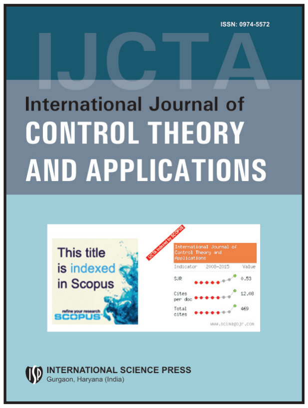

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Grid Deployment with Clustering in Wireless Sensor Networks

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Abstract: Wireless Sensor Networks (WSN) has not only become an important technology in current scenario but also established as a core for many applications such as Internet of things (IoT). The disadvantage of limited and non-rechargeable energy resource in WSN creates a challenge for designing an energy efficient routing algorithm has become the research focus. Node deployment is regarded as a potential solution towards this problem as it significantly reduces energy consumption of the sensor nodes and thus enhances network lifetime. The paper proposes an approach for improving network lifetime by using grid based node deployment and PSO based clustering. So in this paper, a grid based node deployment is used and next, global optimal cluster head (collect data from all member nodes) and are selected using Particle swarm optimization based clustering is designed. Finally, the proposed algorithm is presented.

Keyword: Particle swarm optimisation, clustering, routing algorithm, network lifetime, grid deployment, Wireless Sensor Networks.

1. INTRODUCTION

A wireless sensor network (WSN) [1] consists of hundreds of low cost, low-power portable sensor nodes deployed in close proximity to a physical phenomenon which can be use in a numerous applications such as national security, environment monitoring, military reconnaissance, traffic control. Nevertheless, any real time application that requires data gathering from a geographically localized region. Each node in a WSN must send data to a special node called Base Station (BS), which is placed far away from the sensor network. These sensors in a network have limited, non-rechargeable energy resource; thus energy efficiency is a very important criteria for designing the network topology and routing path. A WSN is measured by various performance parameters including network scalability, network lifetime, routing overhead, energy consumption [1]. The clustering has been proven an effective means to increasing scalability and the lifetime of WSNs [1]. In clustering scheme, the complete network of sensors divided into graphically confined regions called clusters. Each cluster contains a cluster head, which is either pre-defined special purpose node or selected from one of the sensor nodes of a cluster using appropriate algorithm. This cluster head is used to receive data from the rest of the nodes of belonging cluster in a TDMA fashion [1] (or any of the other multiple channel access protocols). After removing the redundancy by aggregate the data, the cluster head further send these data to BS. However, sending the data to BS from one sensor node may not always be possible due to the fact that BS may be beyond the transmission range of that sensor node. The multi-hop techniques can be a solution to overcome this problem by sending the data to BS via a series of intermediate sensor nodes. Additionally, an efficient multi-hop routing algorithm can also increase the network lifetime.

The distance from the BS is a crucial factor for energy consumption among cluster heads and is imbalanced due to the distance mismatch. The cluster heads farther away from the BS need to transmit data to a longer distance in single-hop networks. However in multi-hop networks, cluster heads closer to BS are used as data forwarding nodes and thus transmit more times than it would in a single-hop network. This creates energy depleted nodes in close proximity, usually termed as the Energy Hole Problem.

2. RELATED WORK

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The energy related issues in WSNs have led to designing many new routing protocols, specifically clustering or routing protocols to support longer network life. The energy efficiency of routing protocols in WSN still remains an open challenge for research community [1]. There are several clustering and routing protocols were proposed in literature for sensor networks [2–4], for generating stable clusters and energy efficient routing path as main objective.

This is worth to noting that energy efficient clustering and routing can be formulated as optimization problems. The Particle Swarm optimization (PSO) is among one of the nature inspired approach to improve network lifetime .The algorithm propose to construct the path and distribute the routing data through the Cluster Heads or gateway node close to the Base Station uses PSO in the present paper, which maximizes the network timeline.

Zahmatkesh et. al., [5] proposed multi-objective algorithm that generate an optimal number of clusters with cluster heads and minimization of transmission cost. There are two objectives, first deals with the optimal cluster heads and second considered the distance for data transmission. Latiff et. al., [6] proposed energy aware cluster head protocol using PSO algorithm. For selection of cluster heads, the energy of the node as well as minimization of intra-cluster distance is taken into account. Main contribution is clustering based on remaining energy and positioning of cluster heads throughout the network. Rao et. al., [7] presented a Gravitational search based algorithm with an efficient encoding scheme and a new fitness function. Euclidian distance is used between sensor node to gateway node and gateway node to sink node. Also residual energy of the gateway node is considered. A distributed energy efficient and fault tolerant routing algorithm is proposed [8]. In this paper the main focus is the section of next hop cluster head in an efficient manner as well as to ensure the connectivity in case of failure. Genetic algorithm based clustering and routing algorithm is proposed [9]. The clustering algorithms consider the residual energy of the gateway node and distance from sensor node to their corresponding cluster heads. The routing scheme is based on the residual energy of gateway node along with tradeoff between transmission distance and number of forwards.

The [10-13] published literature; have proposed few protocols based on application for WSNs such as, cloud based body sensor network ambient intelligence with other network problems. Wireless Network called as a novel chemical reaction optimization (nCRO). It prolongs the network lifetime significantly. Moreover, the CHs interact directly to the BS, which may or may not be feasible for large scale network. An algorithm based on nCRO approach [14] for addressing the scalability problem in reference [14], has been proposed, which solves the hot spot problem in wireless sensor networks to some extent but ignores the fault tolerance and issues related to delaying in WSN. A algorithm based on PSO for time sensitive applications, has been proposed [15], which has accounted for efficiency related to energy and elongates the network lifetime. A genetic algorithm based routing is proposed in [16], which compute new routing schedule based on current network condition.

A. Particle Swarm Optimization (PSO)

PSO is inspired by nature. It is based on swarm intelligence, modeled after noticing the activity of a flock of birds, i.e., their ability to exploit and explore the search space for their living. Particle Swarm Optimization is a very simple algorithm. Over various iterations, the variables adjust themselves closest to the member whose value is close to the solution. It's an algorithm that's simple and easy to implement.

The algorithm based on PSO consists of a pre-defined particle number say N_P, known as a swarm. Every particle gives a potential solution. A particle Pi, $1 \le i \le N_p$ has position $X_{i,d}$ and velocity $V_{i,d}$, $1 \le d \le D$ in the d_{th} dimension of the search space. The dimension D is same for all particles. A fitness function is used to evaluate each particle for verifying the quality of the solution. Each particle keeps an eye on its dimensions in the problem space which are associated with solution that is its best fitness value which it has gained so far. This value is called best. Another "best" value that is traced by the PSO is the best value, obtained so far by any particle in the neighbors of the particle. This location is called Lbest when a particle takes all the nodes as its topological neighbors, the best value is a global best and is called gbest.

To reach the global best solution, gbest, it uses its personal and global best to update the velocity $V_{i,d}$ and position $X_{i,d}$ using the following equations.

$$X_{i,d}(t+1) = X_{i,d}(t) + V_{i,d}(t+1) \tag{1}$$

$$V_{i,d}(t+1) = \omega \times V_{i,d}(t) + C_1 \times \chi_1 \times (C_{Pbest(i)} - X_{i,d}) + C_2 \times \chi_2 \times (C_{Gbest(i,d)} - X_{i,d}) \tag{2}$$

where C_1,C_2, $0 \le C_1, C_2 \le 2$, are the acceleration coefficients, ω, $0 < \omega < 1$ is the weight, and χ_1, χ_2, $0 < \chi_1, \chi_2 < 2$ are the values that are generated randomly. The updating process is repeated til it has reached to a value that is satisfactory. After having the new positions, the particle calculates the fitness function and changes $Pbest_i$ as well as Gbest for minimization problem as follows:

$$Pbest_i = \begin{cases} P_i, \text{if}(\text{Fitness}(P_i) < \text{Fitness}(Pbest_i)) \\ \text{otherwise} \end{cases} \tag{3}$$

$$Gbest = \begin{cases} P_i, \text{if}(\text{Fitness}(P_i) < \text{Fitness}(Gbest_i)) \\ \text{Gbest, otherwise} \end{cases} \tag{4}$$

B. Terminologies Used

1. S: set of sensor nodes deployed, $S = \{s_1, s_2, ..., s_m\}$
2. C: set of the CHs, $C = \{CH_1, CH_2, ..., CH_m\}$. where $m < n$
3. l_j: the number of sensor nodes in jth cluster.
4. R_{max}: maximum communication range of CHs.
5. T_H: maximum threshold value for being CH.
6. d_0: threshold distance.
7. E_{CHj}: energy currently possessed by the CH_j, $1 \le j \le m$
8. dis(s_i, s_j): intra nodes distance.

For the distance parameter, let f_1, be the function of average distance between the clusters and the BS distance of CHs. For optimal CH selection, this must be minimized. For the energy parameter, let f_2 be a function, reciprocal of the total present energy of all elected CHs. For getting efficiency, the energy must be higher, which means the function f_2 must be minimized. Finally, these two parameter are normalized between the number ranging from 0 to 1, in such a manner that we minimize the linear combination of f_1 and f_2. These functions are used later to derive the fitness function of the proposed PSO algorithm. The most important goal is to minimize both these functions. The best way to minimize these functions is by the use of linear combination of f_1 and f_2. The linear combination can be given as follows:

Minimize $$F = \alpha \times f_1 + (1 - \alpha) \times f_2 \tag{5}$$

With constraints as:

$$\text{dis}(s_i, \text{CH}_j) \leq d_{max}, \forall s_i \in C \text{ and } \text{CH}_j \in C \tag{6}$$

$$\text{dis}(\text{CH}_j, \text{BS}) \leq R_{max}, \forall \text{CH}_j \in C \tag{7}$$

$$E_{CHj} > T_H, 1 \leq j \leq m \tag{8}$$

$$0 < \alpha < 1 \tag{9}$$

$$0 < f_1, f_2 < 1 \tag{10}$$

C. Fitness Function

For deriving the fitness function to be used in CH selection, the following parameters are necessary:

1. *Average Intra-Cluster Distance:* It can be defined as the sum of distances of all the sensor nodes from the CH they have been selected from, which is given by:

$$\frac{1}{l_j} \sum_{i=1}^{l_j} \text{dis}(s_i, \text{CH}_j) \tag{11}$$

   In this, all sensor nodes gobble some energy to send it to the CH of their cluster. So as to reduce the energy, this must be minimized.

2. *Average Sink Distance:* Ratio of the distance between a CH and the base station BS to the number of nodes, l_j i.e, $\frac{1}{l_j} \text{dis}(\text{CH}_j, \text{BS})$. In the routing phase, the CHs send their data to BS. This requires for the reduction of consumption of energy. To do so, distance from the CHs to BS must be minimized.

   One objective for optimal solution for CH selection is to minimize this intra-cluster distance and distance from the BS. Therefore:

   Objective 1:

$$\sum_{j=1}^{m} \frac{1}{l_j} \left(\sum_{i=1}^{l_j} \text{dis}(s_i, \text{CH}_j) + \text{dis}(\text{CH}_j, \text{BS}) \right) \tag{12}$$

3. *Energy Parameter:* The current energy of a CH_j is represented by E_{CHj}. The overall current energy therefore of all the CH_s will be $\sum_{j=1}^{m} E_{CHj}$. In the chosing of optimal CHs, it is sensible to pick up those nodes that have maximum total current energy. Therefore, we have to minimize the reciprocal of it. Thus our second objective can be given as:

Objective 2:

$$\text{Minimuze } f_2 = \frac{1}{\sum_{j=1}^{m} \text{E}_{\text{CH}j}} \tag{13}$$

In our approach, as mentioned earlier, it is judicious to minimize the linear combination of both the objective functions. The reason we are not minimizing them differently is because these functions are not strongly conflicting each other. Due to this, there exists a distinctive solution which is optimal. Thus the fitness function we use is:

$$\text{Fitness} = \alpha \times f_1 + (1 - \alpha) \times f_2,\ 0 < \alpha < 1 \tag{14}$$

Thus the main objective is to minimize this fitness function's value. Thus the CH selection is better for lower values of the fitness function.

D. Energy Model

The energy consumed by the nodes depends upon the distance between the nodes and the quantity of data to be sent. In this the energy consumed by any node varies in proportion to d_2, where d is the distance in which the propagation can be made, less than some threshold distance d_0, else its proportional to d_4. The energy consumption of a node transmitting l-bit data in the network is given by:

$$\text{E}_{\text{TX}}(ld) = \begin{cases} l \times \varepsilon_n \times d^2 + l \times \text{E}_{\text{elec}}, \text{if } d < d_0 \\ l \times \varepsilon_{mp} \times d^4 + l \times \text{E}_{\text{elec}}, \text{if } d \geq d_0 \end{cases} \tag{15}$$

where, E_{elec} is the energy released per bit to run the transmitter, is the free space amplification energy, is dependent on amplifier model and d_0 is the threshold value for distance.[1]

Similarly, energy consumed by the receiver of the nodes to receive l bits of information or data is given by:

$$\text{E}_{\text{RX}}(l) = l \times \text{E}_{\text{elec}} \tag{16}$$

3. PROPOSED ALGORITHM

So in this paper, First square grid based Deployment method is used. Next, global optimal cluster head (collect data from all member nodes) are selected using Particle swarm optimisation based clustering. Finally, the proposed algorithm is presented.

A. Particle Swarm Optimisation based Clustering

Algorithm for clustering

1. Initialize all node with constant value of energy
2. Randomly assign 10% of nodes as cluster heads.
3. Find the nearest cluster head for all the nodes

    3.1 For i : 1 to n (total number of nodes)

        3.1.1 Initialize minimum_distance with

            dis(distance of node i from sink)

        3.1.2 For j : 1 to m(total number of cluster heads)

            distance = dij(distance from node i to CH j) if(minimum_distance > distance)

minimum_distance = distance

cluster.id = *j*

end if

End For

4. Calculate the minimum average intra cluster distance and sink distance of all CHs (f_1) using equation (12)
5. Calculate the parameter to maximize the total energy of CHs using (13)
6. Calculate Fitness for each node

For *i* : 1 to *n*

Fitness(i) = $f_1 \times \alpha + f_2 \times (1 - \alpha)$

Pbest(i) = Fitness(i)

End For

7. Initialize velocity of each node with zero.
8. Assign the lowest value of pbest among all pbest to gbest.
9. For *r* : 1 to total number of rounds

9.1 Find the velocity and position of each node using PSO algorithm by equation (1) and (2)

9.2 Repeat step 3 for finding nearest cluster head for all the normal nodes.

9.3 Repeat step 4 and 5 for calculating f1 and f2.

9.4 Calculate Fitness and update pbest

For i : 1 to n

if(Fitness(i) <= Pbest(i))

Pbest(i) = Fitness(i)

end if

End For

9.5 Repeat step 8 to calculate gbest

9.6 Mark 10% nodes with minimum gbest values as the new CHs and all the other nodes as normal nodes

10 Sink moves in from the centre of the Square area to next grid area to collect data from cluster heads.

4. RESULTS AND DISCUSSION

This section presents the simulation results of the proposed algorithm. Different network scenarios were considered, number of nodes is 100 with 7 percent of cluster head are taken for each scenario. And the simulated area is 200×200 m^2 for all nodes taken into consideration. For each network scenario two metrics were used to compare the performance of proposed algorithm. Total energy and Average energy for all nodes and network lifetime is number of iterations that the networks have sustained until any nodes run out of energy. Following are the simulation parameters taken for Particle swarm optimisation based clustering.

Table 1

Simulation Parameters	*Values*
Deploying area	200 x 200 m^2
Sensor node's energy	2J
Number of sensor nodes	100
Location of BS	(100, 100)
Percentage of CHs	10 %
E_{elec}	50 nJ/bit
E_{fs}	10 pJ/bit/m^2
E_{mp}	0.0013 pJ/bit/m^4
d_0	Sqrt(E_{fs}/E_{mp})*m*
Packet length	4000 bits
Number of particles	30
Number of iterations	100
C_1	2
C_2	2
χ_1	.5
χ_2	.7
α	.3
w	.7
D	10-40
V_{max}	200
Communication radius	150 m

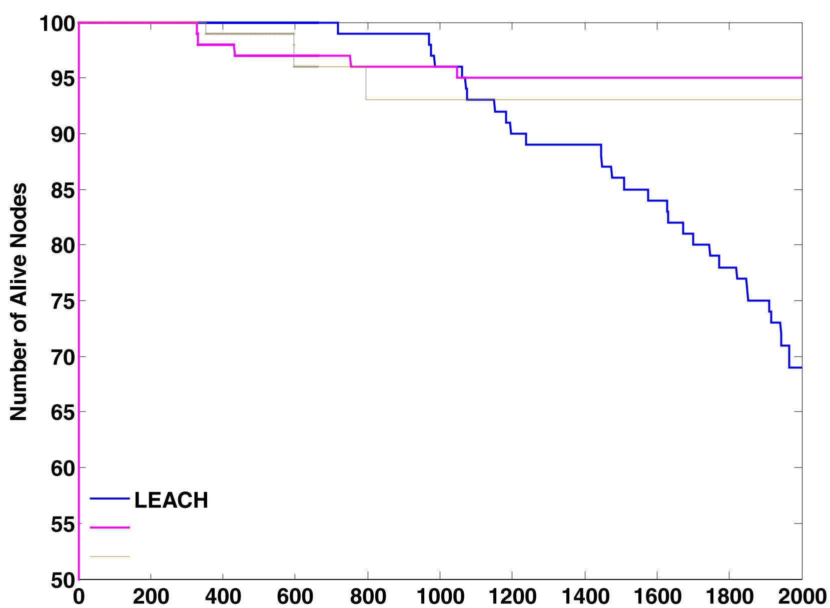

Figure 1: Alive node vs Rounds (Nodes = 100)

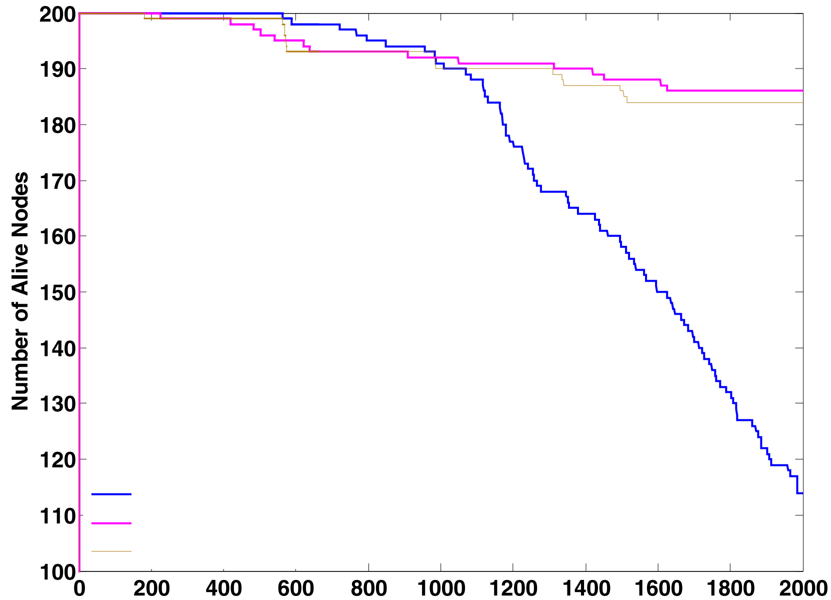

Figure 2: Alive node vs Rounds (Nodes = 200)

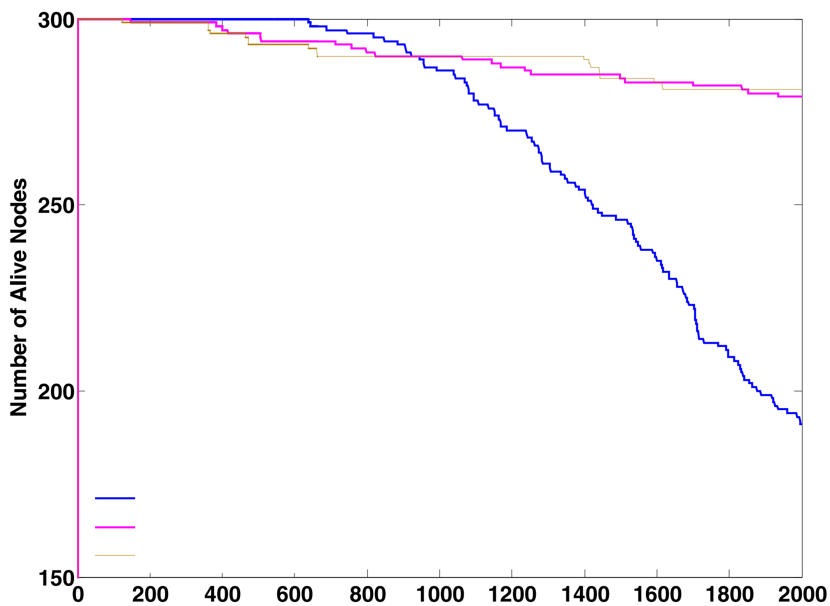

Figure 3: Alive node vs Rounds (Nodes = 300)

In Figure 1-4 number of alive nodes is much higher than the existing algorithms after certain rounds. After certain rounds, the CHs near to the BS can communicate directly to the BS. Thus, the energy consumption due to these mobile BS decreases due to transmission of large amount of traffic load and as a result energy consumption per packet is also decreased. Thus, the energy consumption due to these mobile BS decreases due to transmission of large amount of traffic load to nearby mobile BS and as a result energy consumption per packet is also decreased. This is because of the prevention of node failure from the complete energy depletion.

The results in Figure 5-8 represents the number of dead sensor or inactive sensors which have utilised all of their energies and no longer to be used in the network. Our proposed shows better results in terms of number dead node for varying number of nodes (100-400).

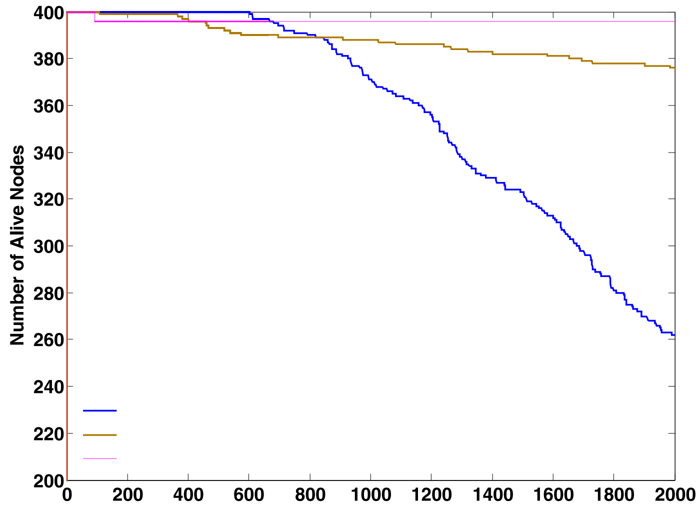

Figure 4: Alive node vs Rounds (Nodes = 400)

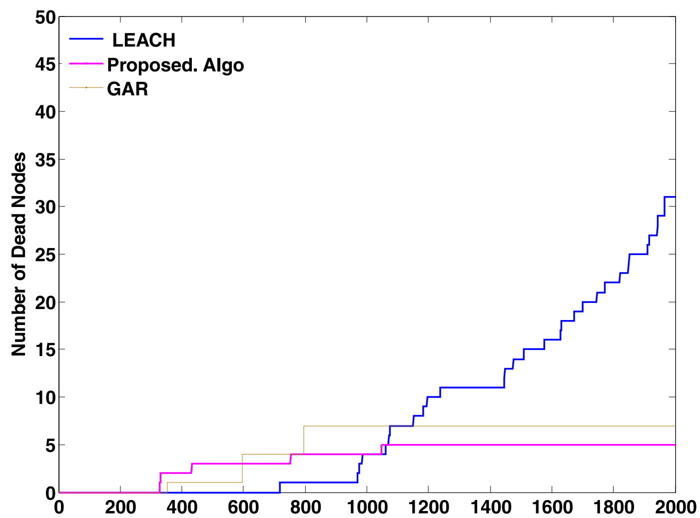

Figure 5: Dead node vs Rounds (Nodes = 100)

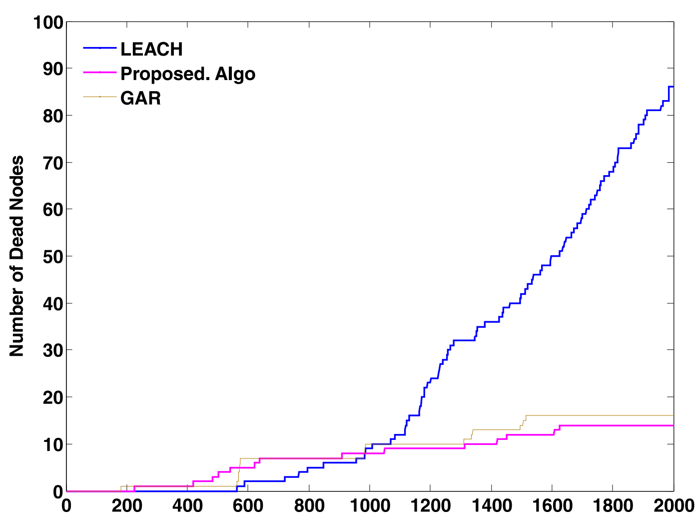

Figure 6: Dead node vs Rounds (Nodes = 200)

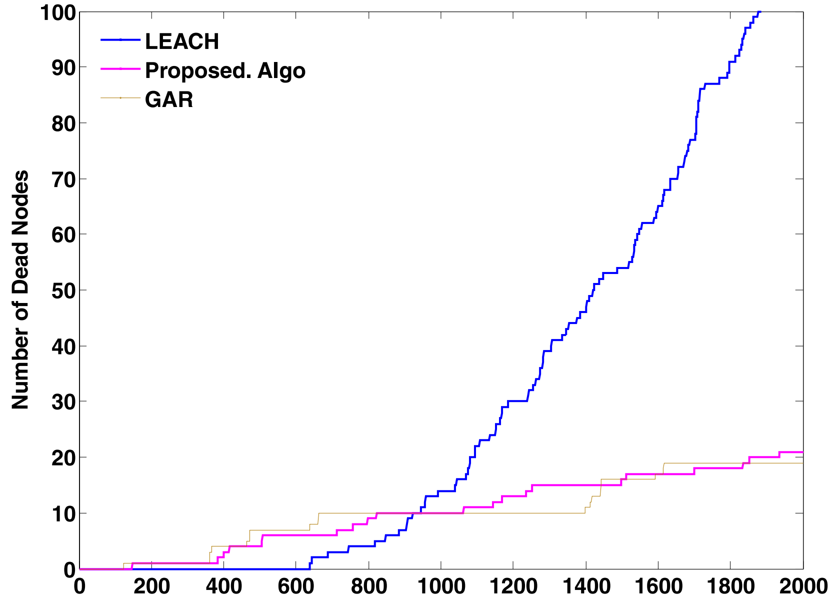

Figure 7: Dead node vs Rounds (Nodes = 300)

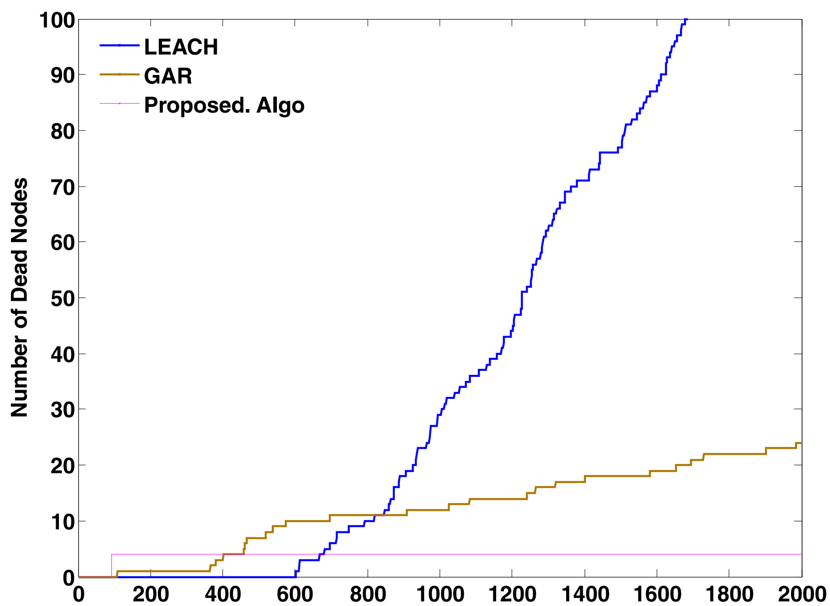

Figure 8: Dead node vs Rounds (Nodes = 400)

Since we carefully utilize residual energy of the CH to make them alive for the longer period of time, as a result the first node die in the proposed algorithm after long time. On the other hand, Figure 5-8 represents the number of inactive sensor nodes which is much lower than the existing algorithms. The reason is same, the number of inactive sensor nodes is lower due to alive of higher number of CHs and mobile BS for the long time.

5. CONCLUSION

In this paper, grid deployment, PSO based algorithm, where cluster head selection is optimized by using PSO based clustering and sink mobility is used for data collection. The proposed approach is efficient as it include more number of parameters in fitness function for selecting better cluster heads and also sink mobility reduces the distance between the cluster head and sink and eases the further communication between them. The simulation results show that Proposed algorithm performs better than other conventional protocol such as LEACH and GAR and can prolong the lifetime of the network.

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