

Cluster Optimization Scheme for Wireless Sensor Network Performance Enhancement

Divya Srivastava¹, Nitin Jain¹, Manish Kumar²

¹*Electronics and Communication Department, BBD university, Lucknow, India*

²*Electronics and Communication Department, SUAS, Indore, India*

Email: divya.div1912@gmail.com

This work mainly focuses on the network-based algorithm development that can support for enhancing the entire network lifetime. The work truly follows the objective that can balance the energy consumption among all sensor nodes to enhance the lifetime of the network so that there would be no overflow sensor nodes used to run out of energy before the others. Generally, the energy consumption by a sensor node integrated sensing, communication and data processing. Among the three operations, a sensor node expends the maximum energy in the data communication. A major concern is the design and development of energy management algorithm that wishes to recover energy in order to extended network lifetime.

Keywords: Cluster Optimization, Data Transmission, Node Distribution, WSN.

1. Introduction

Wireless sensor networks (WSNs) are special ad hoc networks that provide the monitoring of physical world through numerous tiny, cheap and smart sensor nodes dispersed in desired area of interest [1]. These sensor nodes are autonomously accommodated to sense, process and wirelessly convey environment conditions to a base station [2]. WSN has been widely used in different applications such as habitat and industry monitoring, medical diagnosis, environment monitoring and agriculture [3-5]. Wireless sensor nodes are commonly powered by restricted capacity batteries which replacement is delicate in hostile environment where hundreds of nodes are randomly deployed. Therefore, nodes must be able to operate in low power modes to increase the longevity of their power supplies. Hence, energy optimization and efficiency are extremely important factors to be considered in WSN [6]. Among energy consumption sources in a sensor node, energy used in wireless data communication has the most critical impact. Routing is one of the crucial energy efficient techniques employed in WSN that aims to lower the communication energy burden [7, 8]. Cluster-based routing architectures are widely used in wireless sensor network due to their energy efficiency and load balancing in the network [9-11]. Sensor nodes in cluster architecture are grouped into clusters in which a cluster head (CH) is elected and group of source nodes are directly attached to the cluster head.

Generally, a cluster network employs single hop routing in each cluster [12]. The one-hop clustering can reduce the energy consumption of communication by forwarding source nodes data to the cluster head via one hop. However, when communication distance increases, single hop communication consumes more energy and becomes less energy efficient method. For a large network, where inter-node distance is important, multi-hop communication is energy efficient approach [13,14]. For this reason, we proposed to employ a multi-hop communication in clustered routing architecture to mainly prolong the network lifetime by saving transmission energy.

2. Related Work:

Wireless sensor networks with steady sink hub every now and again be distressed by warm spots bother thinking about that sensor hubs near the sink regularly have more noteworthy traffic weight to ahead for the span of transmission process. Using cell sink has been demonstrated as a powerful strategy to beautify the local area generally speaking execution along with energy execution, local area lifetime, and inactivity, and numerous others. In this compositions, Jin Wang, (2017) [11] proposed a molecule swarm enhancement essentially based grouping calculation with versatile sink for wi-fi sensor local area.

Remote Sensor Networks (WSNs) are enormous scope and high-thickness networks that normally have inclusion region cross-over. Likewise, an arbitrary sending of sensor hubs can not totally ensure inclusion of the detecting place, which winds up in inclusion openings in WSNs. Along these lines, inclusion control plays a fundamental capacity in WSNs. To mitigate unnecessary power wastage and upgrade local area execution, we remember every energy effectiveness and inclusion cost for WSNs. In this compositions, Jin Wang, (2018) [12] provided a remarkable protection control set of rules in view of Particle Swarm Optimization (PSO).

Energy execution and energy adjusting are significant examinations issues as in accordance with directing convention planning for self-coordinated wi-fi sensor organizations (WSNs). Numerous written works utilized the grouping calculation to acquire strength productivity and power adjusting, notwithstanding, there are commonly strength openings Because of the high weight of sending, it's best to keep it near the bunch heads (CHs). Because the bunching problem in lossy WSNs has become an NP-hard problem, many metaheuristic calculations have been used to solve it. An exceptional grouping approach known as Energy Centers is mentioned in Jin Wang's (2019) [13] work. To prevent those power openings and look for energy offices for CHs option, the use of Particle Swarm Optimization (EC-PSO) is introduced.

Lavanya Nagarajan et al. (2021) [37] proposed a clever half breed dim wolf optimiser-based sunflower streamlining (HGWSFO) calculation for ideal CH determination (CHS) under specific element imperatives, such as energy spent and detachment distance, with the goal of increasing the organisation lifetime. Sunflower advancement (SFO) is used for a larger project (research) in which the size of the progression size boundary is varied to bring the plant closer to the light looking for worldwide refinement, hence expanding the investigation effectiveness. Dark wolf advancement (GWO) is utilized for a restricted inquiry (abuse), where the boundary

coefficient vectors are purposely expected to underscore double-dealing. This adjusts the investigation abuse compromise, draws out the organization lifetime, builds the energy effectiveness, and upgrades the presentation of the organization as for in general throughput, lingering energy of hubs, dead hubs, alive hubs, network survivability record, and combination rate. The unrivaled quality of the recommended HGWSFO is approved by contrasting its presentation and different other existing CHS calculations. The general exhibition of the proposed HGWSFO is 28.58%, 31.53%, 48.8%, 49.67%, 54.95%, 70.76%, and 87.10%, better than that of GWO, SFO, molecule swarm enhancement (PSO), further developed PSO, low-energy versatile grouping ordered progression (LEACH), LEACH-concentrated, and direct transmission, individually.

With the advancement of data innovation, remote sensor networks have been generally utilized in rural water system the board, military interruption checking, modern control and different fields. Instructions to diminish the hub energy utilization and keep up with energy balance has been a hotly debated issue in remote sensor network research. Jian Wu et. al. (2021) [38] proposed a multi-bounce information sending calculation for remote sensor networks fueled by sunlight-based cells and batteries, and presents a multi-objective dynamic model for information sending hub choice of next jump. The Pareto ideal arrangement set is acquired by utilizing multi-objective molecule swarm improvement calculation. The qualities of sun powered energy securing are examined, and a sun-oriented energy supply model is planned. The recreation results show that the information sending calculation can adjust to the difference in network energy, and lessen network energy utilization and organization delay.

3. Methodology:

Our proposed algorithm is composed of two clustering and data transmission phases

3.1. Clustering Phase: In clustering phase, the particles are generated randomly. Then the best points are selected as the cluster heads and other nodes which are located near each cluster head becomes the member of the cluster and then fitness function is calculated for every cluster heads. If the fitness function is better than global best it is substituted. This process is done for 1000 generation. Then each node prepares a control message that contains identity and value of its residual energy and sends it directly to the base station. The base station which receives the information performs clustering operation.

3.2. Proposed Validation index: As previously mentioned, the clustering is more desirable in which intra-cluster density is higher and, in another word, the clusters are more cohesive and inter-cluster density is lower. Based on this principle, in the proposed method to estimate the optimal number of clusters. The first Select the number of clusters. Also to measure rate of clusters separation the different distance between cluster than total center of data set for the number of clusters considered, and then calculated the ratio between two, since the clustering is more desirable. The clusters are more compact and farther apart So, for the number of clusters where the index is maximum the clustering is more desirable and the optimal number of clusters is achieved. Validation index is composed of two parts, F1 and F2:

$$\text{validity} = \max (F1 + F2) \quad (1)$$

Whatever the amount of the above criterion is greater clustering is better. eq. (8) denotes the F1 index and Figure 3 illustrates the cluster dispersion and density of nodes in each cluster:

$$F1 = \left(\frac{\text{inter} \times 2}{\sqrt{\text{intra} \times Z}} \right) \quad (2)$$

Inter: inter-cluster distance for which farther is better.

Intra: intra-cluster distance for which closer is better.

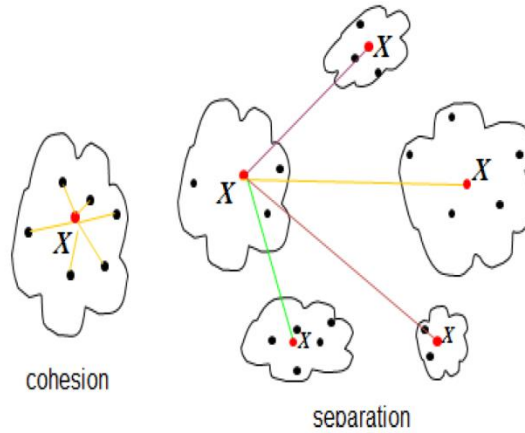


Fig 1. Performance of the proposed index

Eq. (9),(10) denotes the intra and inter cluster separation:

$$i_{\text{intra}}(c) = \sum_{i=1}^c d \sum_{j=1}^N (X_j - X_i) \quad (3)$$

In Eq. (9) the total distance between nodes in each cluster and its cluster head is calculated in which c is the number of clusters, N is the number of nodes, X_j is the cluster head and X_i denotes the distance of the nodes from its relative cluster head. The intra cluster separation is shown in the following equation:

$$\text{Inter}(c) = \sum_j^c (X_j - X) \quad (4)$$

To calculate the inter clusters separation, the distance between the centers of the clusters and the center of total data set is calculated. For cluster range specified the amount of this index calculate and show in chart. In the conditions in which the slope of the curve is sharper the estimate of the number of clusters is more accurate. Then with local search around the slope the optimal number of clusters can be reached. Eq. (4) Explains how to calculate F2. F2= cluster heads degree+(2. residual energy) / centrality + distance to base station. Residual energy : because of the rest energy effect in being cluster heads is more effective we considered double its coefficients. Cluster scale: the number of inter-cluster nodes divided by the total number of network nodes. Moreover in the above relationship (centrality) is obtained as follows:

$$\text{centrality} = \frac{\sqrt{\frac{\sum \text{dis}^2}{100n}}}{100} \quad (5)$$

In which, $\sum_{i=1}^N d_i^2$ is the sum of squared distances of nodes to cluster heads. It is assumed that each node is aware of its position, and can calculate its distance from the base station. F2 associated per experimental cluster heads to obtain and then its total for 12 experimental cluster heads is summed. Using 2 coefficient for energy is due to that in discussion of election the rest energy of cluster heads than other parameters have more important and is more effective and for a reason we are considered double its coefficient. In F1 formula without use of value coefficient, F1 than F2 was too small and invalidity could not significant effect so, we used - more coefficients that could balance between F1 and F2 effect is created. As can be seen in this experiment, when the number of clusters change from 2 to 16 the slope of our validity index change dramatically. Now with local search around the intervals, the exact number of clusters can be achieved.

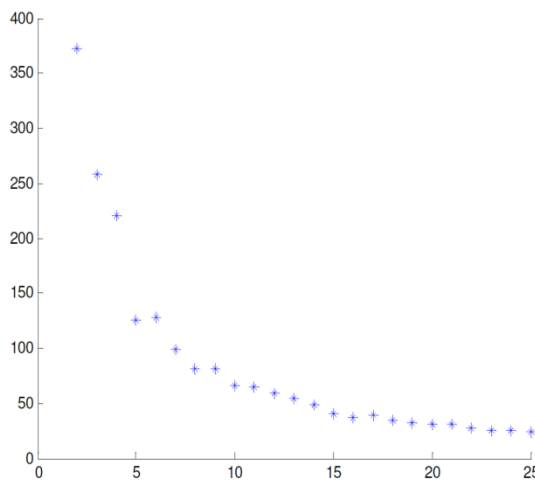


Fig 2: The proposed validity index when of the number of clusters change

3.3 Data transmission phase

After cluster formation and cluster heads election of each cluster; data can be transmitted by the normal nodes to corresponding cluster heads. In this phase, each normal node is connected to the nearest cluster head. Cluster heads are assigned with the implementation of a TDMA schedule to each cluster member. Each node in the allocated interval sends its data to cluster head in the form of data message. The cluster heads aggregate and transmit data towards base station after receiving all messages from cluster member nodes. Then the energy consumption of all nodes is computed.

4. Result and Discussion:

To evaluate the proposed approach and analyze its impact on the energy of the entire network, we have performed in MATLAB tool multiple simulations with various random node placements. Table 1 shows simulation parameters used in this work. A packet size of $L = 2000$ bits is used, 50 sensor nodes are randomly deployed in a network dimensions of $100\text{m} \times 100\text{m}$ as shown in Fig.4.1. The base station is placed at $(x=50\text{ m}, y=-100\text{ m})$ and 0.05 is the

probability of a node to be a cluster head in the proposed approach. All nodes begin with a starting energy level of 0.5 J. This value is commonly used in the literature since it provides small enough energy to quickly see the effect of the suggested algorithm.

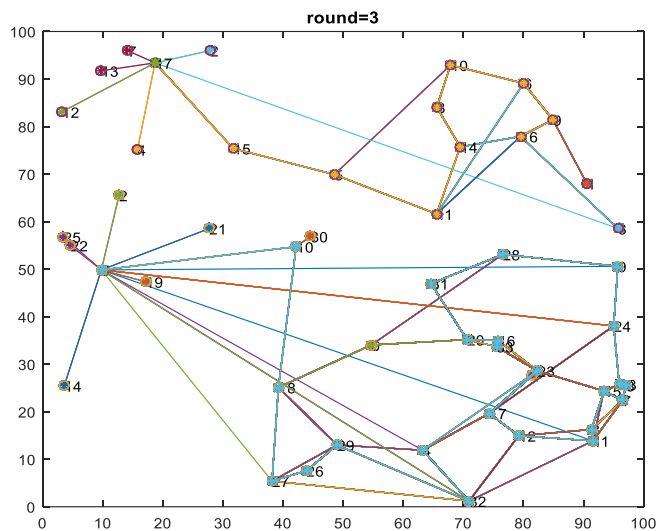


Figure 3: Node distribution and routing in WSN

Table 1. Simulation parameters

Parameters	Values
Transmission and receiving energy	50nJ/bit
Energy amplification for free space	10pJ/bit/m ²
Energy amplification for multi path	0.0013pJ/bit/m ²
Nodes initial energy	0.5J
Data aggregate energy	5nJ/bit/message
Packet size	2000 bits
Percentage of CH	5%
Number of nodes	50
Network size	100m x 100m
Base station position	50mx-100m

The comparison we carried-out in this work between the proposed approach and MTE protocols is based on some key performance metrics such as: First Node Dies (FND), Half of Nodes Alive (HNA) and Last Node Dies (LND) and Energy Depletion Rate (EDR). Table 2 summarizes the results of these metrics (FND, HND and LND) for LEACH, MTE and our proposed approach.

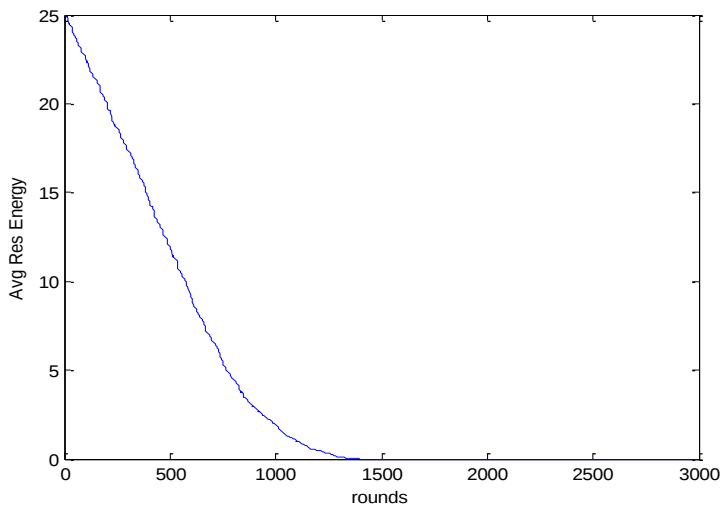


Fig 4: Average Residual energy and Number of rounds.

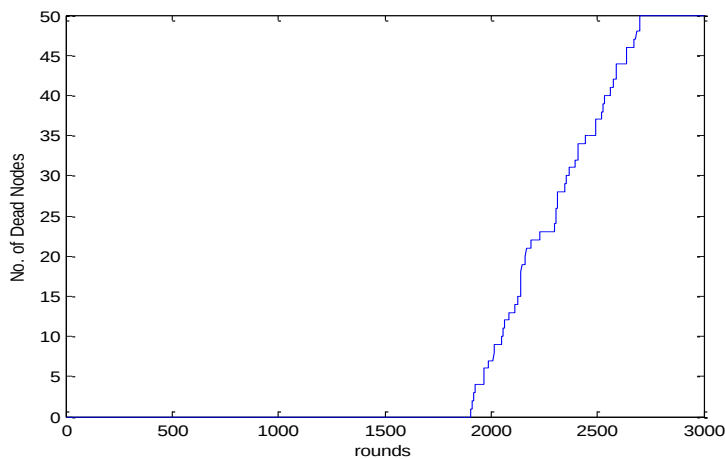


Fig 5: Number of dead node and Number of rounds.

Fig. 5 displays the number of dead nodes per round of base paper and the proposed approach. The stability period, which represents the time interval is extended with more rounds than the base paper approach. The first node of the proposed approach is dead after 1800 rounds approximately, besides that the first node of base paper is dead after 700 rounds approximately. However, all the sensor nodes are died after 2500 rounds approximately for base paper protocol, where at the same round; almost 20% of nodes are still alive in the proposed approach. Consequently, the performed sensor network using the combined multi-hop and cluster routing approach remains alive during more rounds.

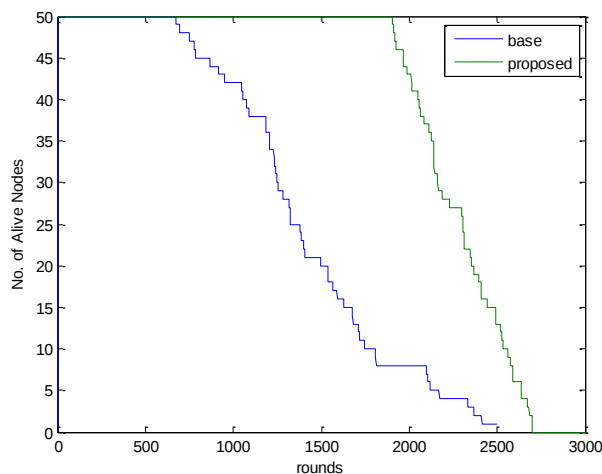


Fig. 6: Number of alive node and Number of rounds.

We evaluated the technical capability of the proposed approach vis-à-vis the metric performances. Fig. 6 displays the number of alive nodes per round of base paper and the proposed approach. The stability period, which represents the time interval between the start of the network and the death of the first sensor node, is extended with more rounds than the base paper approach.

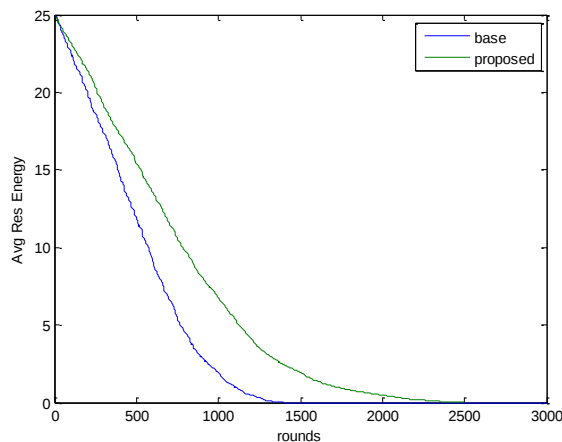


Figure 7: Average residual energy and Number of rounds.

Fig. 7 displays the comparison of total system average residual energy in each round for the three approaches. The network lifespan in multi-hop cluster based routing approach is extended and lasts more than base paper protocols. The performed approach optimizes the data routing by employing PSO algorithm in each cluster. The distance between nodes is considered and free space propagation is mostly adopted, hence the minimization of inter-nodes distance result as the link cost parameter instead for multi-path propagation. This propagation model transformation effectively increases the energy efficiency of the network.

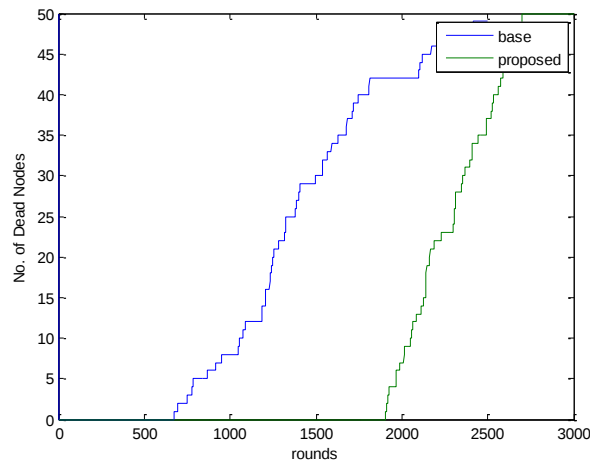


Fig 8: Number of dead node and Number of rounds as compared to base paper.

Table 2. Nodes die-off statistics of the proposed approach, LEACH and MTE protocols

Protocol	Metric			
	FND	HND	LND	EDR
Base Paper	25	225	624	0.148
LEACH	1019	1381	1818	0.035
Proposed Approach	975	1485	2539	0.031

5. Conclusion:

In this work, we introduce a new approach for sensor network clustering using Particle Swarm Optimization (PSO) algorithm. The parameters which are used in the algorithm are residual energy, density, distance from the base station, intra-cluster distance and cluster heads distance from each other. Our goal was to propose a new cost function to select the best cluster heads that combine the various criteria affecting the energy efficiency of cluster heads and cluster heads rotation among the nodes. Also, using the proposed algorithm the network coverage is evaluated and compared with some previous methods which have proved better performance and improved network lifetime and energy consumption.

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