PARTICLE SWARM OPTIMIZATION BASED ENERGY EFFICIENT CLUSTER HEAD SELECTION ALGORITHM FOR WSN

GROUP-11
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ABSTRACT

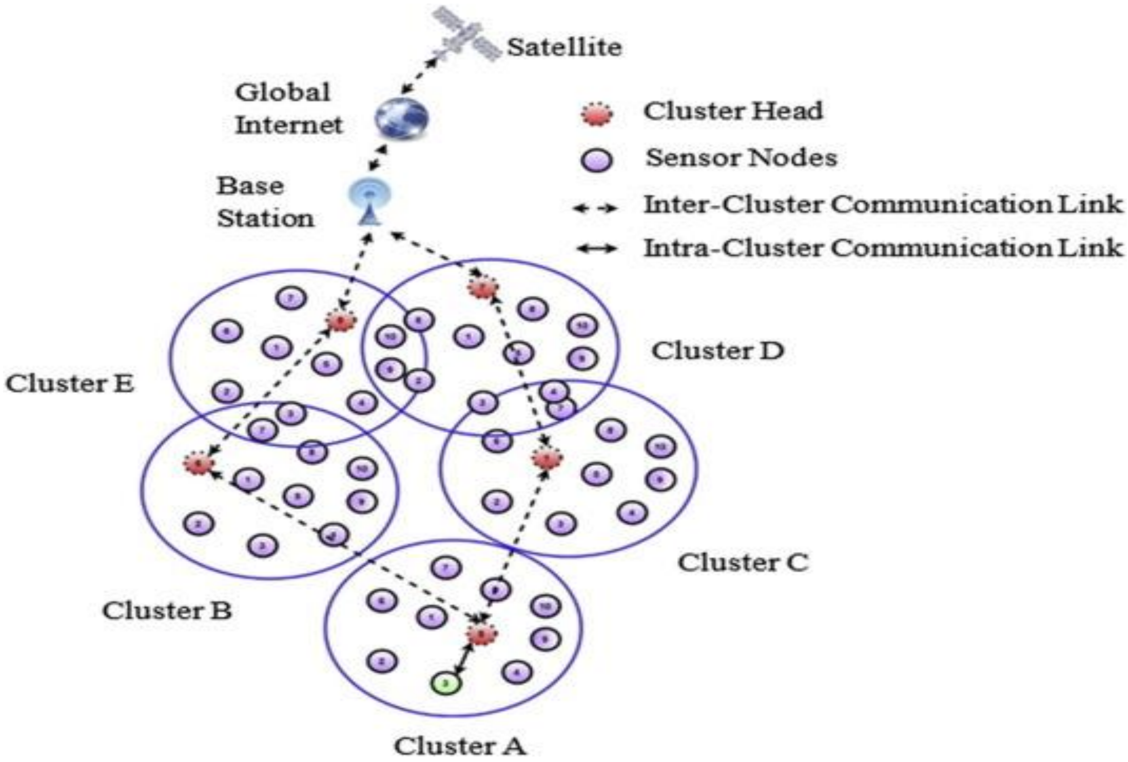
Cluster heads (CHs) spend more energy in a hierarchical cluster-based WSN owing to the additional workload of collecting and aggregating data from their member sensor nodes and transferring the aggregated data to the base station. As a result, the right selection of CHs is critical for preserving the energy of sensor nodes and extending the lifetime of WSNs. The network lifetime is also a critical aspect for selecting cluster heads as the longer the network alive the better and accurate information it will provide. Hence, it is important to select the right cluster heads. This report presents an energy-efficient cluster head selection approach based on particle swarm optimization in this study (PSO)

INTRODUCTION

WSN is organized into clusters for effective data collection in the context of energy dissipation. Clustering not only organizes a deployed network into a linked hierarchy but also balances network load, extending the system's lifespan. In a cluster-based WSN, each sensor node communicates the information it has acquired to the cluster coordinator. The cluster coordinator is responsible for aggregating the gathered data and routing it to the deployed network's sink.

The main problem is cluster head selection in the wireless sensor networks. Cluster heads are elected so that they will gather all the local data from their own area and forward it to the base station after aggregating it. If we don’t select cluster heads then there will be a lot of data redundancy and that will have to be handled by the base station alone. For this purpose, the base station delegates its work to these cluster heads.

Sensors lose energy over time as they transmit data. To minimize the energy loss it is inevitable to develop a clustering protocol that is efficient in conserving energy for dragging out the span of the network. Clustering improves the scalability of the network significantly and conserves communication bandwidth



The study focuses on the CH selection problem and presents a PSO-based solution to solve it. Among the regular sensor nodes, the proposed technique efficiently picks the CHs. The CH selection issue is given a linear programming (LP) model. It is suggested that a PSO-based method be used. The suggested PSO technique is based on a particle encoding approach that is both efficient and effective. To make the PSO-based technique energy efficient, the fitness function is also generated by considering various distance factors and residual energy.

This research develops a PSO-based CH selection method with an efficient particle encoding technique and fitness function after formulating an

LP for the CH selection issue. It simulates the suggested algorithm to show how efficient it is in comparison to other algorithms.

In the next section, we go through papers tackling the same problem of selecting cluster heads. In the proposed work section we have given a detailed explanation of how the algorithm works and also given the pseudo-code. Later we have discussed the simulation environment and the results. Then the conclusion and future work is given ending with references.

RELATED WORKS

[1] presents fuzzy logic-based clustering methodologies such as energy-efficient cluster head selection, FCM, two-level fuzzy logic, fuzzy logic-based cluster head election mechanism, neuro-fuzzy methodology, and cluster adaptability method.

In [2,] hierarchical protocols, power-efficient gathering in sensor information systems (PEGASIS), and threshold sensitive energy-efficient sensor network protocol are characterized as analogous to the LEACH protocol.

For the selection of the cluster head, the following distributed clustering algorithms employ Type-1 fuzzy logic and a fuzzy inference system. The cluster head selection in [3] employs the RE and predicted RE of the node (assuming it is chosen as the cluster head) as fuzzy inputs to choose the node. If you choose to be the cluster head, the number of nodes surrounding you (node degree) and the centrality of those nodes are utilized to calculate the cost (energy expenditure).

The self-management concept uses a virtual gridding technique to partition the network into clusters [4]. The sensor node's possibility of becoming the cluster head is determined using the fuzzy inference technique. As fuzzy inputs, RE and radio energy dissipation are employed, while chance is used as a fuzzy output. As the cluster head, the sink chooses the sensor node with the highest chance value.

The cluster head is chosen as the node with the lowest cost. To compute the competition radius, a fuzzy energy-aware uneven clustering method [5] employs RE and the distance to the sink as fuzzy inputs. For the following round, the node with the highest competition radius is chosen as the cluster head.

Summary Table

Protocol	Aim	Problems solved	Issues	Use
LEACH	Cluster head selection	Energy-efficient algorithm	If cluster head dies that cluster becomes useless	The most commonly used and basic protocol
FLEEC(Fuzzy-Logic based Energy-Efficient Clustering)	Cluster head selection	Uniform distribution of cluster heads across the ROI	The longevity of the WSNs still isn't very long	Medium number of randomly placed nodes
LEACH_ERE	Cluster head selection	Decides the number of cluster heads depending on the load on the network	Just makes a minor improvement on the LEACH protocol	Used in handling mobile sensor nodes
Fuzzy	Cluster head selection	Solves the clustering problem in large-sized networks	Time complexity is very high	Used in cases where the death of nodes needs to be prevented at the best.
EAUCF	Cluster head selection	Decreases the intra-cluster work of the cluster-heads that are either close to the base station or have low remaining battery power.	Distance from the base station is given more preference compared to residual energy	Data packet transfer using relay node

How PSO Algorithm is different from the above approaches?

In contrast to current methods, it employs an efficient particle representation scheme and a unique fitness function that takes into account distance parameters and residual energy. It facilitates cluster formation by allowing non-CH sensor nodes to join a CH based on a weight function, whereas previous methods allow non-CH sensor nodes to join a CH based solely on distance, which can result in CH load imbalance and substantial energy inefficiency. In the above existing methods imply that the nodes are equipped with a position-finding device like GPS, which is ineffective for deploying a large-scale WSN. No GPS is required for the suggested method.

PROPOSED WORK

The Particle Swarm Optimization algorithm is used to choose the cluster head. The residual energy and distance parameters are used in the cluster head selection method. During the cluster head selection phase, all sensor nodes report their position and residual energy to the base station to see if they satisfy the threshold energy (average energy of the sensor nodes) to be considered for a cluster head. At the base station, the PSO-based cluster head selection process is then executed, followed by the cluster formation phase.

The proposed algorithm's main goal is to pick CHs from among conventional sensor nodes based on energy efficiency in order to extend the network lifetime. We examine residual energy of the sensor nodes and different distance characteristics, such as the average intra-cluster distance between the sensor nodes and their distance from the sink, for effective CH selection with energy efficiency. Let f1 be a function of the CHs' sink distance and the average intra-cluster distance. For optimal CH selection, we must reduce f1. Let f2 be a function that is the reciprocal of all the CHs' total current energy. It's worth noting that this ratio should be maximized for the best CH choice. This implies that the reciprocal, f2, should be decreased. Let f3 be a function that is the transmission time delay exist between the sensor nodes. If the delay increases, then energy consumption also increases in the network. The relay nodes should have minimum time delay for efficient data transmission, we must reduce f3. We normalize the three objective functions between the range of 0 and 1 in such a way that we minimize the linear combinations of these two functions in an efficient manner. These three functions f1, f2 and f3 are used to derive the fitness function for the PSO algorithm. Hence, we can treat it like a linear programming problem where we have to minimize the functions f1, f2 and f3 and the constraints are as follows

- The sensor nodes are within the intra-cluster communication range with the CH nodes.
- The BS will be within the maximum communication range of the CHs
- The energy of all the CH nodes must be greater than the threshold value, which is the average energy of all the sensor nodes.

The essence of the PSO algorithm lies in its fitness function. An efficient fitness function makes sure that the CH selection process will be efficient. So, in the next, the derivation of the fitness function is described.

Derivation of the fitness function

It depends mainly on the following parameters-:

1. *Average intra-cluster distance*
   It's the average of all the sensor nodes' distances from the CH they've chosen. All sensor nodes need the energy to communicate data to their CH in intra-cluster communication. We must minimize the average intra-cluster communication distance in order to utilize less energy. As a result, we must choose a sensor that is close to all of the sensor nodes as the CH.

$$\frac{1}{n}\sum_{i=1}^{n} \mathrm{dis}(\mathrm{SN_j}\,, \mathrm{CH_j})$$

   Where,
   n is the total nodes in the cluster,
   SN is the sensory node,
   And $\mathrm{CH_j}$ is the cluster head of that cluster.

2. *Average Sink Distance*
   The ratio of the distance between a cluster head CH and the base station BS to the number of sensor nodes is what it's called. All CHs

must send their aggregated data to the BS during the data routing phase. As a result, in order to reduce energy consumption, we must reduce the distance between all CHs and the BS.

F1 = $\sum_{j=1}^{m}(\sum_{i=1}^{Ij} dis(S_i\ ,\ CH))$

3. *Energy Parameter*

ECH_j is the current energy of each cluster head CH_j. As we have to maximize the energy of the cluster heads for simplicity we can simplify the reciprocal of the summation.

F2 = $\frac{1}{m}$ x $\sum_{i=1}^{N} E_{res}(N)$

4. *Transmission Delay*

It is the transmission time delay that exists between the sensor nodes. If the delay increases, then energy consumption also increases in the network. The relay nodes should have minimum time delay for efficient data transmission. By relying on the transmission delay (TD), propagation delay PD, and expected transmission count (ETC) of the node, the delay of node is resulted in a network and it formulates using equations

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

F3 = $\sum_{I=1}^{m} \min\ (\ \mathrm{D}t_{Si}\ )$

Hence, in our PSO algorithm as the 3 objective functions are not strongly conflicting there exists a unique optimal solution. Therefore, we will use the fitness function as follows:

Fitness function ($pbest_i$) = $w1$x F1 + w2 x F2 + w3 x F3
(where w1 + w2 + w3 = 1)

The lower the fitness value the better the position of the particle.

F1 = Minimize $\sum_{1}^{m}\frac{1}{n}(\sum_{j=1}^{n} \mathrm{dis}(\mathrm{SN_j}\ , \mathrm{CH_j})\ +\ \mathrm{dis}(\mathrm{CH_j}, \mathrm{BS}))$

F2 = max $\{residual_{energy}(n)\}$

F3 = minimize {delay (S_i)}

$$pbest_i = \omega_1 * \frac{1}{M} * \sum_{i=1}^{N} E_{res}(N) + \omega_2 * \sum_{j=1}^{m} (\sum_{i=1}^{Ij} dis(S_i, CH)) + \omega_3 * \sum_{i=1}^{m} \min(Dt_{Si})$$

$$Gbest_i = max[pbest_i]$$

Pseudo Code

Input:
Set of sensor nodes: S = {s1, s2, s3,.....,sn}.
Predefined swarm size: NP.
Number of dimensions of a particle: D=m.

Output:
Optimal positions of cluster heads CH = {CH1, CH2, CH3,.....,CHm}

Algorithm:

Step 1:
Initialize particles Pi and initialize their positions randomly in the region of interest.

Step 2:
for i = 1 to swarm size do
    2.1 Calculate Fitness(Pi)
    2.2 Pbesti =Pi
endfor

Step 3:
Gbest = {Pbestk|Fitness(Pbestk) = min(Fitness(Pbesti),∀ i, 1≤ i ≤ swarm size)}

Step 4:

```
for t = 0 to TR /*TR = Max. number of iterations*/
        for i=1 to Swarm Size do
                4.1 Update velocity and position of Pi
                4.2 Calculate Fitness(Pi)
                4.3 if Fitness(Pi) < Fitness(Pbesti) then
                        Pbesti =Pi
                endif
                4.4 if Fitness(Pi) < Fitness(Gbest) then
                        Gbest =Pi
                Endif
        endfor
        for k = 1 to n
                4.5 Calculate dis(Xi,j(t + 1), sk)
        endfor
endfor
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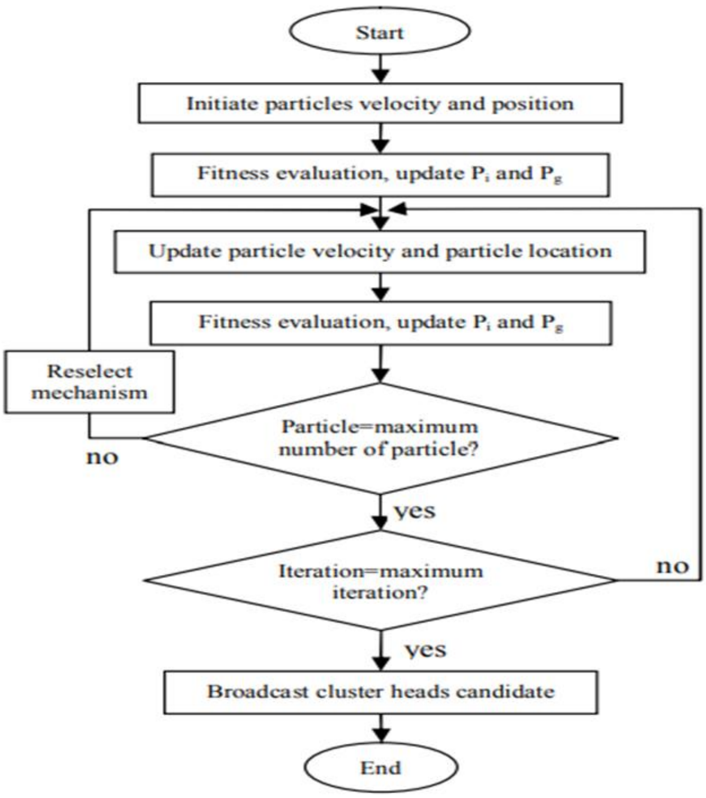
Step 5: Stop



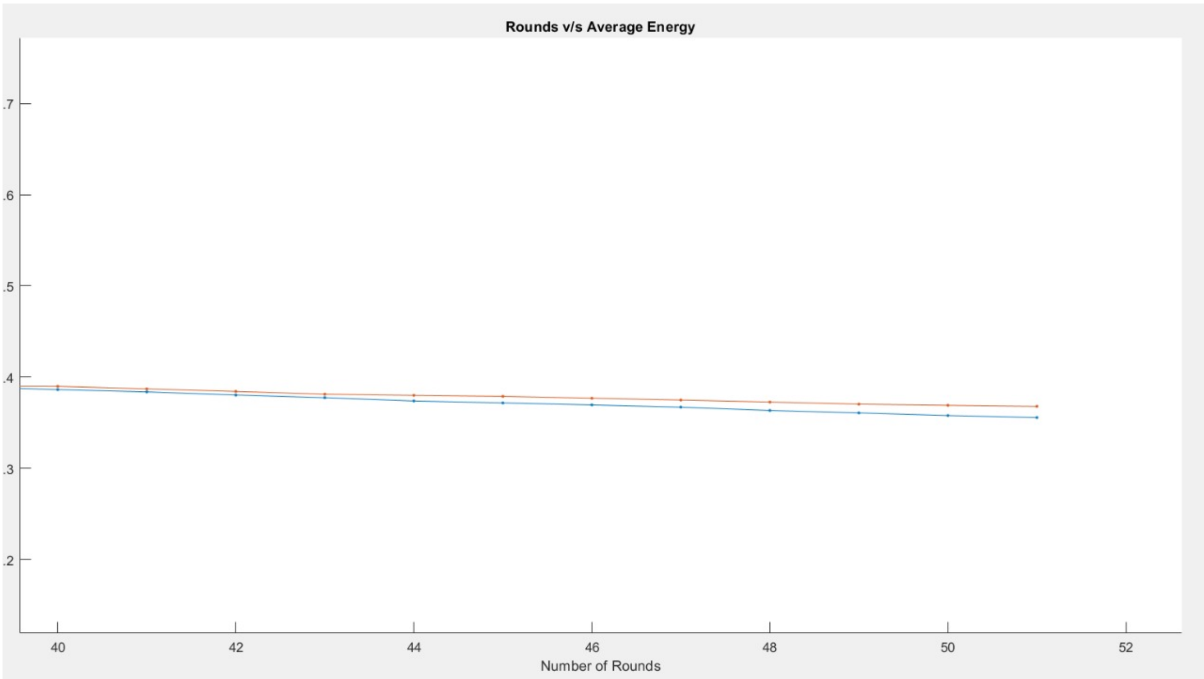
General flow chart for proposed PSO

PERFORMANCE EVALUATION

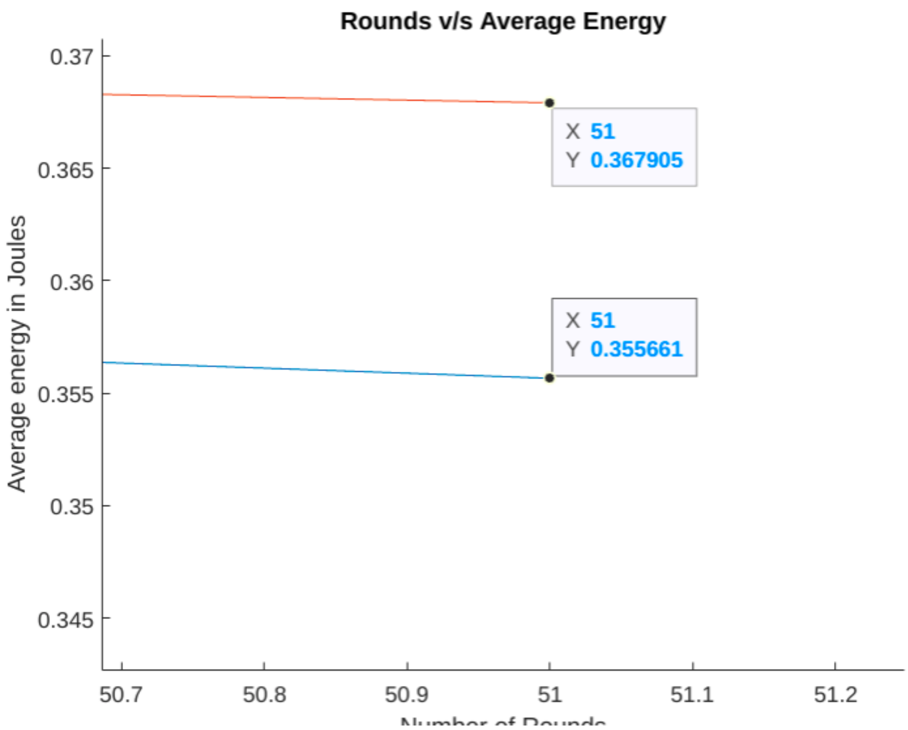
The following measures are used to assess the performance of the suggested algorithms.

1. **Total energy consumption** This is the total energy consumption for a set number of cycles in which CHs collect data, aggregate it, and route it to the BS. It is worth noting that the energy usage increases as the number of rounds increases.
2. **Network lifespan** as previously stated, we define network lifespan as the number of rounds until the final node dies, abbreviated as LND. The longer the network lifespan, the better the network performance.
3. **Packet delivery** This is the total number of data packets received by the BS over the network's lifespan. The more packets received, the better the performance.

- Average Energy vs Number of Rounds Graph:

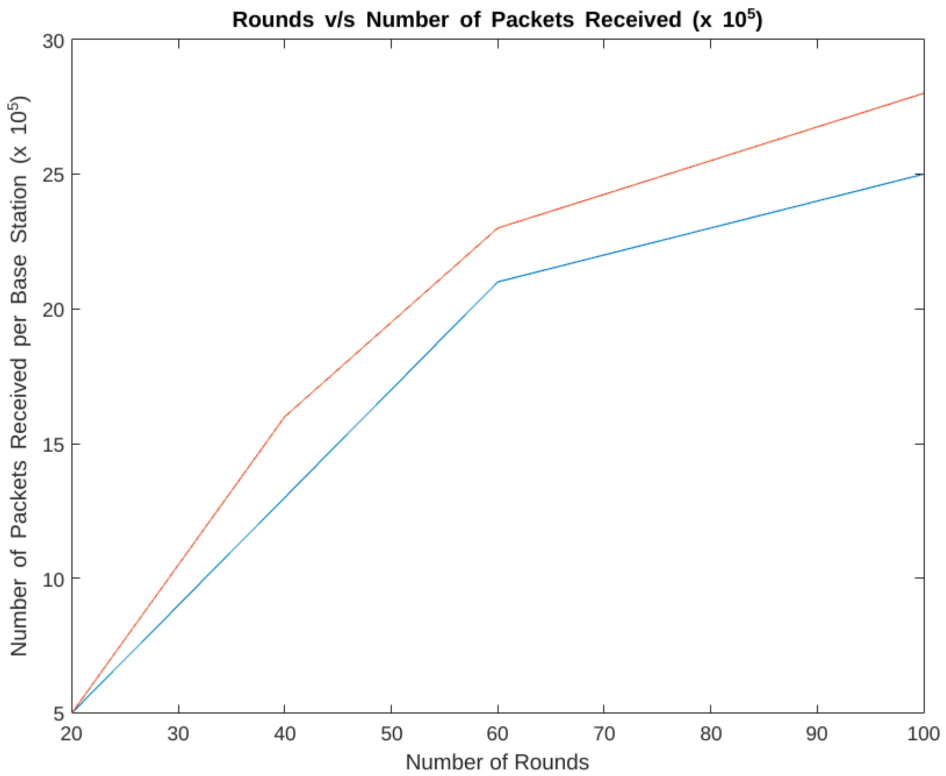


This is the graph where we did a comparison in terms of total energy consumption for WSN using Fuzzy vs WSN using PSO optimization.
From the above figures we can observe that the initial performance of a PSO based algorithm is not much more than the Fuzzy algorithm.



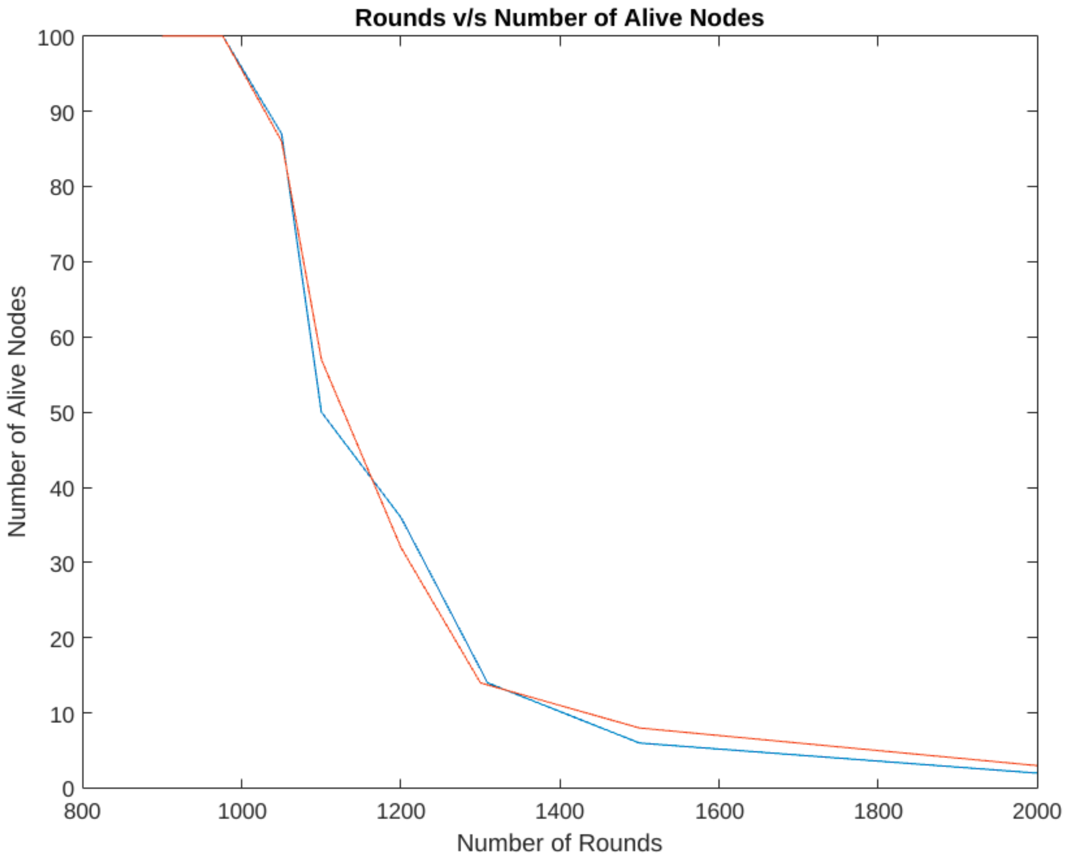
But here in the end you can see the overall energy is saved by the PSO algorithm.

- Packets Received vs Number of Rounds Graph:



This is the graph where we did a comparison in terms of the number of packets received by the base station for WSN using Fuzzy vs WSN using PSO optimization. As the number of rounds rises, the residual energy of sensor nodes decreases. The selection of CHs is critical to reducing energy consumption, and our method takes optimal care for the selection of CHs using an unique fitness function. From the above figures we can observe that the initial performance of a PSO based algorithm is not much more than the Fuzzy algorithm. But overall packets received by PSO WSN are more than the Fuzzy one.

- Number of Nodes alive vs Number of Rounds Graph:



This is a graph that compares the number of living nodes for WSN in Fuzzy based algorithm vs WSN using PSO optimization. The leftover energy of sensor nodes reduces as the number of rounds increases. According to the statistics above, the initial performance of a PSO-based algorithm is not much better than that of the Fuzzy method. However, if the longevity of network is observed over all the rounds PSO algorithm outperforms Fuzzy. As the size of the network grows, the performance of the existing methods degrades, as shown by Graph.

CONCLUSION

We introduced an energy efficient CH selection technique based on PSO that makes use of an efficient particle representation and fitness function. We included intra-cluster distance, sink distance, and node residual energy while calculating the algorithm's energy efficiency.
The weight function for cluster formation was then constructed. We presented simulation results as well as comparisons using the Fuzzy Algorithm. The method has been thoroughly tested with a variety of situations and WSN instances. According to the experimental results, the suggested algorithm outperforms the existing methods in terms of overall energy consumption, network lifespan, and the number of data packets received by the base station.

FUTURE SCOPE:

In the suggested method, we did not take into account any routing algorithms. Our next research will try to create a routing algorithm utilising a metaheuristic method. We will address several challenges for such an algorithm, such as energy balance and WSN fault tolerance. We also want to develop it for heterogeneous WSNs, as opposed to the suggested approach, which only works for homogeneous networks.
Here we can also use PSO for optimising localisation of Nodes which can save a lot of energy because a lot of current algorithms do random deployment of nodes initially.

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