An improved LEACH protocol to improve Cluster head Node Coverage for Wireless Sensor Networks

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Abstract - Clustering approaches for Wireless Sensor Networks (WSNs) have been extensively researched to reduce energy consumption, improve fault tolerance, and enhance node deployment and latency. Clustering strategies, such as the Low Energy Adaptive Clustering Hierarchy (LEACH), have significantly extended network lifetimes. LEACH randomly selects Cluster Heads (CHs) but suffers from limitations, like prioritizing low-energy nodes equally with high-energy ones, leading to premature depletion. To address these limitations, the CNC-LEACH protocol was proposed, enhancing CH selection using parameters like Node degree, Node centrality, Energy consumption rate, and Distance to the base station. This method ensures better energy management by improving coverage and communication efficiency. Further enhancements include a relay node selection strategy based on Particle Swarm Optimization (PSO), yielding improvements in energy consumption, network lifetime, and communication quality, as shown in simulations.

Keywords: WSN, LEACH, Cluster head, Energy consumption, PSO, Network lifetime.

I. INTRODUCTION

In especially complex situations, sensor nodes have a challenge when it comes to the issue of recharging or replacing the small and somewhat expensive batteries that power them [1]. In situations that are based in the real world, it is very necessary for the individual nodes that make up a Wireless Sensor Network (WSN) to maintain the highest possible level of energy efficiency in their operations in order to assure the continued survival of the WSN.

Extensive study has been carried out by scientists on a variety of strategies with the goal of improving the energy efficiency of the operations of wireless sensor networks (WSN), with a special focus on clustering [2]. Clustering has evolved as a very successful tactic for reducing total energy consumption, improving the stability of network topologies, and extending the lifespans of network systems. The amount of time over which a network continues to function can be broken down into discrete intervals based on certain landmarks, such as the point at which the first node stops operating (abbreviated as FND), the time at which half of the nodes have stopped functioning (abbreviated as HND), and the time at which the last node stops functioning (abbreviated as LND).

Within the realm of clustering-based routing, WSNs go through the process of being partitioned into a large number of separate clusters, each of which includes essential procedures such as the creation of the cluster, the designation of the cluster head (CH), and the development of routing paths between the nodes and the base station (BS) [3]. A CH and the necessary number of cluster members, who are also sometimes referred to as CMs, are included into each cluster. One of the most notable aspects of this clustering-routing protocol is that, in comparison to other routing protocols, it has a much lower overall energy usage. This is a characteristic of the protocol that should not be overlooked.

In this particular setting, a substantial amount of attention has been focused on the formation of clusters as well as the diversity of communication channels that have been utilized for the transfer of data [4]. Figure 1 is an exemplary picture of the standardized design of a clustered network, and it is provided here for the convenience of those who find visual representations more appealing.

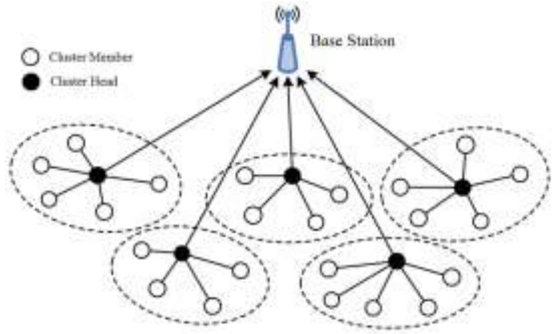

Fig 1: Network topology of a clustered WSN

Cluster-based routing protocols, as opposed to those that do not implement clustering, often display an effective usage of the sensor nodes within the network [5]. This is in contrast to routing protocols that do not employ clustering. When contrasted with procedures that don't use clustering, this effectiveness stands out especially clearly. Eliminating correlated data is one of the responsibilities that fall on a cluster leader, who is sometimes referred to as the cluster head (CH). This is done in an attempt to lower the total amount of data. Next, the CH starts the process of transferring the aggregated data to the base station (BS), which is the final destination for the data. Cluster-based routing protocols include the division of sensor nodes into a large number of clusters. This was done as a way to reduce the amount of energy needed for long-distance communications. Clustering is an attempt to mitigate the noticeable energy differential that exists between CHs and other nodes [6]. This is accomplished by lowering the overall energy usage and distributing the workload in an equitable manner across all of the nodes. As a consequence of this, clustering has emerged as a solution that is both effective at reducing energy consumption and capable of extending the lifespan of networks. In addition, the majority of clustering protocols include optimum CH selection mechanisms, which are designed to prevent the early depletion of sensor nodes and further increase the operational lifetime of the network, which in turn ensures the network's continuous usefulness. These approaches are targeted at preventing the premature depletion of sensor nodes.

LEACH protocol

LEACH is credited as being the first clustering-based routing protocol [7], which is an impressive accomplishment. This recognition is a result of its ability to provide solutions that are scalable and to extend the lifetime of networks. LEACH's core functionality is predicated on the constant distribution of the network load throughout its many nodes, which leads to a decrease in the system's total need for energy.

In most situations, the sensor nodes are organized in a hierarchical fashion, resulting in the formation of clusters. A person who is given the title of cluster head (CH) is in charge of supervising each cluster. The CH is responsible for the gathering of data from nodes that are part of its assigned group, in addition to the aggregation of data reports that have been created. After that, the aggregated reports are sent to the sink node that has been assigned specifically for the purpose of data processing.

Within the LEACH protocol, the selection of a node to take on the function of the CH is dependant on a probability that is produced from a random integer ranging from 0 to 1. This probability may range anywhere from 0 to 1. This probability has to be much lower than a predetermined threshold value, which is expressed by the equation $TH(n)$. In the meanwhile, the remaining nodes decide which cluster they belong to by selecting the CH that requires the least amount of communication energy in order to stay connected. The CH duty is frequently switched between all of the sensors in the network so that the battery of any one sensor does not run completely out. This keeps the network from completely failing.

$$TH(n) = \begin{cases} \frac{P}{1-P\left[\left(r \bmod \frac{1}{P}\right)\right]}, & if\ n \in G \\ 0, & otherwise \end{cases} \quad \text{Eq (1)}$$

In the equation 1 that has been supplied, $TH(n)$ is a symbol for the threshold value that is associated with n nodes, and P is the symbol for the probability value. Every node in the network chooses a random integer between 0 and 1 to represent its position in the network.

LEACH's operation is divided up into numerous rounds, the first of which is focused on the grouping of nodes into clusters. This is followed by a lengthy steady-state phase, which is in charge of controlling data transfer to the sink node [8]. The operation of LEACH is broken up into several rounds for the sake of methodical organization. When compared to the setup phase, the steady-state phase is given a longer length in order to facilitate the streamlining of administrative responsibilities. When a node decides to take on the function of a Cluster Head (CH) during the setup phase, it is the node that kicks off the process of spreading an advertising message to the other nodes in the network. After being given this message, every non-clustered node makes a choice on which specific CH it would want to become a member of. During the period known as the steady-state, data transmission takes place between each of the network's member nodes. After then, the CH is responsible for aggregating the data that has been sent to it from the different nodes that are part of the cluster, and it then sends this data that has been aggregated to the sink. It is important to emphasize that LEACH functions in a totally decentralized fashion, independent of any control information coming from the sink. This is a key aspect of the system. In addition, the operation of the system is not contingent on individual nodes having a comprehensive understanding of the network as a whole.

LEACH has a number of positive aspects, but it also has a number of drawbacks, all of which may be summed up as follows:

- Because the selection of cluster heads in LEACH is done in a random fashion, there is no assurance that an optimum amount and uniform distribution of cluster heads will be achieved.
- Another one of LEACH's limitations is that it does not take into account the size of the cluster when determining the number of cluster heads.
- In addition, nodes that have a low amount of energy left over are given the same priority for taking over leadership of the cluster as nodes that have a big amount of energy left over. Due to the fact that this strategy gives precedence to nodes that have a low amount of energy left, it has the potential to result in the early depletion of energy in nodes that have a smaller total amount of energy reserves.

During the course of this inquiry, a fresh iteration of LEACH that is more advanced than previous versions has been developed with the intention of overcoming the limitations that are often associated with using traditional methods. The ultimate goal of this project was to improve the process for choosing cluster heads (CH), with the hope of achieving greater energy efficiency as a result. In this improved method, the random number that is used inside the traditional LEACH framework has been made more complex by the addition of a wide variety of selection factors. This was done in order to accommodate this technique. The degree of the node, its centrality, the pace at which it uses energy, and its closeness to the base station are all included in these factors. The incorporation of these additional qualities guarantees an increased presence of proximal nodes within the coverage area, which ultimately leads to a proportionate decrease in the amount of energy that is used by component nodes. In addition, the energy consumption rate ensures that some CHs display relatively greater energy consumption levels in comparison to their contemporaries. In addition, the seamless integration of an improved relay selection mechanism based on Particle Swarm Optimization (PSO) has been accomplished in order to further magnify the energy-efficient data transmission capabilities among the clustered nodes. This was done in order to further improve the overall performance of the system. This concerted effort has been made with the ultimate goal of improving the performance of the system.

Contributions in this paper

- The random number is supplemented with data such as the node degree, centrality, energy consumption rate, and distance to the base station in the recommended CH selection method.

- The proposal's node degree and centrality criteria ensure that the selected CHs have a higher number of surrounding nodes within their coverage area. As a result, the amount of energy that is required for member nodes to make contact with the CH is reduced.

- The data aggregation process is handled by the relay selection method, which is based on Particle Swarm Optimization (PSO) as it was proposed. This technique is used for communication between clusters as well as inside clusters. It does this by creating a channel that is both energy-efficient and free of interference, so increasing the total network's lifetime to the greatest possible degree.

II. RELATED WORK

The design of wireless sensor networks (WSNs) presents a substantial issue in the form of the conservation of energy resources. The only thing that can determine how long the network will continue to function is how long its batteries will last. Clustering is an approach that is often used to increase the lifetime of wireless sensor networks (WSNs). The most recent study has revealed a great deal of different clustering methodologies.

SCHFTL [9] is one of them, and it uses a fuzzy logic system. In this system, sensor nodes make use of a variety of parameters that are then grouped into different levels. On the first level, some characteristics such as total energy and defense against DOS assaults are included; on the second level, certain elements such as communication quality and distance from the base station (BS) are included; and on the third level, certain parameters such as remaining energy and centrality are included. Because of these characteristics, one of the cluster heads that has been chosen will be promoted to the role of super cluster head. As a consequence, the lifetime of the network is extended as a direct result of the efficacy of the protocol in minimizing data overload, loss, and the need for retransmission. An uneven clustering method is presented in DFCR [10] with the purpose of addressing hotspots in WSNs by lowering the cluster size that is located closest to the BS.

Mehra et al. [11] presented a fuzzy-based improved cluster head selection (FBECS), which takes into consideration the node's residual energy, the node density in its vicinity, and the distance between the node and the base station (BS) as inputs for the fuzzy inference system. Additionally, the FBECS uses a fuzzy-based enhanced cluster head selection (FBECS) algorithm. A high eligibility index or probability for each node is used to choose the cluster heads (CHs) that will represent each cluster. This protocol covers the process of CH selection, however it does not go into detail on the best method for cluster formation.

An energy-efficient clustering system for wireless sensor networks (WSNs) was presented by Hamzah et al. [12], and it was based on fuzzy logic with an imposed minimum separation distance between CHs (FL-EEC/D). In this study, the inputs for the fuzzy logic model that define the possibility of a node becoming a CH include things like node density, node residual energy, site appropriateness, computing capabilities, and the distance between the node and the BS. These things are taken into consideration to estimate the likelihood of a node becoming a CH. The Gini index is used to do the computing for the clustering techniques that are done when the clusters are being formed. It is important to note that with this protocol, one and the same node has the potential to become a CH many times, which would eventually shorten the lifetime of the network.

Bayrakdar [13] investigated and simulated a number of different monitoring strategies developed for wireless sensor networks. The Time Division Multiple Access (TDMA) protocol was chosen to be used for medium access in order to facilitate operations that are less taxing on the environment's resources. Ricean and Rayleigh fading channels, both of which are examples of attenuation processes, were modeled and simulated using computer software.

In the context of the deployment of sensor nodes in agricultural settings, Bayrakdar [14] presented an approach that decreases the necessary number of sensor nodes while simultaneously eliminating coverage area conflicts. This method has been referred to as the Bayrakdar method. A method based on fuzzy logic was used for the selection of relays in order to improve the sustainability of the network. However, the specifics of extending the lifetime of sensor nodes were not addressed in this study, thus such questions remain unanswered.

In a separate research, Bayrakdar [15] presented a novel method that entailed the exploitation of cooperative relays by unlicensed users during idle mode and the detection of idle frequency bands when the system was in sleep mode. Bayrakdar's method was described as a new technique since it required the utilization of cooperative relays by unlicensed users.

The life expectancy of wireless sensor networks was intended to be increased as one of the key goals of the protocol that was introduced in [16], along with the goal of achieving equal energy dissipation to balance the load on the network. The protocol covered both the selection of cluster heads (CH) and the construction of clusters. Cluster heads (CHs) were selected according to their rank with the assistance of fuzzy inference algorithms, and cluster formation was carried out inside of the wireless sensor network (WSN). An analysis of the suggested protocol, known as EE-LEACH, was carried out in order to determine how it fares in contrast to other protocols, namely SCHFTL and DFCR, in terms of network longevity, the amount of packets sent, and the length of time during which stability is maintained.

Throughout the course of human history, many different kinds of protocols have been established to address issues of energy consumption, with the primary goal being to lengthen the lifespan of the network. An energy-efficient cluster head selection technique that is based on fuzzy logic was presented in a previous paper [17] with the intention of extending the lifetime of the network. This was accomplished via the use of fuzzy logic. During the process of forming clusters, the k-means method was used to efficiently produce clusters, and a fuzzy logic system was used to choose which clusters would serve as the heads of the newly formed clusters. The outcomes of the simulations that were carried out at the time suggested that the proposed algorithm shown greater performance when compared to other methodologies that were already in use.

III. SYSTEM MODEL

Energy usage model

Within the world of Wireless Sensor Networks (WSN), the level of energy consumption plays an essential role in determining the level of performance delivered by the system. In order to extend the life of the system, the techniques that are put into place inside the network always seek to cut down on the amount of energy that is used. Figure 2 represents the energy usage model.

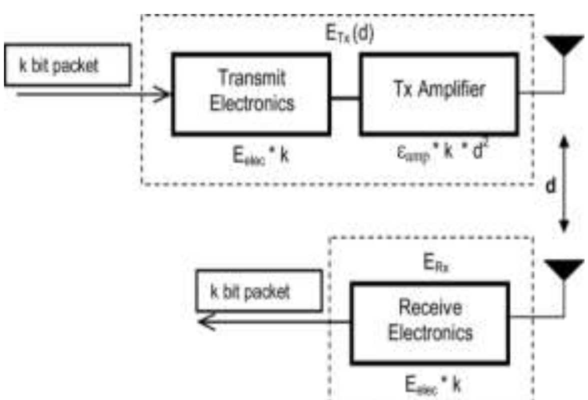

Fig 2: energy usage model in WSN

In the world of wireless sensor networks, more generally known as WSNs, communication between nodes is carried out by radio signals, and an energy model is used to determine the amount of energy that is used for data transmission and reception. The open space channel and the multi-path fading channel are both included in this model's scope of application as distinct kinds of channels. The distance (d) between the transmitter and receiver in comparison to a predetermined threshold distance (d_0) is an important factor to consider when choosing which channel to use in a communication system. When d is less than or equal to d_0, the network uses the free space channel; on the other hand, it switches to the multi-path fading channel when d is greater than or equal to d_0. The equation that is derived from this acts as a representation of the amount of energy that is needed by the model in order to send a message with k bits across a distance d.

Radio signals are used in Wireless Sensor Networks (WSNs) to carry out the communication between the nodes of these networks. An energy model is used in order to determine the amount of power that is required for the transmission and reception of data. The free space channel and the multi-path fading channel are both included in this energy model. Both of these channels are unique from one another. These channels function in a manner that is distinct from one another. The decision between the two is governed by the distance (d) that exists between the transmitter and the receiver in reference to a threshold that has been established in advance and is symbolized by the symbol d_0. When this threshold is exceeded, the multi-path fading channel is activated in the communication system. The following equation depicts the energy quantum required by the model in order to convey a k-bit message across a distance denoted by d, and it is shown in graphic form below equation 2.

$$E_T\,(k,d) = \begin{cases} kE_{elec} + k \in_{fs} d^2, & d \le d_0 \\ kE_{elec} + k \in_{mp} d^4, & d \ge d_0 \end{cases} \qquad \text{Eq (2)}$$

In this discussion, d_0 is used as a pre-established threshold value, E_{elec} represents the energy needs of the electronic circuit, $\in_{fs}$ signifies the energy consumption connected with the free space channel, and $\in_{mp}$ refers to the energy usage related with the multi-path channel. d_1 is the energy consumption linked with the multi-path channel. The amount of energy that must be present in order to accomplish the receiving of data at a pace of k-bits may be written as follows equation 3:

$$E_R(k) = kE_{elec} \quad \text{Eq (3)}$$

A variety of parameters, including as digital coding, modulation, filtering, signal dispersion, and others, may have an effect on the amount of energy that is used by an electronic circuit and is represented by the symbol (E_{elec}). On the other hand, the amount of energy that is used by the amplifier in either a free space situation ($\in_{fs} * \ d^2$) or a multi-path scenario ($\in_{mp} * \ d^4$) is not only dependent on the bit error rate but also the distance that separates the transmitter and the receiver.

Proposed CNC- LEACH CH SELECTION

An explanation is given in this part on the approach that has been suggested for selecting CHs, as well as the mechanism that will be used to guarantee that random number generation will be consistent. The next sections will go into further depth on each of these subjects and provide more information. The suggested technique modifies the process of generating random numbers by including characteristics from the network, such as Node degree, centrality, Energy consumption rate, and Distance to Base station parameters. This makes the algorithm reliant on the energy levels of the nodes, which may be thought of as an adjustment to the random number production process.

The creation of random numbers plays a significant role in the CH selection process, which is used to choose applicants. Before moving on to the subsequent stage of the CH selection process, nodes in the standard LEACH protocol are first required to produce a sequence of random numbers before moving on to the subsequent stage. The next step is to examine how these numbers, which were created at random, stack up against a minimum standard. In the event that the randomly generated value is lower than the threshold for that particular round, the node will take on the function of CH.

In the approach that has been developed, the selection of CH is based on the features of Node degree, centrality, Energy consumption rate, and Distance to Base station. This results in improvements to both the performance of the system and the lifetime of the network. Modifications are made to the method of producing random numbers in order to improve the energy efficiency of the CH selection process. To be more specific, the values that are associated with the sensor nodes are multiplied by the random number that is created. As the size of the network increases, the dependability and performance of the individual nodes will become an increasingly important factor in the creation of random numbers. The proposed selection parameters are explained as follows:

Node degree: - When opposed to other scenarios, those in which the network area is large have conditions in which the significance of communication inside clusters is accentuated to a greater degree. If the choice to designate a node as a relay depends simply on its detachment from surrounding nodes, there is a danger of picking a node that is very far from the majority of other nodes within the network. This is because the detachment from nearby nodes is used to determine whether or not a node qualifies as a relay. The selection procedure takes into account the total number of nodes that are located in close proximity as a means of addressing this problem and shown in equation (4).

$$ND = \frac{D_{ij}}{NUM_c} \quad \text{Eq (4)}$$

D_{ij} represents the distance between the nodes i and j; NUM_c represents the total number of member nodes in the cluster.

Node centrality: - The aggregation of data coming from other nodes within the cluster and the subsequent routing of this data to the base station are two of the many duties that come within the purview of cluster heads. The selection of cluster heads according to the degree to which their locations are vital to the cluster may improve the efficiency and reliability of data routing. When calculating the centrality of a node, one must take into account the distances that separate it from the other nodes in the network. The following equation 5 are the results of this calculation:

$$NC \ = \sum_{i=1}^{1-M} \frac{\sqrt{DIST(i,j)/n_{ch}}}{network_{dimension}} \quad \text{Eq (5)}$$

Here, n_{ch} is total number of neighbouring nodes and the distance between the node and the neighbour is denoted as $DIST$.

Energy consumption rate (ECR): - During the process of selecting nodes to participate in a network, the rate at which a node expends energy is an important criterion to consider, and it is given a high level of importance. This rate is established by calculating the disparity between a node's starting energy and the amount of energy it still had after the first round. As following rounds are played, the node's new beginning energy is determined by the amount of energy it had at the end of the previous round. As a consequence of this, the Energy Consumption Rate (ECR) is determined, and it is then contrasted with the average value of the threshold. If the computed value is lower than the threshold average value, then the node is considered eligible; on the other hand, if the calculated value is higher than the threshold average value, then the node is not eligible for that particular round. The equation 6 shows the Energy consumption rate.

$$ECR = \frac{(E_P - E_C)}{E_P} \quad \text{Eq (6)}$$

E_P & E_C are node energy in previous round and current round.

Distance to BS: The distance factor is what determines how much energy a node requires in order to successfully communicate with other nodes. The consumption of power by a CH node is decreased as the distance between that node and the base station (BS) is cut down. As a result, the selection techniques take into account this feature in order to guarantee that the typical distance that separates the CH nodes and the BS continues to be as short as possible. This can be formulated as follows equation 7.

$$D_{toBS} = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2} \quad \text{Eq (7)}$$

Where, x_i& y_i are the x & y positions of $CH(i)$ and x_j& y_j are the x & y positions of Base station (BS).

An analysis of the selection criteria is performed in order to determine the weight coefficient that should be allotted to each node in accordance with the features of that node. The parameters are brought into equilibrium by using a Weighted Sum Approach (WSA), which involves multiplying the value of each parameter by the weight that corresponds to it, and then summing the values that this produces. This procedure will eventually result in the many goals being consolidated into a single scalar objective function. The methodology that is being discussed in this scenario takes into account the node degree, the node centrality, the rate of energy consumption, and the distance to the base station (BS) as essential parameters for the efficient selection of cluster heads (CH). This can be represented as equation 8:

$$w = (\alpha 1 \times ND) + (\alpha 2 \times NC) + (\alpha 3 \times ECR) + (\alpha 4 \times D_{toBS})$$

$$w_n = \left(\alpha 1 \times \left(\frac{D_{ij}}{NUM_c}\right)\right) + \left(\alpha 2 \times \left(\sum_{i=1}^{1-M} \frac{\sqrt{DIST(i,j)/n_{ch}}}{network_{dimension}}\right)\right) + \left(\alpha 3 \times \left(\frac{(E_P - E_C)}{E_P}\right)\right) + \left(\alpha 4 \times \left(\sqrt{(x_j - x_i)^2 + (y_j - y_i)^2}\right)\right) \quad \text{Eq (8)}$$

Here $\alpha 1 + \alpha 2 + \alpha 3 + \alpha 4 = 1$.

CH selection

$rand(n)$ is the notation used to indicate the traditional random number. In the context of the suggested method, the procedure for generating improved random numbers may be characterized as follows equation 9:

$$rand(n)' = rand(n) * (w_n) \quad \text{Eq (9)}$$

Because it bases its choices on the probabilities associated with individual nodes, the threshold function is a very important component of the CH selection process. It does this by making effective use of the usual amount of energy contributed by each node in the network. In order to guarantee that each node in the network receives an equal amount of energy, the task of CH is routinely cycled among all of the nodes. The selection of a node to play the CH role is dependent on the node's current energy level. In the CNC-LEACH technique, the threshold function takes into account the average energy of the nodes throughout the course of the whole network's lifespan.

$$TH(n) = \begin{cases} \frac{P_n}{1 - P_n\left[\left(r \bmod \frac{1}{P_n}\right)\right]} * (w) + \frac{r}{P_n}, & if\ n \in G \\ 0, & otherwise \end{cases}$$
Eq (10)

In the above equation 10, P_n denotes probability of n to become CH, r denotes the round number.

Now, the value of the modified random number is matched with the threshold function.

$$rand(n)' \leq TH(n)$$

If the random value is higher than the threshold, the node in question will continue to play the CH role. If the random value is lower than the threshold, the procedure will continue with the node that comes next in the sequence.

Energy efficient relay selection scheme

Particle swarm optimization (PSO)

The Particle Swarm Optimization (PSO) method was conceptualized after observing natural occurrences, such as the grouping together of fish in schools and the gathering of birds in flocks. When birds are engaged in these natural behaviors, they typically travel as a coherent group in order to prevent collisions while they are on the lookout for food or refuge. Every bird in this flock adjusts its speed and where it is located relative to the others depending on the information that is gathered from the group as a whole. The members of the group are able to share information with one another, which results in a significant reduction in the amount of time and energy spent by the group as a whole looking for food and a safe haven.

PSO is composed of a predetermined number of particles, which are indicated by the symbol (S_n). Each particle in PSO suggests a solution for a particular instance of the issue. A fitness function is used in order to carry out an analysis of the performance of each particle. Dimensionality is the same across the board for all particles. Within the dth dimension of the hyperspace, each particle has a location that is denoted by the notation (P_{id}) as well as a velocity that is denoted by the notation (Vel_{id}). As a consequence of this, the characteristics of the particle P_i at each particular instant may be broken down into the following categories:

$$P_i = P_{i,1}, P_{i,2}, P_{i,3}, \ldots . P_{i,d}$$

In order to direct the iterative process of updating its location and velocity, each particle P_i aligns itself with its own individual best ($pbest$) as well as the global best ($Gbest$), with the end goal of arriving at the position that is ideal for the system as a whole. This process of updating is carried out until either the $Gbest$ has been determined or the maximum iteration limit has been achieved, whichever comes first.

Relay selection using PSO

The proposed method makes use of PSO methodology in order to select effective relay nodes in order to facilitate data transmission between sensor nodes and CHs, the authors write. During this procedure, nodes are conceptualized as particles, and their viability is evaluated with the use of a fitness function that takes into consideration a variety of conditions, including transmission latency and residual energy. After that, a fitness value is calculated for each sensor node while the method for selecting the relay nodes is being carried out. The candidate node in the competition for selecting the relay node that has the greatest fitness value, also known as Gbest, is declared the winner of the competition and is given the responsibility of acting as the relay node for sending data to CHs. This strategy leads to the conservation of energy across the network and assures the effective transport of data between sensor nodes and CHs.

The PSO method is used in the process of selecting the relay nodes, and this method is based not only on the amount of transmission delay but also on the amount of node residual energy. The relevance of the metrics that were employed in this selection procedure to choose the CH node with the highest efficiency cannot be overstated. It is the responsibility of the relay node to ease the flow of data from member nodes to the CH in order to extend the battery life of the network. In order to determine the fitness values of the CH nodes that are participating, the PSO method uses relay selection parameters. The following are the parameters used for selecting the relay:

Residual Energy: The transfer of data from each node that is a member of the network to the CH that it belongs to is carried out by relay nodes. When it comes to selecting relay nodes, the energy levels of those nodes are of the utmost significance since nodes with greater energy levels are better able to carry out relay jobs and have a longer operational lifespan. During data transmission, nodes that have a low amount of energy have a greater chance of experiencing energy depletion or operational failure. It can be formulated as follows equation 11.

$$f_1 = \frac{1}{M} * \sum_{i=1}^{N} E_{res}(N) \quad \text{Eq (11)}$$

Transmission delay: The possibility of a transmission time delay occurring between sensor nodes is something that has to be taken into consideration. As a consequence of this delay being longer and longer, there will be a commensurate increase in the amount of energy that will be used by the network. For effective data transmission, it is essential to keep the amount of time delay in the relay nodes to a minimum. The anticipated transmission count (ETC) of the node, the propagation delay (PD), and the network transmission delay (TD) all have a direct impact on the amount of time it takes for the node to complete its transmission. This can be formulated as follows equation 12:

$$Delay\ D(t) = \sum_{i=1}^{m} ETC_i(t)(TD + PD_i)$$

$$f_2 = \sum_{i=1}^{m} \min(Dt_{Si}) \quad \text{Eq (12)}$$

The PSO method that was created is used in the relay selection process, which results in the generation of fitness values for each of the nodes that are involved. Once these fitness values have been created, the nodes will send a message to other nodes within their coverage area that includes their node ID and the associated fitness value. After that, the nodes that are taking part in the relay selection compare the values of their fitness with the values of the other sensor nodes that are included inside the cluster. The node that has the greatest fitness value is the one that is chosen to be the ideal relay. This node will take on the job of a relay node and will be responsible for the transmission of data to the CH. The fitness function for the relay selection process is given as equation 13:

$$pbest_i = \omega_1 \times f_1 + \omega_2 \times f_2$$

$$f_1 = max\{residual_{energy}(n)\}, \qquad 1 \le n \le N,$$

$$where\ N = total\ number\ of\ nodes$$

$$f_2 = minimize\{delay(S_i)\}$$

$$pbest_i = \omega_1 * \frac{1}{M} \times \sum_{i=1}^{N} E_{res}(N) + \omega_2 \times \sum_{i=1}^{m} \min(Dt_{Si}) \quad \text{Eq (13)}$$

$$Gbest_i = max[pbest_i]$$

The values of the weight coefficients for the fitness functions, designated as ω_1 and ω_2, range from 0 to 1, with 0 representing a value that is less than and 1 representing a value that is larger than.

The node that competed in the relay competition and had the greatest fitness value was chosen to do the job that required them to convey the information. The information that is gathered by the sensor nodes is sent to the relay node that is located in the area that is most immediately next to them geographically. After that, the relay nodes send this information to the relay node that is geographically nearest to them. This procedure is carried out again up to the point at which the data finally reaches the CHs.

Algorithm

For all nodes 'n'

Calculate w

Calculate $TH(n)$

Estimate $rand(n)$

$rand\ (n)' = rand(n) * w$

If $rand\ (n)' \le TH(n)$

CH = n;

End if

End for

Data transmission phase

Calculate $pbest$

If $pbest_j > pbest_i$

$pbest = pbest_j$

End if

If $pbest_j > Gbest$

$Gbest = pbest_j$

End if

Compute relay nodes using $Gbest$

End for

IV. RESULT AND DISCUSSION

In order to evaluate how well the suggested procedures work, simulations built in NS2 were used. After obtaining these findings, they were compared to the outcomes produced by the EE-LEACH and FEECS methodologies. A random distribution of sensor nodes was carried out throughout an area with dimensions of 1000 meters by 500 meters, and each sensor node was given an initial configuration of 100 joules of energy. The size of the network was scaled up or down within a range consisting of fifty to two hundred nodes. In the following table 1, you will find a detailed description of the experimental parameters, along with the values that correspond to each of those parameters.

Table 1. Network Simulation parameters

Parameter	**Value**
Area of network	1000 m x 500 m
Nodes	50 to 200
Traffic Protocol	CBR
Transmission Protocol	UDP
Initial energy of node	100j
Size of packet	1024 bytes
Routing protocol	AODV

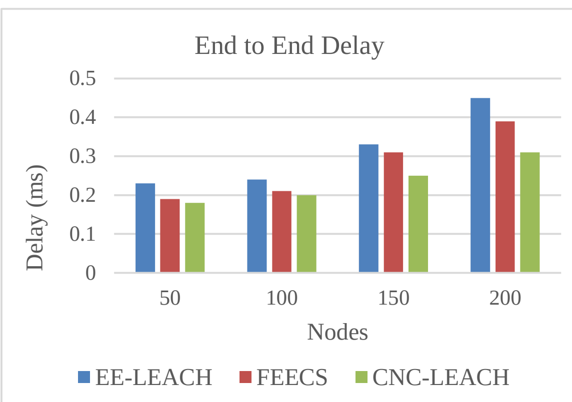

Fig 2: Performance on Delay

NODE	**EE-LEACH**	**FEECS**	**CNC-LEACH**
50	0.23	0.19	0.18
100	0.24	0.21	0.2
150	0.33	0.31	0.25
200	0.45	0.39	0.31

The analysis of the entire data transmission duration, spanning from initiation to completion, is depicted in the provided chart. In this network, the delay times ranged from a minimum of 0.3 milliseconds to a maximum of 0.45 milliseconds, particularly when the network size expanded to 200 nodes. The network exhibited the lowest delay when the average was just 0.3 milliseconds. The LEACH approach under consideration, which factored in elements like transmission delay, excelled in identifying the path with the shortest delay and achieving minimal time delays compared to alternative methods. Furthermore, the proposed technique adeptly determined the path with the least delay. Conversely, the highest time delays observed in EE-LEACH and FEECS were 0.45 milliseconds and 0.39 milliseconds, respectively. Figure 2 represents the end to end delay.

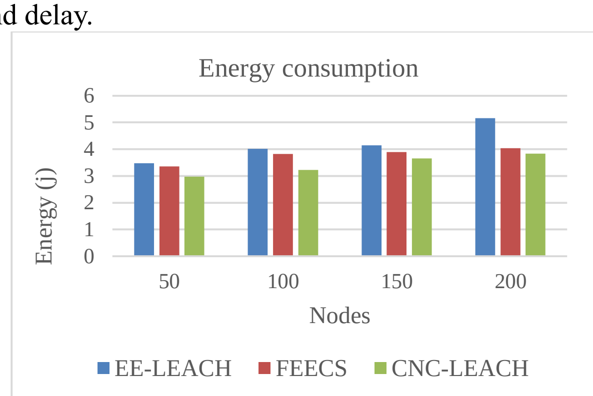

Fig 3: Energy consumption

NODE	**EE-LEACH**	**FEECS**	**CNC - LEACH**
50	3.48	3.36	2.98
100	4.02	3.82	3.23
150	4.15	3.9	3.66
200	5.16	4.04	3.84

The findings of the simulation that were supplied earlier point to the levels of energy consumption that can be ascribed to both the ways that are now in use and the strategies that are being suggested. In the beginning, the energy levels of all of the sensor nodes were the same. Throughout the many different functions of a network, it is not uncommon for energy to be depleted. The outcomes of the experiments indicated that the process under examination required an average amount of energy equal to 3.6 joules. In comparison, the average amount of energy that was used by EE-LEACH and FEECS was 5.1 and 4.2 joules, respectively. It is essential for the process of choosing the cluster head that measures like residual energy, node centrality, and node degree be included into the process. When compared to other ways, the recommended methodology has been shown to have a much lower total energy usage. This may be attributed to the fact that. Figure 3 shows the energy consumption.

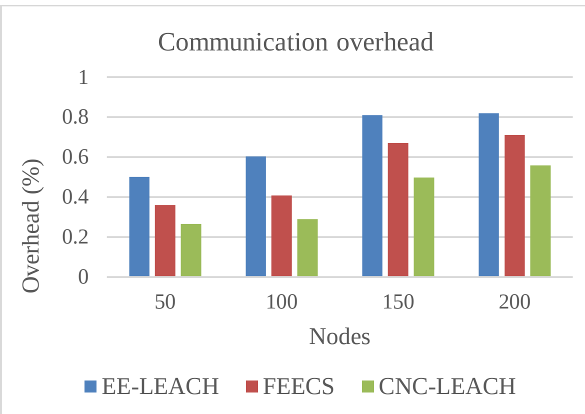

Fig 4: Performance on Overhead

NODE	EE-LEACH	FEECS	CNC - LEACH
50	0.501	0.36	0.265
100	0.604	0.408	0.29
150	0.81	0.67	0.498
200	0.82	0.71	0.559

The results of the simulation that were presented in the figure 4 before this one show the overhead that was encountered by the network. The quantity of control packets that need to be distributed over the network in order to make it function properly is directly proportional to the overhead. The suggested technique and FEECS both recorded an overhead of roughly 0.46%, while the EE-LEACH protocols both revealed an overhead level of approximately 0.7% and 0.82%, respectively. Incorporating criteria such as transmission delay into the relay selection process helps to a lower likelihood of route failures, which, in turn, reduces the need for performing frequent control packet broadcasts. As a direct result of this, the solution that was suggested successfully maintains a minimal degree of overhead.

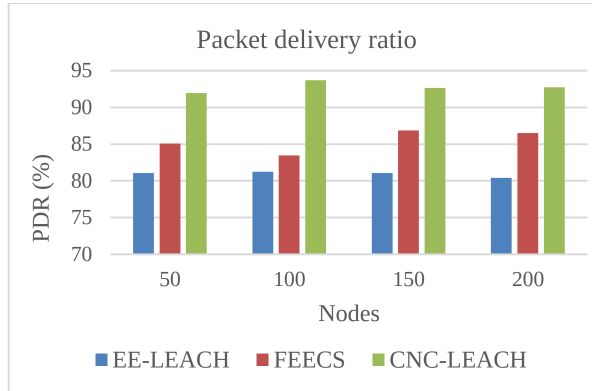

Fig 5: Packet delivery ratio

NODE	EE-LEACH	FEECS	CNC - LEACH
50	81.08	85.08	91.96
100	81.26	83.48	93.72
150	81.05	86.85	92.65
200	80.43	86.53	92.75

PDR is a useful metric for determining the quality of data transmission inside the network. The maximum PDR that can be reached using the existing techniques is between 80.43% and 85.53%, whereas the greatest PDR that can be reached using the approach that has been described is an amazing 92.75%. The addition of characteristics such as transmission delay and the selection of cluster heads based on node degree and centrality are responsible for the current systems' superior performance, which may be ascribed to their superiority over the older approaches. These factors help to reduce the distance between nodes that are involved in communication, which ultimately results in paths that are more effective for the transfer of data. Figure 5 represents the packet delivery ratio.

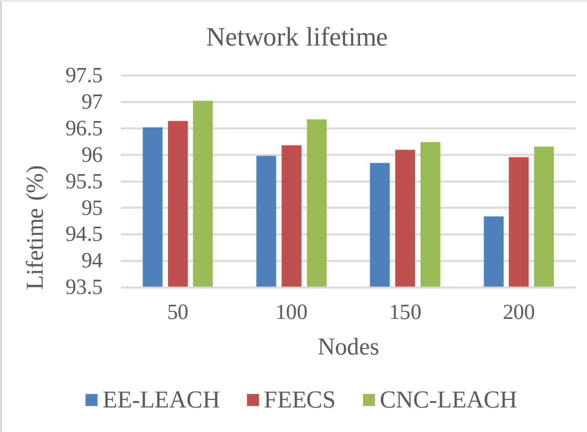

Fig 6: Performance on Network lifetime

NODE	EE-LEACH	FEECS	CNC - LEACH
50	96.52	96.64	97.02
100	95.98	96.18	96.67
150	95.85	96.1	96.24
200	94.84	95.96	96.16

The phrase 'network lifetime' refers, in broad terms, to the time period during which a network continues to function as intended or the time span during which the energy stored in the network's initial sensor node or a set of sensor nodes within the network is depleted. When it comes to our experimental setup, the lifetime of the network is directly related to the amount of energy that is still present inside the network after all of the network's numerous operating operations. There is a correlation between having a larger reservoir of leftover energy and having a longer network lifetime. The data that are shown in the table that is located above offer proof that the suggested strategy considerably improves the overall lifetime of the network when compared to other ways that are currently being used. Figure 6 shows the analysis of network lifetime.

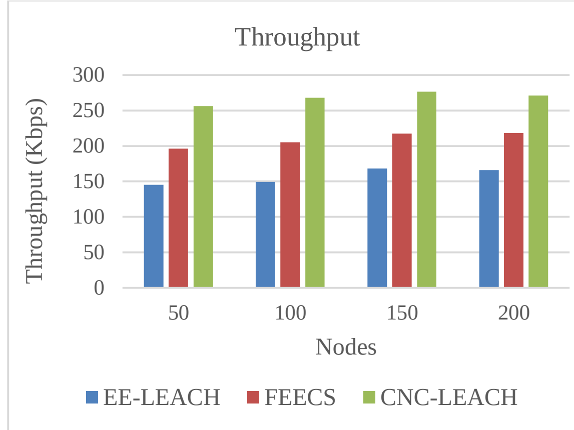

Fig 7: Network performance

NODE	EE-LEACH	FEECS	CNC-LEACH
50	145.09	196.08	256.25
100	149.34	205.05	268.08
150	168.18	217.35	276.56
200	166.18	218.21	271.3

The simulation results for Throughput, pertaining to both the proposed and current methods, are depicted in the provided charts. Throughput, simply put, measures the data transfer capacity between sensor nodes, ensuring efficient data delivery. The data in the table above validates that the proposed approach achieves a significantly higher throughput rate compared to the current methods. Throughout the experiment, the proposed method consistently maintained an average throughput rate of up to 270 kbps, outperforming the FEECS and EE-LEACH methods, which maintained the highest throughput rates at 218 kbps and 166 kbps, respectively. Figure 7 shows the network performance.

V. CONCLUSION

In the traditional LEACH protocol, cluster heads (CHs) are chosen at random, which may result in the identification of nodes with a low amount of residual energy as CHs. An improved protocol known as CNC-LEACH was developed in response to this problem and has now been implemented. During the CH selection process, CNC-LEACH takes into account a number of criteria, some of which include the node degree, the node centrality, the rate at which energy is used, and the distance from the base station. Because of these factors, the selected CHs will have a greater number of nearby nodes inside their coverage area, which will result in a reduction in the amount of energy that is necessary for member nodes to connect with CHs. In addition to this, a more developed mechanism for selecting relays that is based on particle swarm optimization (PSO) has been put into place. CNC-LEACH improves the performance of wireless sensor networks (WSNs) in terms of energy efficiency, secure data transfer, network lifetime, and communication quality, according to the findings of simulations and subsequent analyses.

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