Energy Minimization Using Cluster-Based Approach in Wireless Sensor Network

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Abstract:A wireless sensor network (WSN) consists of a set of mobile nodes, which are small energy-consumed devices. The effective use of energy in mobile nodes is the most ideal standard for extending the life of WSN. Therefore, designing an effective route to reduce energy consumption is an important factor. Mostly the existing routing protocols in WSN do not completely turn off the radio frequency. This results in increase in energy consumption. LEACH (Low Energy Adaptive Cluster Hierarchy) is a cluster-based protocol in which non-cluster head nodes will completely turn off their RF until their pre-allocated time slots. However, LEACH has a shortcoming, that is, due to the random rotation of its local Cluster Head (CH); the clusters are not uniformly distributed. To overcome this problem, K-means algorithm is used, which divide the network area into equal parts. For route formation between the source and the destination node LEACH as hierarchy routing protocol is used. Later on, the concept of AI is also introduced to find the dead and the failure node within the route.The performance is examined in MATLAB simulator. The resultant outputs are observed at different nodes ranges from 20 to 100. The results reveals that the concept of ANN with K-means and LEACH performed better and we obtained better results in terms of quality of service parameters. These include energy consumption, delay, throughput, and Packet Delivery Ratio (PDR). To show the efficiency of the proposed technique comparison between proposed and existing approach has also been presented, which reveals that energy upto 25.17 % has been saved compared to existing OK-means approach.

Keywords: Wireless Sensor Network, Low Energy Adaptive Clustering Hierarchy Routing Protocols, K-means, Artificial Neural Network.

1. Introduction

Wireless Sensor Node (WSN) is a collection of number of small size mobile nodes that are operated with low power. These nodes are deployed in remote areas from where they collect information and send that towards the destination node. After reaching at the destination node, the information is forwarded to the end user [1]. As these nodes are mobile and are operated at

very small batteries, therefore it is very difficult to recharge these mobile nodes manually, which limits the life of these nodes and is one of the major concerns in WSN. Most of the energy is consumed by these sensor nodes during the data transmission and reception process. Therefore, it becomes a challenging issue for today's researchers to design an energy efficient WSN [2].
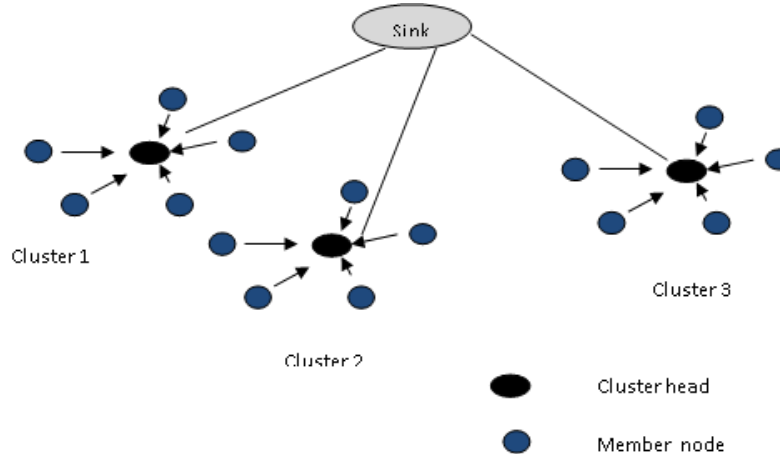

Figure 1Architectute of LEACH

Among different routing protocols, routing using cluster based approach is more efficient. Low Energy Adaptive Clustering Hierarchy (LEACH) is considered as the very first cluster based routing protocol. It uses the concept of data aggregation by keeping both the energy efficiency and the quality of data in mind. The communication architecture is shown in Figure 1[3].

In this Figure, we have considered two types of nodes one is member node, and another is cluster head node, each represented by blue circle, and black circle, respectively. Among these member nodes, one acts as source node, whenever it wants to send data to the sink node. Therefore, initially, it sends data to its cluster head node as represented by the dark black circle and then forwarded to the Base Station (BS). In this way the energy of mobile nodes is saved [4]. A set of rounds are initiated at the start of LEACH protocol, and it is believed that it runs with number of rounds. Each round runs in two phases first one is cluster setup and another is steady phase. In first phase, every node is deciding that which of the node has become a CH node for the current round [5]. This is decided based on the number lies between 0 and 1. If the number is smaller than the defined threshold value then that node is selected as CH for the current round otherwise not. The value of threshold is defined by using the formula written below.

$$T_n = \begin{cases} P_r - P_r\left(n \bmod \frac{1}{p_r}\right) & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases}$$

$P_r \rightarrow$ Required %age of CHs

$n \rightarrow$ Current rounds

$G \rightarrow$ Set of sensor nodes, which are not selected as CHs in the previous round.

After the selection of CH node, each nearby node within the cluster zone (member nodes) sends data toward the CH node. In this way, first phase of LEACH is completed. After this, CH assigns time slot to each node so that the member nodes can transmit data frames once within their allocated time slots using TDMA mode. This time the network enters into the second phase [6].

Among different routing protocols, LEACH is considered as one of the best energy efficient routing protocol. After LEACH a number of researchers have improved its working by integrating LEACH with other schemes. These techniques include E-LEACH, N-LEACH, D-LEACH, EE_LEACH and so on. Using these methods, appropriate CH selection has been performed. In E-LEACH, the remaining power of each deployed node is considered for CH selection. In this method, the round time remains fixed, and the selection of CH is performed at random [7]. In N-LEACH, CH selection is performed by considering the benefits of the remaining mobile nodes energy. The spanning tree is constructed based on the separation between CH and BS, thus avoiding the communication of intermediate CH [8]. In D-LEACH, the energy of sensor nodes is balanced by adjusting the threshold, and the threshold is set as per the radius of the mobile node [9]. In the EE_LEACH clustering algorithm, the choice of CH is based on the position of the node and the current energy of the node [10].

In this research, we have used LEACH as clustering protocol to create route between the source and the destination node in addition with K-means and ANN. K-means is integrated to overcome the problem of unequal cluster formation by LEACH and ANN is used to find any dead and failed node in the network.

The rest of the paper is organized as follows: section 2 represents the state-of-art; the methodology is presented in section 3. The result and discussion is presented in section 4, and section 5 presents the conclusion of the proposed work followed by the references.

2. Related work

In both ideal and working state of nodes energy is consumed by the nodes and if this energy is below the survival level of nodes then the node is said to be dead or failed node. Therefore, it is very important to design an effective clustering algorithm that can balance the energy of deployed nodes in the network.

Sharma et al. (2021) have presented an energy efficient routing protocol to enhance the QoS of WSN. The main purpose of this paper is to enhance the performance of the existing e Enhanced Developed Distributive Energy-Efficient Clustering (EDDEEC) and Average Threshold Energy-Efficient Routing (ATEER) protocols. The drawback of these protocols such as not considering the distance between the BS and Cluster Head (CH) has been overcome. The work has been performed on MATLAB simulator and different parameters such as percentage of dead nodes, the average energy consumption, end to end delay, throughput and lifetime of network have been analyzed [11].**Radhika, and Sivakumar (2021)** have designed an improved LEACH protocol

by introducing the concept of Genetic Algorithm, and named it as (IGA-LEACH). The protocol improves the Ch selection process by saving energy while comparing to the base techniques. The fitness function of GA has been used for the selection of CH. Mutation and crossover has been performed by GA. Also comparison between the fitness value and the set initial value has been performed. If the fitness value is less that the initial set value, then, data transfer between the nodes took place and data is transferred from the mobile nodes to the Ch and then reached to the BS [12].**Neji et al. (2020)** have presented a threshold based LEACH protocol, in short it is known as T-LEACH. The heterogeneity of mobile nodes has been taken into consideration along with the remaining energy for the selection of CH. The threshold energy is compared to the residual energy. If residual energy is more than each node select a random value between 0 and 1 otherwise considered node as normal node. If the value is less than threshold then send information to the selected CH otherwise transmit data without Ch selection. At the end performance parameters are measured in terms of number of dead and alive nodes, energy consumption, and number of packet sent to BS [13].**El Khediri et al. (2020)** have presented a Manifold Weight- LEACH protocol named as MW-LEACH) for WSN. Using this technique, the CH has been selected based on the number of member nodes, separation between the mobile nodes, and remaining energy of nodes. Based of higher energy, the nodes were selected and hence form initial set of CH's. These nodes travel in various directions in order to gather information from their member nodes and then sending that information to the BS. The results show that MW-LEACH is fast and hence increase the lifetime of the network [14].In the last decade, a number of clustering algorithms have been design to increase the lifetime of the nodes by minimizing the energy consumed by each node. **Behera et al (2019)** have designed a CH selection algorithm, by which the election of CHs have been performed based on the energy of nodes. The nodes having higher energy in current communication round is selected to be CH. Thereafter, the nearby nodes (member nodes) join the CH based on the distance between the CH and the member nodes [15].**Xu et al. (2015)** have presented an integrated approach that used both clustering as well as routing algorithm to minimize energy consumption within the large size WSN. The integrated approach has adopted the backoff timer as well as gradient routing to form clusters with maximum communication range [16]. **Zhang et al. (2015)**have designed a clustering based algorithm in which clusters are formed based on the concept of node density. That is the node, which is surrounded by number of nodes is selected as cluster head. This enhances the routing efficiency of the intra-cluster routing algorithm [17].**Mazumdar and Om (2017)** have presented a multi-objective based clustering algorithm by which the member nodes are assigned to appropriate CH. Then to balance energy load among nodes appropriate energy efficient routing algorithm is used.

Against the existing work, this research paper, proposes an improved LEACH as clustering algorithm in addition to K-means with ANN algorithm. This helps to balance the power consumption of all nodes in WSNs and extend network life.

3. Proposed Work

Initially a network of size 1000*1000 has been created, and nodes are deployed with x and y coordinates. After defining nodes, nodes are labelled as Node 1 (N1)…..node 100 (N100) respectively as shown in Figure 2. As shown in the figure 2, the nodes are randomly distributed in the range of 0 to 1000, and various nodes are found to be very close to each other such as node N49, node N35, and node N4 that were lies in the range of 600 to 800 along the X axis. In the area of 300×1000, the number of nodes is small and far away from each other, such as node N14, node N38, node N26, node N48, node N43, node N35, node N2, node N50, node N46 and other nodes.
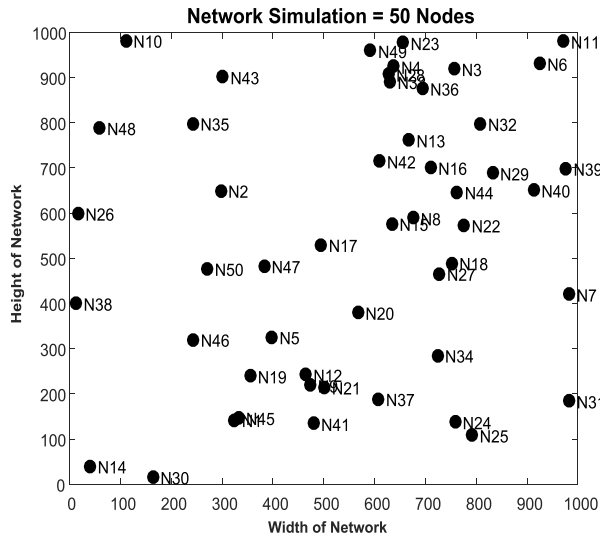

Figure 2: Deployment of Nodes

In order to take care of these nodes, a leader node is required to manage all available nodes in a similar manner. Using clustering mechanism it becomes easy to handle such high dense nodes. In this research, initially, the nodes are grouped into 5 numbers of clusters by using unsupervised K-means clustering approach. Also, the selection of the center of cluster is performed based on minimum distance and remaining energy of the nodes. The formed cluster using K-means is shown in Figure 3.
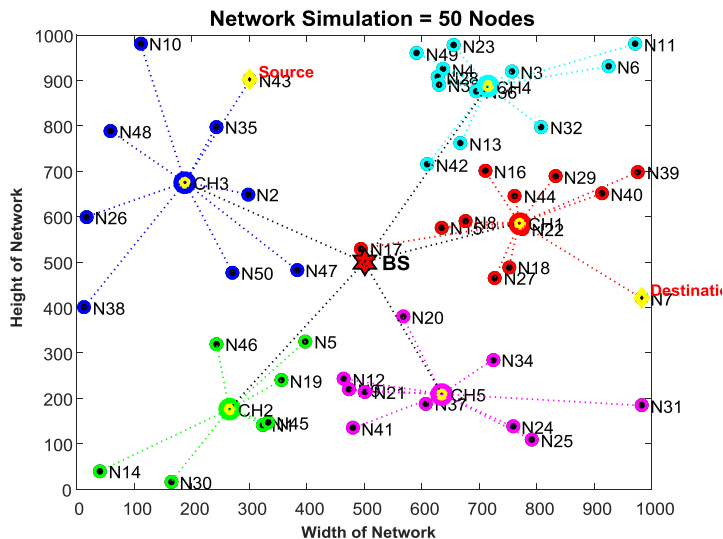
Figure 3 Clustering using LEACH with K-means

After the cluster formation, each CH's are connected to the BS, which is placed at the centre of the designed network area as shown in Figure 3. Now, our next task is to create route between the source node and the destination node, which is done by applying LEACH as routing protocol. The source node passed data to the nearest CH which resend the collected data to the BS and from BS, the data is passed to the destination node. If any node is found to be failed node or having energy less than its survival energy then that node with add delay in the communication or drop data as that node is not able to forward the collected data to the nearby coverage node. To overcome this problem, we use the concept of Artificial Neural Network (ANN). Using ANN, the system is trained based on the energy consumption and delay of the nodes. If the node's energy of communication delay is found to be less than the defined parameters then that node is considered as failed node, and system will now consider any of the nearby node as communication node and add it into their communication path. The trained structure of ANN with Mean Square Error (MSE) is shown in Figure 4.
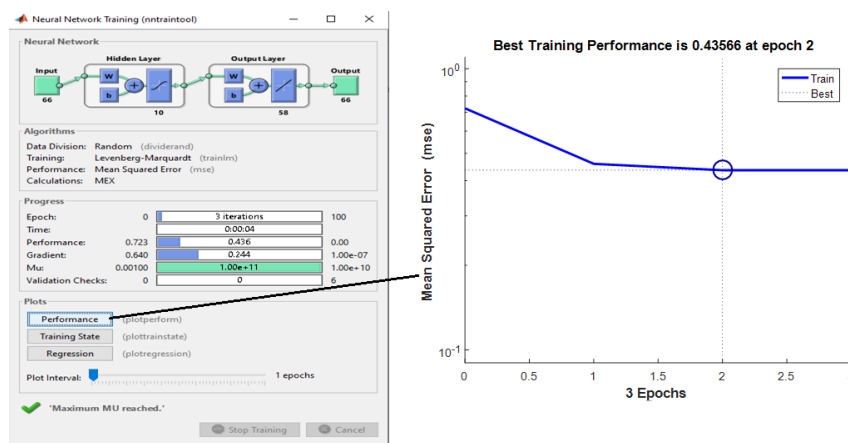

Figure 4 Trained ANN Structure

The trained structure shows that in the routing process, there are 66 numbers of neurons that were participated in the communication. Therefore, these nodes properties like as energy and delay is passed to the input layer of ANN. In the hidden layer number of neurons is set as 10, where we obtained better performance. At output we obtained 58 numbers of neurons which shows that out of 66 neurons 8 numbers of nodes are failed node and hence need to be removed from the network. In this way the energy of nodes is saved and hence increase the lifetime of the network.

4. Result and Discussions

This section presented the results obtained after simulating the network in MATLAB. The main goal of this research is to minimize energy by using enhanced LEACH protocol with AI approach. The performance of the network has been measured in terms of different parameters such as:

Packet Delivery Rate (PDR): It is defined as the total number of delivered packet to the total number of transmitted packet sent by the source node to the destination node. Mathematically, it is given by equation (1).

$$PDR = \frac{Total\ number\ of\ packets\ received}{Total\ number\ of\ packet\ sent} \tag{1}$$

Delay: It is used to measure the average data transmission time occupied by each packets travelling from the source to the destination node. Mathematically, can be given by equation (2)

$$E\ to\ End\ Delay = \frac{\sum_{i=0}^{n}(tend - tstart)}{Total\ no\ of\ packets} \tag{2}$$

Where, tend and tstart represents the end and start time of the packet forwarded from the source to the destination node.

Throughput: This metric defines the success rate of data packet transmission on a specific communication medium. Mathematically, it is given by equation (3).

$$Throughput = \frac{Total\ data\ sent\ (kb)}{Total\ Time\ (s)} \tag{3}$$

Energy Consumption: It is defined as the total energy enthusiastic by the participated nodes during the communication process. Mathematically, it is given by equation (4).

$$Energy\ Consumption = \sum_{i=0}^{n}(Total\ energy\ consumed\ by\ nodes) \tag{4}$$

The results are computed by considering two distinct scenarios.

    i.   Without ANN
   ii.   With ANN

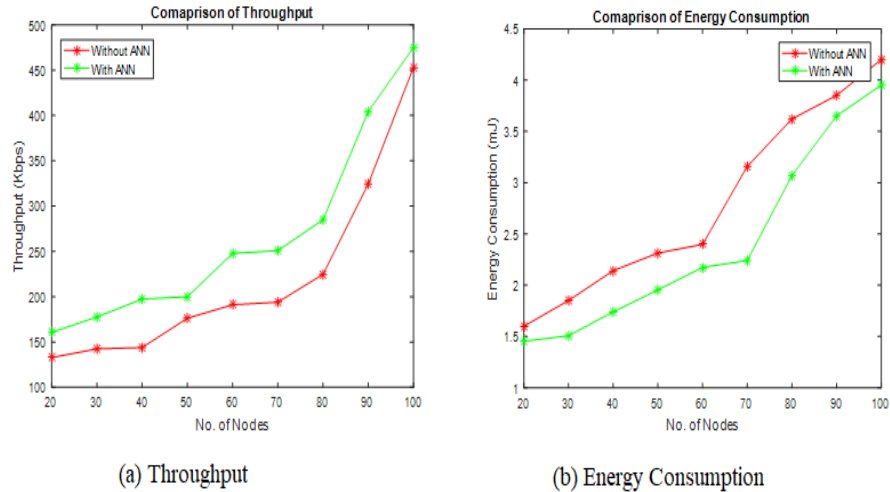(a) Throughput

(b) Energy Consumption

Figure 5: (a) Throughput (b) Energy Consumption

Figure 5 (a) represents the comparison of throughput with or without ANN approach. Without ANN means, data transmission has been performed using LEACH with K-means only. On the other hand, with ANN, ANN is used to find dead or failure node and hence improve the network performance. The graph shows throughput along y axis measure in Kbps with respect to number of nodes varies from 20 to 100. With the increase in the number of nodes network throughput increases, this is due to the presence of number of nodes due to which the nodes get multiple routing paths to send data from the source to the destination node. The average throughput measured with or without ANN approach is examined as 211.5, and 256.44 kbps respectively. Therefore, there is an increase of 21.25 % has been achieved while using ANN in the network.

Comparison of energy with or without ANN is shown in Figure 5 (b). The red and the green line represent the energy consumed without and with ANN technique in the WSN. The graph shows that with the increase in the number of nodes energy consumption increase. This is due to the participation of multiple nodes in the data transmission process. More the nodes participated in the data transmission higher is the energy consumed by them. The average energy consumed by the nodes without ANN and with ANN network is 2.71 and 2.32 mJ respectively. Therefore, a reduction in energy consumption of 14.32 % has been obtained while using ANN compared to without ANN technique.
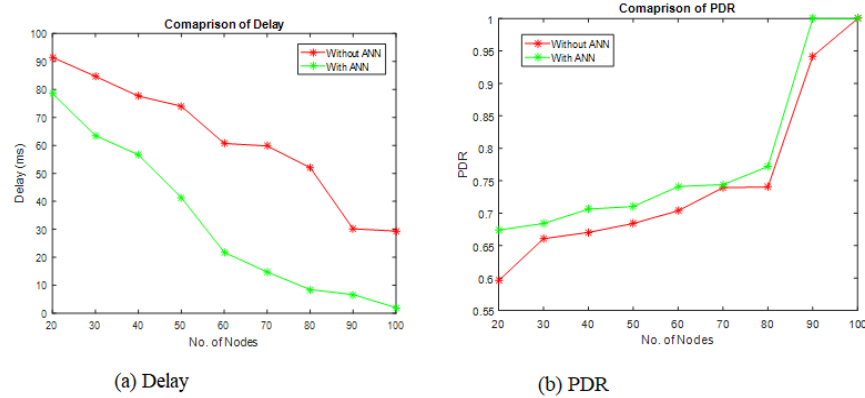
(a) Delay

(b) PDR

Figure 6: (a) Delay (b) PDR

The parameter delay examined with and without ANN is represented by the green and the red colour respectively and shown in Figure 6 (a). From the graph it is observed that with the increase in the number of nodes, the delay decreases. The reason behind the reduction of delay is due to the participation of multiple nodes for the data transmission. More will be the nodes, the speed of data transmission increases as the nodes send data from one node to nearby to find CH and then from the CH to the BS. The average delay examined without and with ANN approach are 65.38 ms and 32.22 ms respectively. Therefore, the reduction in delay using ANN approach compared to without ANN approach is examined as 50.72 %.

Packet Delivery Ration parameter analyzed for ANN and without ANN wireless network is shown in Figure 6 (b). The red and the green lines represent the PDR examined without ANN and with ANN respectively. From the graph it is clearly seen that with the increase in number of nodes, PDR increases and becomes maximum 100 % for 90 and 100 number of nodes. The average PDR analysed for ANN and without ANN network are 73.77 and 77 % respectively.

To show the improvement of the designed WSN in MAETLAB, comparison between the proposed and the baseline method has been presented. The comparison has been performed on the basis of energy consumption as the existing researcher has analyzed energy consumed by node with respect to number of nodes.
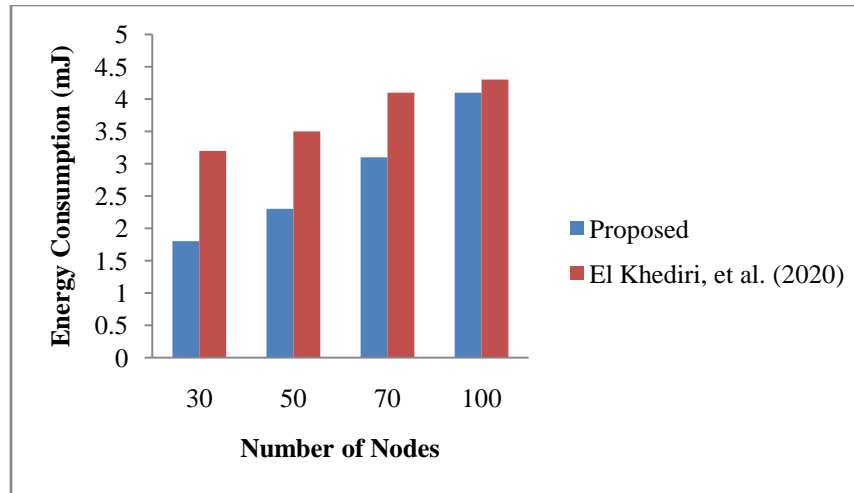
Figure 7: Comparison of Energy Consumption

The comparison of proposed work with existing work [14] has been presented in Figure 7. The x-axis and the y-axis of the graph show number of nodes and the measured energy consumed by nodes. From comparison it is clear that using LEACH with K-mans for appropriate selection of CHs and ANN for the detection of dead and failure nodes in the network energy consumed by nodes is less as represented by the blue bars. The average energy consumed by the nodes using LEACH with K-means and ANN approach is observed as 2.825 mJ. In the existing work, the researchers have used LEACH in combination to K-means and obtained energy consumption of 3.775 mJ. Therefore, there is an reduction in energy consumption of 25.17 % has been attained while using ANN in addition to LEACH with K-means approach.

5. Conclusion

In this research, an improved K-means with LEACH protocol in integration with ANN technique has been presented. The aim of adding K-means with LEACH is to minimize the energy consumption during the data communication process. This is done by using this approach instead of sending data directly to the BS using LEACH protocol; the data is send to the appropriate CH. The area is divided into equal number of areas using K-means. This is done because LEACH select Ch based on probability basis and sometimes selects cluster heads, which are very close to each other. Using K-means with LEACH, the node having higher energy is defined as CH and the nearby member nodes have to send their collected data to this CH. Another technique that is integrated to this is ANN. The aim is to find the failure or dead nodes if any in the created route between the source and the destination node.

From the experiment results, performance of the WSN has been observed based on different QoS parameters. These include energy consumption, PDR, throughput, and delay. The results have been presented in the presence and in the absence of ANN technique. The observed values shows that better results has been analysed while ANN technique is applied in the network compared to the without ANN results. Also, the comparison has been provided in terms of their energy

consumption parameter. The comparison reveals that using LEACH with K-means and ANN Algorithm provided better energy consumption rate compared to the LEACH with K-means. Therefore, we can conclude that ANN as classification approach has performed better with K-means LEACH.

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