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Network Life Time Analysis of WSNs Using Particle Swarm Optimization

Amita Yadav[1], Suresh Kumar[2, 3] Singh Vijendra

[1]MSIT Janakpuri, New Delhi-58, India
[2]MRIU, Faridabad, India,
[3]The NorthCap University, Gurugram

Abstract

Today, Wireless Sensor Networks (WSN's) are used at various places in the form of alarm detectors and sensors. Numbers of clustering algorithms have been developed to improve the energy balance of the WSN's because energy is the main aspect of WSN's during data transmission. These algorithms are mainly used for increasing the lifetime of these sensor networks. One such basic algorithm is LEACH. Energy efficient algorithms and load balancing are used during the clustering algorithms. This paper suggests an algorithm based on Particle Swarm Optimization (PSO) technique for improving network life time. It helps in forming the clusters as well as the Cluster Head (CH) selection. The proposed algorithm is extensively experimented and then the results of this algorithm are compared with the previously proposed algorithms such as LEACH, etc. It is concluded that the PSO based clustering algorithm gives better results.

Keywords: WSNs, CH, PSO

1. Introduction

Wireless Sensor Networks (WSns) refer to a group of dispersed sensors [1] that are placed in a large area and mainly help in monitoring, detecting and recording the physical or the environmental conditions of that particular place. These physical conditions mainly include temperature, sound, wind, etc. It is described as collection of nodes that are placed randomly in sensor field. These nodes are connected to each other through a wireless channel such that the data transmission can take place between them. Energy efficient algorithms are required as the sensor nodes are battery operated. This is mainly required because of several reasons which are no human intervention, in

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accessible remote areas, no recharging facility, etc. Data transmission is not possible over the network, whenever node is energy deficient. Clustering is one such technique which is used to enhance the lifetime of these nodes. Hierarchical routing protocol divides the network in to clusters with one cluster head and member nodes[2]. The CH nodes collect the data from remaining nodes in the cluster and then send the data to a Base Station (BS). But this is possible only till the network is alive. Network life time is directly related to the battery. Therefore, major concern in WSN is to save node energy. Energy is required in formation of clusters as well as in selection of CHs. CHs depletes their energy in receiving the data from sensor nodes, in data aggregation and in transmission of data to the sink. Therefore, CHs must be energy efficient nodes because of the transmission and reception responsibility. If CH nodes die quickly the respective cluster disconnected from the network and important events may be missed out. In this research, we have focused on achieving energy efficiency through optimal selection of cluster head.

PSO is a meta-heuristic search algorithm [3] that plays an important role in increasing the life span of the wireless sensor networks. This algorithm obtains faster and cheaper results compared with other methods. Particle swarm optimization (PSO) is influenced by behavior of birds or fish in a group. They always travel in group in search of food without colliding and hence reduce their own individual effort while searching for food, water and shelter. Various studies and algorithms have been developed using the PSO algorithm in WSNs. This paper provides a thorough explanation of different previously proposed algorithms and their features at different platforms. PSO has played a major role in increasing the efficiency of the wireless sensor networks. The structure of paper is given as. Section 2 describes literature review. Proposed work is summarized in section 3. Section 4 describes the researched methodology and the implementation details of the proposed algorithm.

2. Literature Review

This section describes the literature review in the direction of cluster head selection in WSNs. In [4], the two main problems of the WSNs which decrease the data transmission rates of the nodes have been addressed which are routing and clustering. Two separate fitness functions have been defined which are based on PSO. In the routing algorithm, the tradeoff is considered between the transmission distance is measured and in the clustering algorithm, balancing of energy consumption among the nodes is taken into account. [5] Modifies the PSO algorithm with a fitness function which is mainly residual energy upon the average distance between the nodes and Base Station (BS) and helps in improving the clustering of the nodes in the WSNs. Then this algorithm is compared with popular algorithms like LEACH and LEACH-C.

Fuzzy Clustering is done in [6]. Initially the fuzzy clustering is done during the formation of clusters of the node and after that the fitness function is generated using the PSO algorithm. In fuzzy clustering, all the nodes present in a cluster are considered as one which means data can be sent to any node in a cluster. This is done on the basis of the energy consumption and the distance factors of wireless sensor networks. Harmony Search Algorithm [7] (HSA) is similar to the PSO algorithm and it minimizes or maximizes the optimal solution similar to PSO. A hybrid of HSA and PSO [8] is used to enhance the efficiency of the wireless sensor networks and to provide efficient data transmission.

A two-tier structure [9] is made and is used for cluster head selection and the router problem. It is a two-step process. The first one helps in selecting the Cluster Heads (CH) and the second one helps in the formation of the routing tree that helps the nodes in a cluster to communicate with the Base Station (BS). Distance-Energy Cluster Structure Algorithm (DESCA) [10] is based on the famous clustering algorithm LEACH. It considers distance and residual energy of the nodes. It also improves the Cluster Head (CH) selection as well as the data transmission over the network.

Bird Flocking Behavior Clustering (BFBC) [11] is an energy efficient clustering algorithm. This algorithm based on the collective behavior of bird flocks. In WSNs, bird flocks are considered as nodes of clusters. This algorithm uses Received Signal Strength Indicator (RSSI). This algorithm provides better results in terms energy consumption and residual energy. Genetic Algorithm (GA) [12] based algorithms have also been used in this field. This projected algorithm balances the lifetime of the CH and reduces the general energy consumption of the sensing element nodes. The algorithm rule has been represented with proper chromosome representation and therefore the fitness operate comes by necessary GA primarily based operations.

Enhanced OEERP has been proposed in [13] and this algorithm is based on PSO and GSA for cluster formation and routing algorithms. In this algorithm, an assistant Cluster Head is selected to reduce the load of overloaded CH. Enhanced OEERP algorithm is then compared with all the other algorithms like LEACH, OEERP, etc. [14] proposes EPSO-CEO which is Enhanced PSO based Cluster Energy Optimization in which clustering and CH selection is done by minimizing the total energy and the power consumption of the sensor nodes in WSNs. The performance of WSNs has been improved through this algorithm in terms of throughput, residual energy, number of active nodes, etc.

Bacterial Forging Optimization (RBFO) and Hybrid BFO-BSO [15] are two algorithms based on Cluster Head Selection for the WSNs. These algorithms are used for the measurement of the number of clusters formed, packet ratio, lifetime of the node sensors, etc. These algorithms are compared with KBFO and LEACH graphically and experimentally. Hybrid technique is used to reduce the computational costs. [16] demonstrates the programming formulation of the energy efficiency problem and then provides an efficient algorithm with the PSO approach. Average distance of the cluster is taken into consideration to maximize the lifetime of CHs. The nodes die during the data transmission and hence, the nodes are placed near their Cluster Heads.

Multi Objective PSO (MOPSO)- Differential Evolution (DE) [17] (MOPSO) is an optimizing clustering technique. CH selection is done through a set of fitness functions in an analytical manner. Various constraints of energy are also taken such as Energy Constraint (EC) as well as the remaining energy. DE performs better protocol optimization than any other algorithm along with the convergence speed. PSO based Energy Efficient Clustering Algorithm (PEECA) [18] is used for energy efficiency and its main focus is on CH selection.CH selection is based on remaining energy of the nodes and their average energy. This algorithm is then compared with LEAH and DEEC equations

3. Proposed Work

3.1. Sensor Field

The sensor nodes are placed in 100 × 100 m area in random order as given in Fig.1. All the placed nodes will perform both transmission and gathering of data (messages and affirmations) and so on. Every sensor node will send the information to CH or a cluster member and further, CHs process the information and send the processed information to the base station (BS). The base station decides the CH for every round based on the clustering algorithm. The CH is accountable for data aggregation and communication.

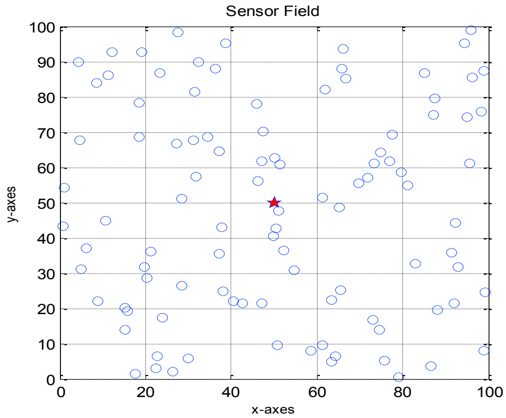

Fig. 1: Sensor field used for experiment

3.2. Objective Function

In WSNs, success of the CHs selection algorithm depends on the fitness function designed to choose the nodes as CHs. In this work, a new fitness function is designed for CHs selection. This function comprises the two-important aspect of WSNs i.e. first, the energy consumption between CH and sensor nodes; second, the amount of energy consumption for aggregating the data at CHs level plus transmitting the information to BS. The energy consumption between sensor nodes and CHs is computed using equations 1-3.

$$E_1(j) = \sum_{k=1}^{K} \sum_{\forall n_{k_j} \in C_k} \left\{ \frac{E_{k_j} - f(k_j, C_k)}{E_{max} - E_{min}} \right\} \times k_j \qquad where\ j = 1,2, \dots\dots .n \tag{1}$$

$$f(k_j, C_k) = \begin{cases} s^2(k_j, C_k) & if\ s\,(k_j, C_k) \le d_0 \\ s^4(k_j, C_k) & if\ s\,(k_j, C_k) > d_0 \end{cases} \tag{2}$$

$$s(C_k, k_j) = min(k_j, C_k) \qquad \forall\ k = 1, 2, 3, \dots., K \tag{3}$$

The energy consumption between CHs and BS is computed using equations 4 and 5.

$$E_2(j) = \sum_{k=1}^{K} \left\{ \frac{E_{C_k} - g(C_k, BS)}{E_{max} - E_{min}} \right\} \times C_k \tag{4}$$

$$g(C_k, BS) = \begin{cases} d^2{}_{(C_k, BS)} & if\ d^2{}_{(C_k, BS)} \le d_0 \\ d^4{}_{(C_k, BS)} & if\ d^2{}_{(C_k, BS)} > d_0 \end{cases} \tag{5}$$

The total energy consumed to transmit the M bit data from sensor nodes to BS is measured using equation 6.

$$F(j) = E_1(j) + \ \mu\, E_2(j) \tag{6}$$

3.3. Proposed PSO Algorithm

Particle swarm optimization (PSO) is influenced by behaviour of birds or fish in a group. In this algorithm, particles update their position relative to the position and velocity of the group. The notation for representing the i^{th} particle (P_i)of the population n D- dimensional can be given as.

$$P_i = [X_{i,1}, X_{i,2}, X_{i,3} \ldots., X_{i,D}] \tag{7}$$

Each particle's position is evaluated using a fitness function which judges the quality of the solution provided by it in that iteration. To reach the global best position, a particle tracks its personal best position (Pbest*)*and the globally best position (Gbest). The velocity and position of each particle i.e. V_{id} and X_{id}can be updated as follows.

$$V_{new,i} = w * V_i + c_1 * r_1 * (Xpbest_i - X_i) + c_2 * r_2 * (X_{gbest} - X_i) \tag{8}$$

Where w =inertia weight, c1 and c2 represent the acceleration factor (non-negative constants), r1 and r2denotes the random numbers in the range of [0, 1]. The inertia weight can be defined using equation 9.

$$w = w_{initial} - \frac{Max.Iteration - Current\ Iteration}{Total\ Number\ of\ Iterations} \tag{9}$$

$$\mathrm{X_{new,i} = X_{old,i} + V_{new,i}} \tag{10}$$

In this work, an adaptive PSO algorithm is employed to generate optimal number of cluster heads. In the proposed PSO algorithm, the value of inertia weight is computed using equation 9 and it is a time varying equation which generates different values for each iteration. Further, a sensor node can be deployed as a cluster head if it is in its communication range. The fundamental knowledge model remains like classical algorithms such as leach. All through each new iteration every node sends information to the cluster head in which the facts are aggregated, the redundant statistics is discarded and the remaining is passed on to the next hop, which can be either another head or the base station.

Steps of the proposed PSO Algorithm

1. Set w, c1, c2 and c3 parameters
2. Initialize particles $\mathrm{P_i}$, $\mathrm{i, j, 1 \leq i \leq NP, 1 \leq j \leq D = m}$,number of CHs.
3. Compute the fitness (P_i) of each particle using equation 6 and find the personal best position of particle and set it to $pbest_i$
4. Compute the global best position of particle using the following equation.

$$\mathrm{Gbest = \{Pbest_k | Fitness(Pbest_k) = min(Fitness(Pbest_i|), i, 1 \leq i \leq NP)\}}$$

5. Update velocity and position of $P_i$using equations (8) and (10) and CalculateFitness (P_i)
6. If$\mathrm{Fitness(P_i) < Fitness(Pbest_i)}$then $\mathrm{Pbest_i = P_i}$
7. If$\mathrm{Fitness(P_i) < Fitness(Gbest)}$thenGbest=$\mathrm{P_i}$
8. Repeat the steps 3-7 until the stopping criteria are not met.

4. Experimental Results

This section describes the various parameters and experimental set up of the proposed protocol. This section also demonstrates the results of the proposed protocol. A 100 x 100-dimension field is taken for conducting the experiment. All sensor nodes are uniformly dispersed in above mentioned sensor field and it is supposed that the BS is located inside the sensor field. The proposed protocol is implemented in MATLAB 2010a environment using window seven based PC with 2.93 GHz, Intel Core i7 processor and 4 GB RAM. The parameter settings of the wireless sensor network are as described in Table 1. To validate the proposed algorithm, network life time and packets sent to BS are chosen as performance parameters. The network lifetime parameter is defined in terms of number of live and dead nodes. The result of the proposed algorithm is compared with LEACH algorithm. The results are taken on the average of 30 independent runs and in each run, have 4000 rounds. Table 2 shows the statistics of the network life time parameter. From this table, it is concluded that in LEACH algorithm, first node become dead after 1100 rounds as all its energy consumed during the data collection and transmission, half of sensor nodes die up to 1265 rounds and after 1570 rounds, no live node is present in the sensor field. In LEACH-PSO algorithm, first node become dead after 1150 rounds as all its energy consumed during the data collection and transmission, half of sensor nodes die up to 1340 rounds and after 3880 rounds, no live node is present in the sensor field.Hence, it is observed that incorporation of the PSO algorithm in Leach increases the life time of the network and reduced the power consumption of nodes.

Table 1: Parameters setting of proposed LEACH-PSO algorithm

Parameter	Value	Parameter	Value
Network field	100m x 100m	E_{DA}	5 nJ/ bit/ Message
Number of nodes	100	E_{mp}	0.00013pJ/bit
Initail energy of Nodes E_0	0.5J	Message Size	4000 bits
E_{TX}	50 nJ/ bit	P_o	0.1
E_{RX}	50 nJ/ bit	Maximum No. of Iteration	4000
E_{fs}	10pJ/bit	c_1	2
$W_{initial}$	0.4	c_2	2

Table 2: Life time of network in terms of dead nodes for LEACH and LEACH-PSO algorithm

Algorithm	First Node Die	Half of Node Die	Last Node Die
LEACH	1100	1265	1570
LEACH-PSO	1150	1340	3880

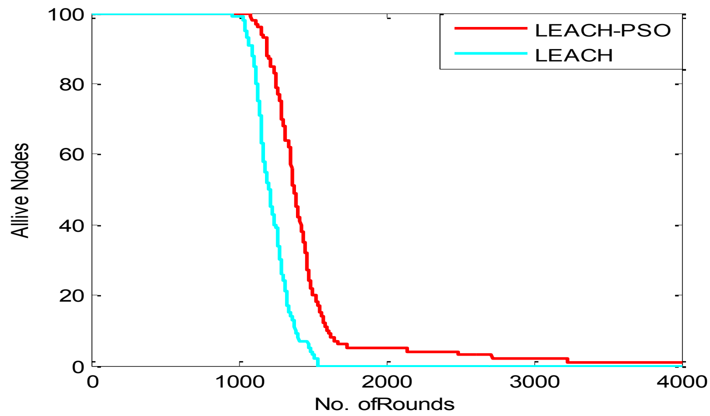

Fig. 2: shows the comparison of live nodes in each round

Fig. 2 and 3 shows the comparison of live and dead nodes in each round for LEACH, and LEACH-PSO algorithms. From these, it is clearly shown the significant difference between the functioning of the LEACHand LEACH-PSO algorithms. In LEACH and LEACH-PSO algorithms, all nodes die after 1570 and 3880 rounds, but it is observed that significant difference occurs between the nodes death rate.

Table 3 shows the statistics of packets sent to the CHs to the BS of LEACH and LEACH-PSO algorithms after 500, 1500, 2500, 3500 and 4000 rounds. It is observed that number of packets sent through LEACH algorithm is 13000, LEACH-PSO protocol is 20000, packets. It seems that there gradually increment in packets sent parameter after integration of PSO algorithm in LEACH protocol. Fig. 4 shows the comparison of packets sent to BS using LEACH and LEACH-PSO protocols for each round and it's indicate that the performance of the LEACH protocol is gradually enhanced.

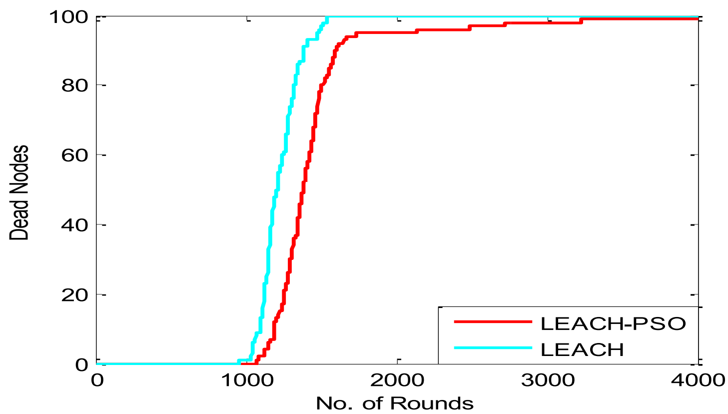

Fig. 3: shows the comparison of dead nodes in each round

Table 3: Packets sent to Base Station (In LEACH-PSO 10 nodes remaining after 4000 rounds)

Algorithm	500	1500	2500	3500	4000
LEACH	5000	11000	13000	13000	13000
LEACH-PSO	7000	13500	17600	18600	20000

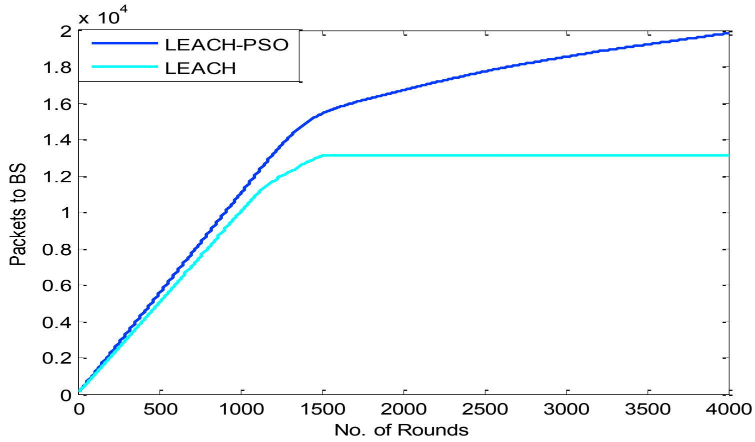

Fig. 4: shows the comparison of packets sent to CHs to BS in each round

Table 4 shows the statistics of packets sent from each node to CHs of LEACH and LEACH-PSO algorithms after 1000, 2000, 3000 and 4000 rounds. It is observed that number of packets sent through LEACH algorithm is 110000, LEACH-PSO protocol is 130000packets. It seems that there gradually increment in packets sent parameter after integration of PSO algorithm in LEACH protocol. Fig. 5 shows the comparison of packets sent to CHs for LEACH and LEACH-PSO protocols for each round and it's indicate that the performance of the LEACH protocols is effectively improved.

Finally, it can be stated that the energy consumption of nodes of proposed LEACH-PSO protocol is less than LEACH protocol and it is directly related to extending network lifetime. The number of packets sent to BS and CHs are also gradually increases which also confirm the impact of proposed CHs selection algorithm.Figs. 6-7 present the number of cluster heads generated in each round of LEACH-PSO and LEACH protocols. It is seen that the number of CHs generated in LEACH-PSO algorithm is less than LEACH algorithm. These CHs are more stable in comparison to LEACH algorithm which directly tends to more energy efficiency.

Table 4: Packets sent to Base Station (In LEACH-PSO 10 nodes remaining after 4000 rounds)

Algorithm	1000	2000	3000	4000
LEACH	48000	105000	110000	110000
LEACH-PSO	56000	122500	130000	130000

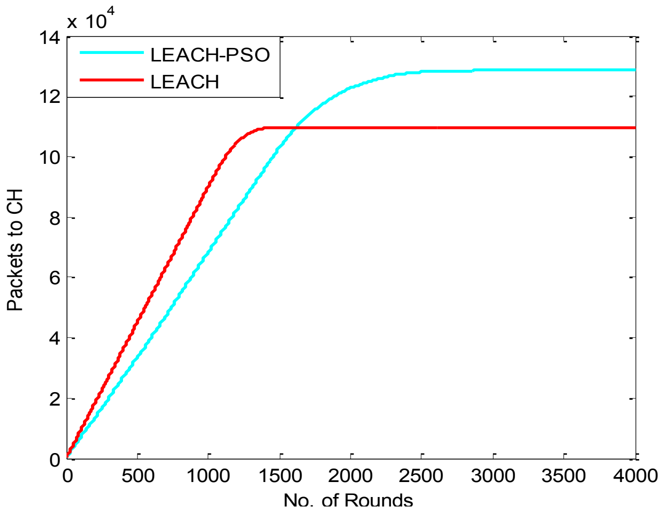

Fig. 5: shows the comparison of packets sent to CHs from nodes

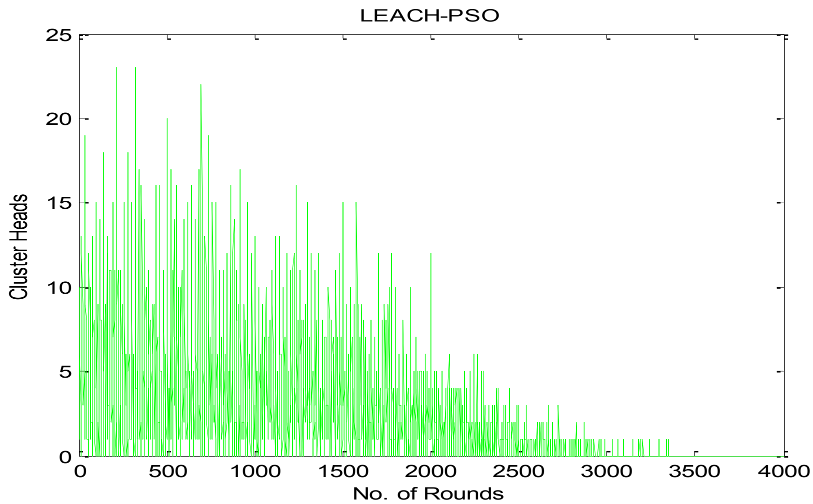

Fig. 6: shows the number of CHs generated during the execution of LEACH-PSO algorithm

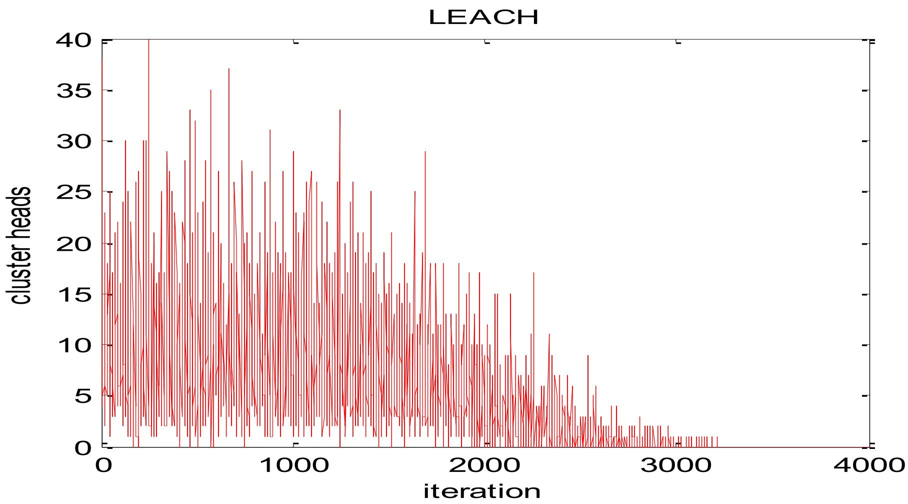

Fig. 7: shows the number of CHs generated during the execution of LEACH algorithm

5. Conclusion

In this paper, an efficient and effective cluster head selection algorithm is proposed to strengthen the LEACH protocol. The proposed CHs selection algorithm is based on particle swarm optimization method. The PSO algorithm is integrated into the LEACH algorithm for enhancing its performance and to find optimum CHs.The cluster head selection is based on the objective function, which comprises the energy dissipation at cluster head. Which includes the energy consumption between sensor nodes and cluster head, data aggregation cost at cluster head and energy consumption between cluster head and base station. The PSO algorithm is used for optimum CH with fitness function and new inertia. The results show that proposed LEACH-PSO algorithm is more effective and efficient algorithm. The incorporation of the PSO algorithm in LEACH improves the performance of the LEACH algorithm considerably. It is also observed that performance of the algorithm enhances in terms of live nodes during each iteration and packet sent to BS.

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