chosen because the cluster head whereas the second level of nodes is that the leader nodes. The nodes that have the utmost energy however doesn't have least distance to the bottom station is taken into account as leader nodes whereas the third level of nodes square measure the entryway nodes. The entryway nodes square measure the nodes that square measure deployed at one hop almost the bottom station. The entryway nodes don't sense any info, it'll simply forward info that is already perceived sort of a hub, whereas the cluster head forwards info to the leader node. The leader node passes the collected info to the entryway node that later passes that info to the bottom station. As a further extension, security issues [54] could be studied in the proposed method, as well as evaluated in various frequency ranges inside the 700 MHz, 900 MHz, and 1800 MHz, as investigated in [55], [56].

The sensor nodes are depicted in dark blue in Figure 7. The cluster heads are depicted in green, whereas the leader nodes are depicted in black. The gateway nodes are shown in light blue, while the base station is shown in magenta at the network's center. The flow chart for the cluster head selection, is shown in Figure 8, the flow chart for the leader node selection, Figure 9 and the flow chart for the gateway node selection for the proposed model, Figure 10 and Algorithm 1.

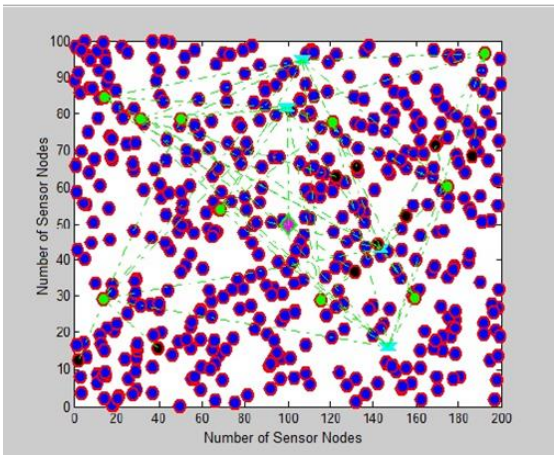

Figure 7. Illustration of planned model

Algorithm 1. Proposed/Improved Scheme

```
Initialize
     B=Base station
S_alive=Set of alive nodes in the network
        K: Number of cluster heads
N_alive=The number of alive nodes in the network
      S_CH =The set of cluster heads
      S_NCH=The set of non-cluster head nodes
         S_NCH2=The set of non-cluster nodes assigned to cluster
S_NC=The set of non-clustered nodes
    S_LN= The set of leader nodes
    S_GN=The set of gateway nodes
    Start
        Process:
    Input
            For every node in S_alive do
           Send energy level to Base station
    k= N_alive*0.05
    For every node in S_NCH do
        For every node in S_CH do
    If Distance (Node1,Node2)< Minimum-distance
    Minimum distance=Distance (Node1,Node2)
                Cluster-head(Node1)=Node2
              End if
            End For
    End For
    For every node in S_NC do
              If Distance(Node1,BS) <Minimum-distance
             Minimum distance=Distance (Node1,BS)
    Leader-Node(BS)=Node1
    End if
    End For
    S_NCH send data to S_CH
           S_CH send data to S_LN
    S_LH send data to S_GN
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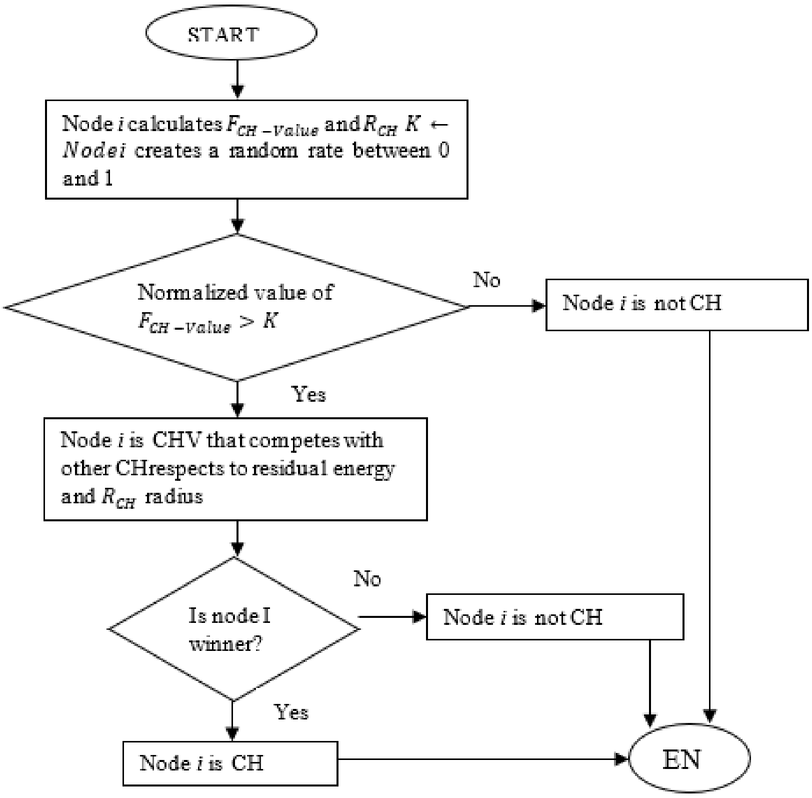

Figure 8. Flow chart for cluster head selection

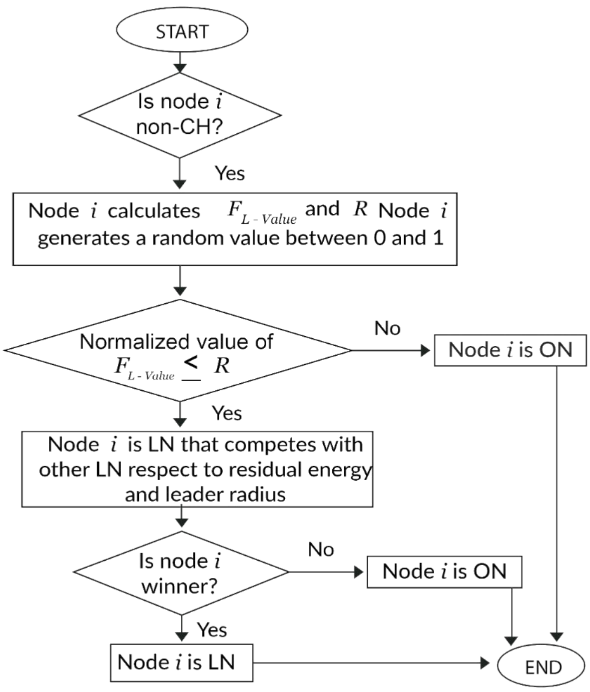

Figure 9. Flow chart for leader node selection

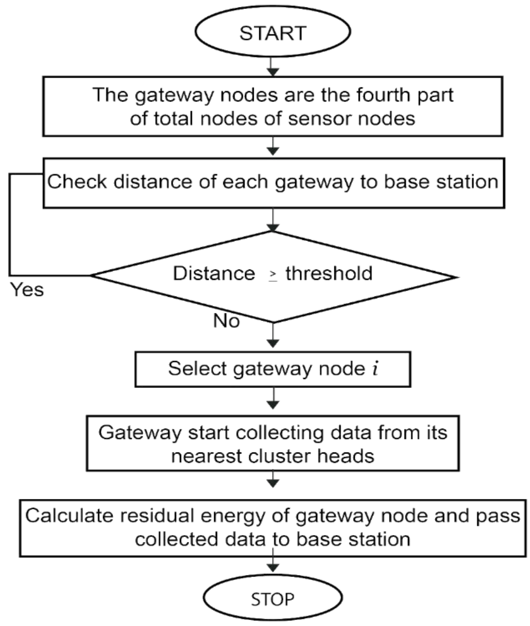

Figure 10. Flow chart for gateway node selection

3. RESULTS AND DISCUSSION

The energy consumption of wireless sensor networks will be compared to various methods in the literature for our simulation's performance analysis. 200 nodes, an omni-directional antenna, five channels, and a priority queue for data transmission on each sensor node are among the simulation elements taken into account. The distance between sensor nodes for data transfer determines the consumption of energy of each sensor node, and each sensor node has a starting energy of roughly 0.5 joules. The sensor nodes are all static and are randomly placed in a particular area. The network necessitates the installation of a base station because the nodes are unable to move. The simulation is run using Matlab's mathematic toolbox. To verify the performance of the proposed model, the simulation is run on three different sets of rounds: 1500, 2000, and 2500. Table 1 illustrates how many nodes are dead, how many are alive, how much energy is used, and how many packets are sent to the base station (simulation parameter).

Table 1. Parameters of the simulation

Metric/Indices	Values
Number of nodes	200
Area (m^2)	800x800
Antenna type	Omni-directional
Queue	Priority Queue
Queue size	50
Channel	Wireless channel
No. of Channel Used	5
Physical medium	Wireless medium
Frequency Bands	2.4 GHz, 5 GHz
MAC Standard/Protocol	802.11

As shown in Figure 11, the number of dead nodes is plotted against the number of rounds. For each round the number of cluster heads and leader nodes are reduced with respect to an increase in number of rounds. In this regard, 2500 rounds are chosen to illustrate the actual distribution of the WSN system. From our findings, the traditional CTNR which is the existing protocol has a large number of dead nodes when compared to the improved CTNR protocol which we proposed in this study with a low number of nodes that are dead. This is due to a high amount of energy consumption of existing CTNR protocol during hopping and forwarding.

In Figure 12, it is unambiguously clear that the improved CTNR outperformed the traditional CTNR. The reasons for this outperformance is predicated on the fact that since there are more alive nodes in the improved CTNR model, it is only natural that these nodes will transmit packets of data due to low energy consumption. On the other hand, the traditional CTNR node lifespan do not last too long. As we know, the more your battery life or sources of energy/power diminishes, the rate of transmitting data will slow that.

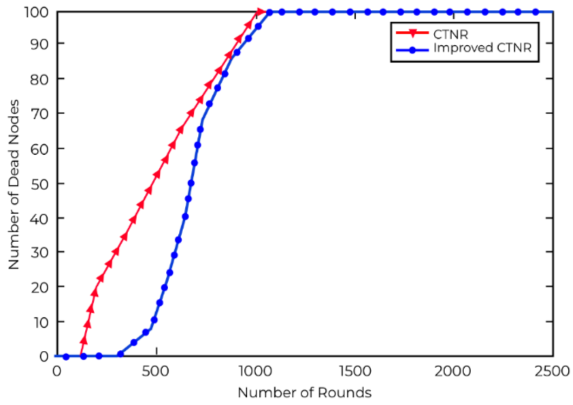

Figure 11. Number of dead nodes vs number of rounds

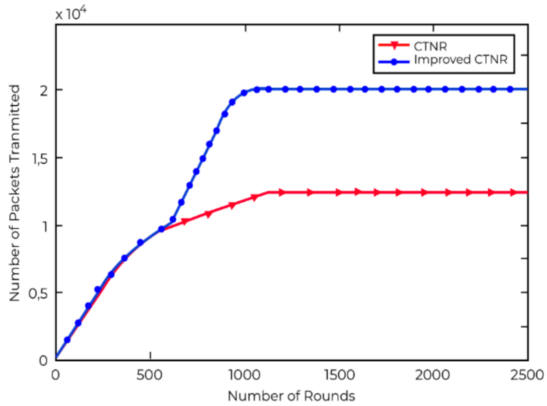

Figure 12. Number of packets transmitted vs number of rounds

The energy consumption of the CTNR protocol and enhanced CTNR are evaluated in Figure 13. According to the results, the revised CTNR model has less dead nodes than the standard CTNR model, as shown in Figure 11. This is owing to the fact that the lifespan of its nodes improves as the number of rounds grows, indicating the purpose for this inquiry. The outcomes are assessed in terms of energy usage. However, the CTNR has a higher number of dead nodes, while the upgraded CTNR has a higher number of alive nodes. When the number of rounds was increased to 2500, neither converged significantly.

As illustrated in Table 2, the various parameters are compared for the comparison analysis of the CTNR and improved CTNR protocol. The various parameters which are considered are number of dead nodes, number of alive nodes, number of packets transmitted and energy consumption. In terms of all four parameters the improved CTNR protocol give high performance as compared to CTNR protocol.

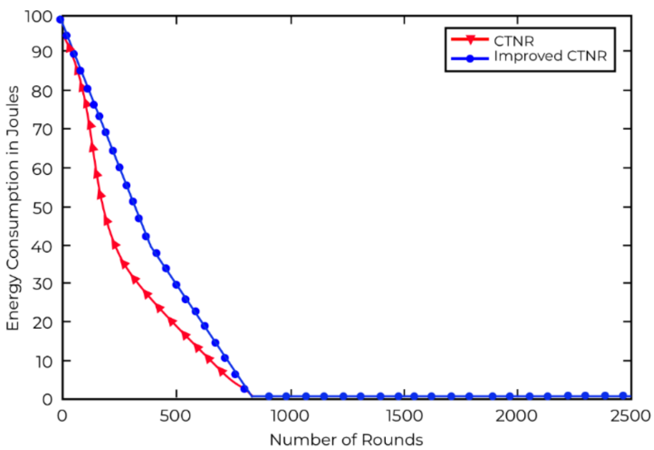

Figure 13. Energy consumption vs number of rounds

Table 2. Performance analysis parameters

Parameter	CTNR protocol	Improved CTNR protocol
Number of dead nodes	99 nodes	80 nodes
Number of alive nodes	1 node	20 nodes
Number of packets transmitted	7000 packets	9000 packets
Energy consumption	7 joules	3 joules

4. CONCLUSION

The CTNR protocol is modified in this paper in order to lower the energy consumption of wireless sensor networks. The CTNR protocol has an energy hole problem, which affects the wireless sensor network's efficiency. For far-away nodes that consume more energy due to distance, the revised CNTR method used an energy-efficient protocol. As a result of this two-level hierarchal routing system, the amount of energy consumed in the sensor network along the critical path is reduced (path with the shortest distance). To put it another way, the gateway nodes are placed in such a close proximity to the base station that they are ideal for any of the node routing options. This design aids in the elimination of the energy gap that exists in the sensor network. When it comes to the network's energy hole problem rectification, the number of dead nodes decreases.

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