Energy Efficient Clustering Algorithm for Software Defined Wireless Sensor Networks

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Declaration of Authorship

This is to certify that the work presented in this thes is the outcome of the analysis and experiments carried out by **Minhaz Uddin Ahmed** and **Md. Shaker Ibna Kamal** under the supervision of **Md. Sakhawat Hossen**, Assistant Professor of Department of Computer Science and Engineering (CSE), Islamic University of Technology (IUT), Dhaka, Bangladesh. It is also declared that neither of this thesis nor any part of this thesis has been submitted anywhere else for any degree or diploma. Information derived from the published and unpublished work of others has been acknowledged in the text and a list of references is given.

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Abstract

To maximize the network lifetime is a major issue for designing and deploying a wireless sensor network (WSN). Clustering is a fundamental and effective technique for utilizing sensor nodes' energy and extending the network lifetime for wireless sensor networks. In this paper, we present a new method to elongate the network lifetime based on the Adaptive Particle Swarm Optimization (APSO) algorithm, which is an optimized method designed to select the target nodes. Takes into account both energy efficiency and transmission distance, and relay nodes to alleviate the excessive energy consumption of the cluster heads. The proposed protocol results in better distributed sensor and optimized clustering system enhancing the network's lifetime. We compare the proposed protocol with comparative protocols by varying a number of parameters, e.g., the number of nodes, the network area size, and the position of the base station. Simulation results show that the proposed protocol performs better against other comparative protocols in different simulations.

This thesis is concerned with the cluster head selection algorithm aiming different goals like maximize the network lifetime, minimizing total interference etc. This Adaptive particle swarm optimization based (APSO) algorithm will eliminate the uncertainty of the cluster head selection problem to attain the goals satisfying certain robust wireless sensor network.

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Chapter 1

Introduction

1.1 Overview

Wireless sensor networks hold the promise of revolutionizing the way we observe and interact with physical world in a wide range of application areas. A wireless sensor network (WSN) is a self-organized wireless network system consisting of a number of low-power sensors, which are capable of sensing, processing and transmitting the data to a base station [1]. In WSN applications, the main objective is to monitor and collect sensor data and transmit the data to the BS. Sensors in different regions of the field can collaborate in data collection and provide more accurate reports about their regions. Wireless sensor networks (WSNs) are extremely important in cyber-physical system (CPS) for observing and recognizing the complicated physical world at low cost [2]. Most deployed WSNs measure physical parameters like temperature, pressure, humidity, or location of objects, to improve the fidelity of reported measurements, and data aggregation reduces the communications overhead in the network, which leads to significant energy savings [3, 4]. Due to the low-power, low-cost and multi functional characteristics of sensors, it has become the main component in WSNs implementation [5]. With the development of cloud technology [6], the implementation of WSNs in the real life applications like smart home, battlefield surveillance, health-care applications [7] etc. have increased significantly. To explore the roles of WSNs in remote and inconvenient environment extensive research efforts are been done [8].

In a sensor network, each node works both as a sensor and a router to send data to the sink. Its computing capability, storage capacity and communications ability are very limited because of their nature. Since the sensor nodes most of the time are deployed in harsh environments, the replacement of dead nodes is either very difficult or expensive. As a result of this, a node in the network must operate for an extended amount of time without any battery replacement [9]. Energy consumption can be efficiently managed through adjusting the network topology and regulating the nodes' transmission power levels in the routing protocol [10], [11]. The clustering technique is useful in reducing power usage in routing protocols [12]. In a clustering architecture, sensor nodes are organized into clusters, where the sensor nodes with lower energy can be used to perform sensing tasks, and send the sensed data to their cluster head at a short distance [13, 14, 15, 16]. A node in a cluster can be chosen as the cluster head (CH) to eliminate correlated data from the members of the cluster, with the objective of reducing the amount of the aggregated data transmitted to the

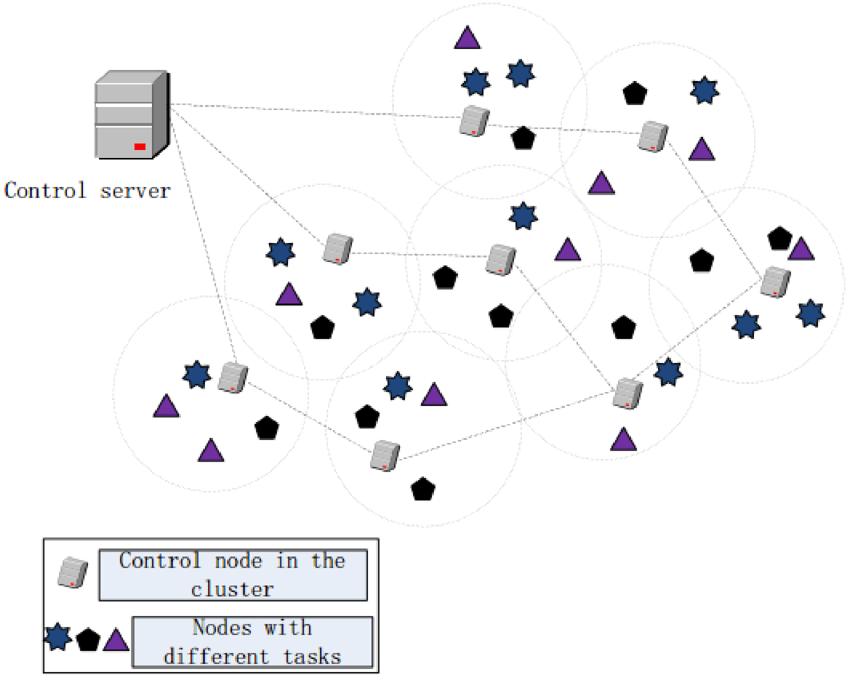


Figure 1.1: An example of the software-defined sensor network with multi-tasks

control server [17]. The clustering approach is able to increase network longevity and to improve energy efficiency by minimizing overall energy consumption and balancing energy consumption among the nodes during the network lifetime [18], [19]. Moreover, it is capable of alleviating channel contention and packet collisions, resulting in better network throughput under high load [20], [21].

1.2 Problem Statements

With wireless sensor network, the most prominent problem is the energy constraint of the sensor nodes. The nodes are equipped with very limited amount of energy source and requires processing of the data. The main problem is though with the transmission of the data to the sink node or control server. The ratio of consumption of energy for data collection and transmission is very much high (1:1000). As the nodes are deployed over an area, the nodes which are at greater distance from the control server drains the energy most in transmitting data in each round. And these distant nodes are the nodes which dies very first because of the limited energy of the sensor nodes. The whole network is wireless and if all the nodes tries to send data to the control server simultaneously then collision occurs and retransmission of the data is needed. The retransmission will cost the same extra amount of energy for the sensor nodes. This is also a major problem for the wireless sensor network. So, the problem can be divided into two categories:

- Energy Consumption in Transmission of data
- Collisions in the network

Detailed problem formulation will be discussed in the later chapters.

1.3 Thesis Objectives

An efficient clustering technique can create optimal number of clusters in the network to overcome the above mentioned problem. A number of clustering algorithm is present in literature [23],[24],[3],[22] aiming to maximize the network lifetime and avoid collisions among the nodes. However the improvement of these existing algorithms is still in process. In [23], the authors proposed a uniform clustering algorithm based on local energy consumption which had a predefined cluster range irrespective of the density of nodes in the network. Authors in [22],[24], integrated an evolutionary Particle Swarm Based Optimization (PSO) with WSN networks to find optimal cluster heads and form clusters, but did not consider the intra-cluster distance as a parameter. Moreover, these algorithms has a tendency to select the central node as a cluster head which will ultimately lead to an early death of the nodes at center. The objective of this thesis is to design a sophisticated clustering algorithm which will maximize the network lifetime and reduce the collision among the nodes in the Wireless Sensor Network (WSN).

1.4 Thesis Contributions

For maximization of system capacity proposed approach considers intra-cluster distance as a parameter along with the residual energy and distance of each node from the control server while calculating the cluster heads. The contribution of this paper is to eradicate the shortcomings of the existing algorithms. Our algorithm removed those uniform clustering issues along with a modified approach of the existing Particle Swarm Based Optimization (PSO) algorithm. After selecting the optimal number of cluster heads, clusters are formed. And the nodes inside each cluster follows a TDMA scheduler to send data to their corresponding cluster heads.

For maximizing network lifetime of a network, our approach showed different options which gives better result than the existing algorithms based on PSO.

1.5 Organization of the Thesis

The rest of the thesis is organized in the following manners. Chapter 2 canvasses prior works related to our topic of interest. Chapter 3 discusses different aspects of system model. Chapter 4 discusses the proposed "PSO based Clustering Algorithm". Chapter 5 discusses the performance evaluation of the proposed algorithm along with the existing one. Finally, chapter 6 draws the conclusion.

Chapter 2

Literature Review

2.1 Related Work

Numerous amount of thesis work has been done on WSN since the development of it. Because of the limitations of a wireless sensor network, to maximize the network lifetime a lot approaches are proposed. LEACH protocol [11] is one of the most well known WSN clustering protocols, it was one of the first protocol to implement clustering in WSN. The protocol selects a cluster head (CH) based on a predetermined probability of rotating the CH role among the sensor nodes to avoid first depletion of CH's energy. However, the selection of CHs is random. Resulting in a node with low energy maybe chosen as the CH, and the CHs may not evenly distributed. Furthermore, the LEACH protocol requires that the transmission between the CHs and the control server be completed via a single hop, which consumes a large amount of energy and destroy the energy balance of nodes if the CHs are located far away from the control server. The LEACH-centralized (LEACH-C) protocol is proposed as an improvement over LEACH, which uses a centralized clustering algorithm to form the clusters. LEACH-C increases the network performance through creating better clusters by disappearing the CHs throughout the network. The information on the residual energy of the nodes is taken into account in the probability formula, so the nodes with higher energy are more likely to be selected as the CHs. But LEACH and LEACH-C have not been able to use effective CH selection methods, and the distribution of CHs is random, which leads to the overload of energy consumption. As a result, BCDCP [16] is proposed to form more balanced clusters. In BCDCP, each cluster head servers an approximately equal number of member nodes so as to avoid cluster head overload, and the CHs utilize CH-to-CH routing to transfer data to the control server.

The above protocols focus only on uniform energy consumption of the nodes. To further prolong network lifetime, some location-aware protocols are proposed to reduce the transmission costs among the nodes. In the HEED protocol [12], cluster heads are selected based on the nodes' residual energy plus a secondary parameter, such as the nodes' proximity to its neighbors or node degree. The cluster heads send data to the control server via multi-hop communications. HEED ensures that only one CH within a certain range achieves the uniform CH distribution across the network. Therefore, the head nodes consume a great deal of power in the HEED protocol, resulting in their quick depletion of energy. The EECS protocol [25] leads to a fair distribution for cluster heads, in which cluster heads are selected based on the residual energy and location of nodes. In EECS, a competitive algorithm is suggested for the CH selection phase, and a fixed competition range is specified for each volunteer node. Any node that finds itself more powerful than the others in its competition radius will introduce itself as a CH and broadcasts to all the other nodes. However, this algorithm causes a potential problem in dense networks for having too many nodes competing for being a CH. The TCAC protocol [26] improves the performance of the EECS protocol, which dynamically controls the nodes' transmission power levels to minimize network energy consumption while ensuring inter-cluster connectivity. The selected CHs send the data to the control server directly. The Hausdorff clustering method [27] introduces a greedy algorithm to select cluster heads based on the location, communication efficiency and network connectivity, while the clusters are formed only once. Therefore residual energy of the nodes consume quickly when the clusters are organized inefficiently at the first time. In [23], a LECP-CP protocol is proposed, and the core of which includes a novel cluster head election algorithm and inter-cluster communication routing tree construction algorithm, both based on the predicted local energy consumption ratio of nodes. What's more, the protocol also provide a more accurate and realistic cluster radius to minimize the energy consumption of the entire network.

In most applications, the control server is far from the sensor network, and thus the cluster heads have to consume much more energy than the other nodes. Thus, task allocation can be done in such a way that the sensor nodes paly a significant role in improving energy efficiency. For example, relay nodes can be used to balance the heavy consumption of the cluster heads. In SEECH [28], some nodes with higher residual energy are selected as the relay nodes, and the CH chooses the closest relay node as its next hop. Thus, the CH collect and aggregates data from all the cluster members, and then transfers the data to the relay node, which relays the data to the control server. In this way, the relay node can share the CH's data transmission, and thus helps offload the CH's energy consumption. However, two or more CHs may choose the same relay nodes, which will expedite the energy depletion of the selected relay nodes. In addition, extra energy consumption is required when a CH chooses its relay node. Moreover, the location of nodes is not taken into consideration in the selection of relay nodes.

Although the aforementioned protocols are able to prolong network lifetime to some extent, there is no guarantee that the selected node is best fit as a cluster head. There are two main reasons. Firstly, some nodes with lower energy are probabilistically determined as the cluster heads, which will exacerbate the energy consumption of these nodes. Secondly, some nodes are not suitable to be at the center of a cluster because of their location. If a node near the boundary of the network is selected as a cluster head, energy consumption will increase because the cluster head is far from the BS. In [22], a non-linear PSO optimization method in the algorithm to select cluster heads. The authors in their proposed algorithm considered two basic parameters, the distance between the control server and sensor nodes, and the residual energy of every sensor node.

Chapter 3

System Model

3.1 Network Model

A wireless sensor network of N sensor nodes is considered, which is deployed in a field to monitor the environment continuously. A sensor node consists of the microcontroller unit, communication unit and power management unit. The following assumptions about the sensor network and sensor nodes are made:

- Each sensor node has the same ability to operate either in the sensing mode to perceive environmental parameters, or in the communication mode to send data among one another or directly to the control server, and each node can gather data packets from the cluster members when acting as the CH;
- Each node has a data link capable of handling all data traffic;
- Each node is assigned an index according to its location;
- The sensor nodes and the control server are stationary after deployment, which is typical for sensor network applications;
- Initial energy is fair for each sensor node, and the network is considered homogeneous;
- All the nodes are left unattended after deployment. That is, it is impossible to recharge battery;
- All the nodes measure the environmental parameters at a fixed rate and send data periodically to the target nodes;
- Each node has a fixed number of transmission power levels. The nodes are capable of adjusting their transmission power in accordance with the distance to the desired recipient;
- The links between nodes are symmetric. A node can estimate the distance to another node only based on the received signal power;
- The sensed information is highly correlated, so the cluster head aggregate the data gathered from its cluster into a fixed-length packet; and
- The control server is externally powered.

3.2 Energy Consumption Model for WSN Nodes

A simplified model shown in figure 1.1 is considered in this paper for communication energy consumption in consideration of path losses [?], [?]. Either the free space (d^2 power loss) or the multipath fading (d^4 power loss) channel model is employed, according to the distance between the transmitter and receiver. Power control can be used to compensate for this loss. If the distance is less than a threshold d_0, the free space model is used; otherwise, the multipath model is adopted. The required energy for transmitting a k-bit packet over distance d is

$$\mathrm{E}_{TX}(k,d) = \begin{cases} \mathrm{k} \times E_{elec} + k \times E_{fs} \times d^2, & \text{if } \ d < d_0 \\ \mathrm{k} \times E_{elec} + k \times E_{mp} \times d^4, & \text{if } \ d > d_0 \end{cases}$$

And for the control nodes, the energy consumed while integrating a *k-bit* of data is

$$\mathrm{E}_{TX}(k,d) = \begin{cases} \mathrm{k} \times (E_{elec} + E_{DA}) + k \times E_{fs} \times d^2, & \text{if } \ d < d_0 \\ \mathrm{k} \times (E_{elec} + E_{DA}) + k \times E_{mp} \times d^4, & \text{if } \ d > d_0 \end{cases}$$

where E_{TX} is the transmission energy, E_{DA} is the amount of energy needed to aggregate data packet, E_{fs} is the energy used for reception, d is the distance between two nodes or between a node and the sink, E_{elec} is the energy dissipated per bit to the transmitter or receiver circuit, which depends on factors such as channel coding, modulation, filtering, and spreading of the signal. E_{fs} and E_{mp} depend on the transmitter amplifier model, k is the length of the data transmitted, and d_0 is the transmission distance threshold given by

$$d_0 = \sqrt{\frac{E_{fs}}{E_{mp}}} \tag{3.1}$$

To receive a k-bit message, the radio consumes the following energy

$$E_{RX}(k) = k \times E_{elec} \tag{3.2}$$

3.3 Network Lifetime Model

In most applications, a network would still function effectively when some nodes fail. Especially when a large number of sensor nodes are deployed in an area, a node has several adjacent neighbors equipped with the same sensing equipment, so that the network will be able to cope with the failure of some nodes. Thus, the time until the first node died (FND) is not the only metric to evaluate the network lifetime [1], [**?**]. As a result, the lifetime that a part of nodes die (PND) is a more effective metric when evaluating the performance in scenarios of high node density [3], [4]. We describe the lifetime of the network as follows:

$$T_N^k = T[\xi = \frac{k}{N}] \tag{3.3}$$

where N is the number of sensors in the network. k is the number of alive nodes. The equation shows that the definition of PND lifetime is time until the fraction of alive nodes falls below a predefined threshold ξ.

Chapter 4

Proposed Method

4.1 Problem Formulation

4.1.1 Cluster Setup Phase:

At the beginning of cluster setup phase each node transmits a $node_msg$ to control server. The message contains node id and node residual energy. The control server calculated intra-node distance matrix *dst*. Using received information, control server also executes following algorithm to select cluster heads.

Limitations Found We worked on [22] paper, the limitations that we found from that paper, we have worked on those problems. The limitations are:

- When the algorithm is executed to select the cluster heads for the first time i.e. when energy of all nodes are equal, the only factor that decides CH is distance of nodes from control server. That is because the ratio of the average residual energy of the probable CHs and other nodes is equal to one. As a result the nodes closest to control server are selected as cluster heads. That is because when the nodes closest to control server are selected as CH, the ratio of avg distances of common nodes to that of CHs becomes maximum. As a result fitness values are maximum. This results uneven distribution of CHs where all CHs are grouped into one place near the control server. This scenario is not energy efficient.

- One of the parameters that influences overall energy consumption in a network is the distance between CHs and cluster members. From equation 4.1 we can see that PSO based approach only considers residual energies and distance between nodes and base stations.

- The version of PSO algorithm used converges rapidly during the initial stage of the search, but often slows down considerably and can get trapped into local optima. The reason is that each particle evolves only around its personal best and global best. But the global optima might be around other particle's personal best also.

4.1.2 Proposed Modifications

To overcome the limitations that we found on the paper [22], we made the following modifications-

- We updated the fitness function to include distance between CHs and cluster members.
- We implemented an adaptive version of PSO to prevent it from converging into local optima.

4.1.3 Fitness Function Modification:

The fitness function in our proposed algorithm contains three parts. Like previous algorithm it contains the ratio of average distances of common nodes to that of CHs from control server. It also contains the ratio of the average residual energy of the probable CHs and other nodes. But to ensure proper distribution of cluster heads even when the energy is uniform for all nodes, we have added average distance between probable CHs and cluster members. The fitness function formula is as follows:

$$f = \gamma f_1 + \delta f_2 + \beta f_3 = \gamma \frac{E_{CH}}{E_{common}} + \delta \frac{d_{common}}{d_{CH}} + \beta \frac{1}{d_{icd}} \tag{4.1}$$

where

$$\gamma + \delta = 1, 5 \leq \beta \geq 10. \tag{4.2}$$

where d_{icd} is the average intra-cluster distance, E_{CH} is the average residual energy of the CHs, while E_{common} is the average residual energy of the common nodes or non-CH nodes. Here, d_{CH} is the average distance between the cluster heads and the control server, and d_{common} is the average distance between the common nodes and the control server. One concern here might be the complexity increase in calculating d_{icd} for each particle in each iterations. To reduce complexity of calculating d_{icd} control server calculates and stores an inter-node distance matrix *dst* before execution of the algorithm, where *dst[i,j]* = distance between nodes i and j . Then in each iteration for each particle we can look up the values in *dst* and take the minimum distance between the node and CHs as the distance. This reduces the overhead of computing the distance between two nodes from their coordinates in each iteration for each particles.

4.1.4 Adaptive PSO Algorithm:

We used an adaptive PSO used by them instead of traditional PSO algorithm. It has the following modifications-

- We divide the search space uniformly into several segments. Then from each segment we select one particle only. If we initiate 50 particle then we need to divide the search space into 50 segments uniformly distributed. This can prevent converging into local optima. On the other hand, this practice may help to find global faster.

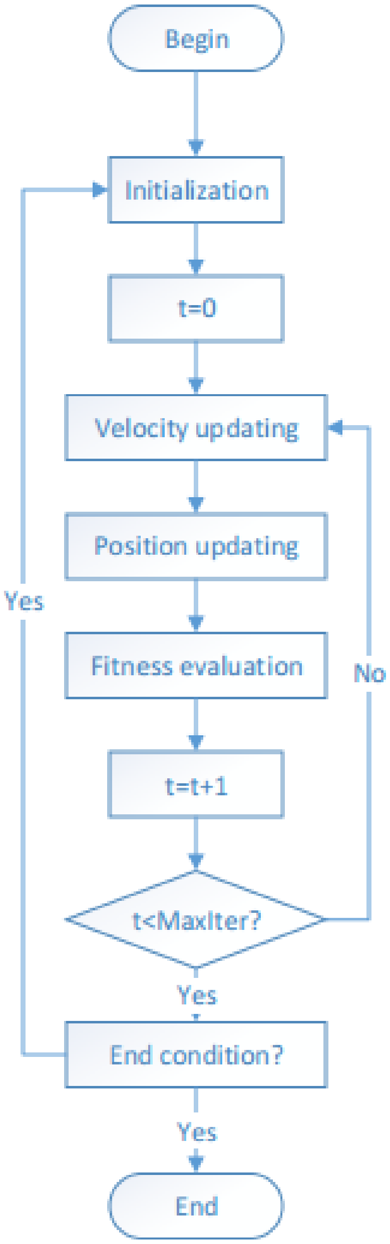


Figure 4.1: Flowchart of the network operation, including clustering setup phase and data transmission phase

- The information sharing is made stronger in the model used in the model we have used. Social information of the swarm is used to determine velocity of next iteration. Every swarm show interest or takes information in all other swarms that have better fitness value than its own. The particles in the swarm that have better fitness value will guide other particles in attaining better fitness value. What it means is that the velocity of the particle in the next iteration will depend not only personal best and global best but also on the personal best of other particles that has better fitness values than itself. As particles are not considering only one global best it has hardly got any chance in getting stuck in local optima.

- In traditional PSO used here, the learning factors C1 & C2 are constant. In the adaptive PSO fitness value is used to adjust the learning factors. How much interest a swarm shows in other swarms depends on the fitness values. For this all the swarms are ranked as per fitness functions in each iterations. The swarm with largest fitness value is ranked 1 and so on. The particle with rank m will follow only particles 1,2,.........,n-1. This will help swarms get out of local optima even when they fall into one.

- The velocity updating equation of proposed algorithm –

$$v_{id} = v_{id} \times w_{id} + \frac{1}{rank(i)} \times rand() \times (p_{best}[i] - x_i) + socialinformation(i); \quad (4.3)$$

$$x_i = x_i + v_i; \quad (4.4)$$

where

```
socialinformation(i)
{
posx ← 0.0
for each particle k of the population
if fitness[k] is better than fitness[i]
    $posx \leftarrow posx + \frac{1}{rank(k)} \times rand() \times (p_{best}[i] - x_i) + socialinformation(i);$   (4.5)
if (posx> $v_{max}$ ) return $v_{max}$;
else return posx;
}
```

Algorithm: CH selection algorithm

4.1.5 Cluster Formation:

After the CHs have been selected by the control server, the following steps are executed to finally form clusters-

Algorithm 1 Cluster Head selection algorithm

```
procedure CHS(distance,Energy)
Initialization:
    while Max number of iterations reached do
        for each particle do do
            Calculate the energy parameters and distance parameters
            Compute the value of fitness function as per equation ??
            Change the weight as per equation ??
            Update velocity and position as per equation ??
            Update the CH
        end for
    end while
end procedure
```

- Control server broadcast a message containing IDs of the CH. CHs upon receiving the message can understand they have been selected as a CH. Then selected CHs broadcasts a CH_adv message using non-persistent CSMA-CA protocol. The message contains packet identifier as CH_adv message and node ID.

- Common nodes select the CH closest to them by analyzing received signal strength of received CH_adv messages.

- After selecting closest CH, common nodes transmit $JOIN_REQ$ message for selected CHs. The $JOIN_REQ$ message contain node id, CH id.

- CHs can get information about the cluster members from the $JOIN_REQ$ messages. After receiving all messages intended for it, CHs assign different tasks to different nodes and sets up a TDMA schedule for each nodes. Common nodes can transmit to CH only in its TDMA slot. This helps to avoid collision of transmitted data.

Each node transmit data to CH only in its TDMA slot. That is why nodes need to be synchronized to avoid collision. Control server periodically transmits synchronization pulse to synchronize the nodes. Common nodes can sleep all the time except its TDMA slots. This reduces wastage of energy more. CHs need to remain awake all the time to receive data from cluster members.

Data Transmission Phase:
The common nodes send data to the CHs according to TDMA scheduler. CHs aggregate data and remove redundancy from collected data. Then CHs compress the data and send to BS. BS remain awake all the time to collect data from common nodes.

Chapter 5

Performance Evaluation

5.1 Simulations and Result Analysis

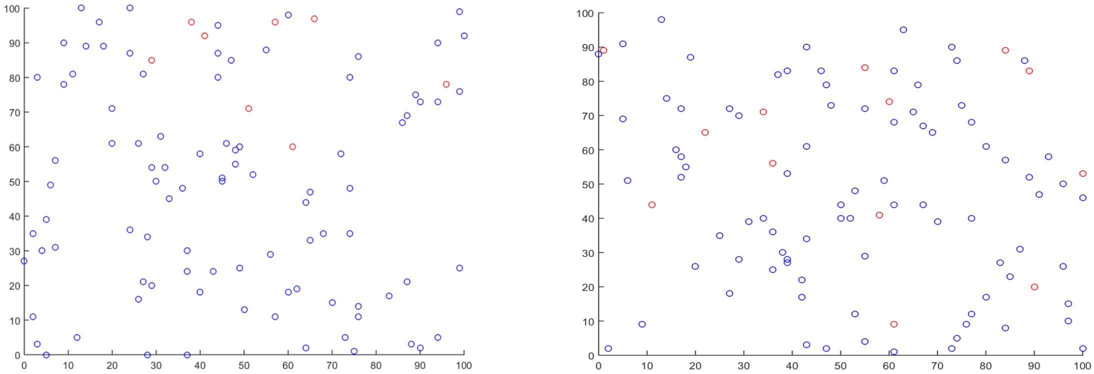
In this section, we evaluate out proposed adaptive PSO based algorithm's performance against traditional PSO based approach. The simulation model was developed in MATLAB. The network lifetime is the timespan from deployment to the time when the network is considered to be non-functional [5]. For the periodic data collection applications, the network lifetime is considered to the time between the network initiations up to the time when the first node dies. Our main objective is to enhance network lifetime by efficiently selecting CHs. To make the results more reliable, average value are taken from 20 simulation runs. Table 5.1 lists the parameters of simulation in cells.

Type	Parameter	Value
Network	Area	(0,0) (100,100)
	Location of data sink	(50,175)
	Initial Energy	2J
Radio Model	E_{elec}	50nJ/bit
	E_{fs}	10pJ/bit/m^2
	E_{mp}	0.0013pJ/bit/m^4
	d_0	75m
	E_{DA}	5nJ/bit/signal

Table 5.1: Simulation Parameters

The network is uniformly spread into a 100x100 units area. The initial energy is uniform (2J) for all nodes. Along with network lifetime following performance matrices have been evaluated:

- Last node dies (LND)
- Half node dies (HND)
- Optimal Number of Cluster Heads



(a) Non linear PSO based approach (b) Proposed PSO based approach

Figure 5.1: Selection of Cluster heads

5.1.1 Selection of Cluster heads

The figure 5.1 depict the cluster heads selected by PSO based approach and proposed adaptive PSO based approach respectively. The red dots are CHs and blue ones are common nodes. From the figures it can be seen that traditional PSO based approach does not select Chs uniformly when energy of all nodes are uniform. Most of the CHs are grouped near BS. On the other hand our proposed adaptive PSO based approach has been able to select cluster heads uniformly distributed in the network. This is because our proposed fitness function considers intracluster distance while the original algorithm does not.

5.1.2 Network Lifetime

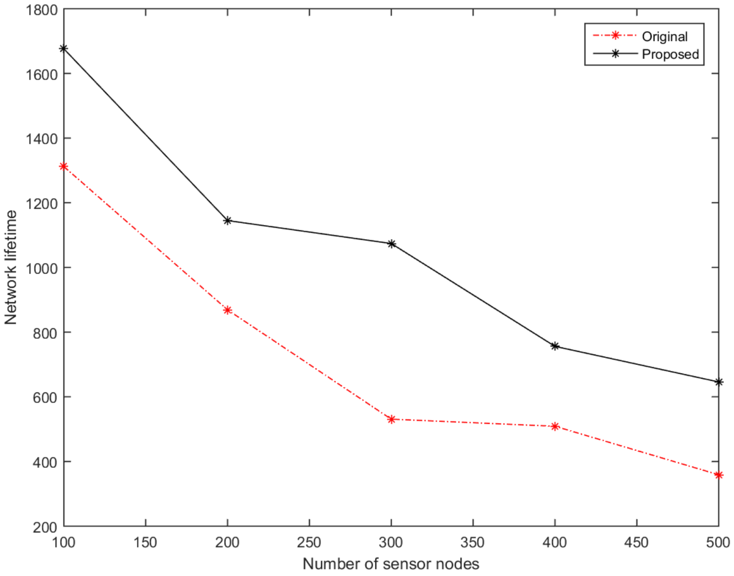


Figure 5.2: Comparision of network Lifetime

The figure 5.2 shows network lifetime comparison of the two algorithms. As we can see our proposed algorithm can ensure much better lifetime when initial energy is uniform. The network lifetime is measured in no. of rounds of data transmission. The reason for increased lifetime is the fact that the CHs are evenly distributed. As a result loads are balanced over all the CHs. So unlike proposed PSO based algorithm, where some CHs in this scenario will have to manage more loads than others, the drainage of CHs are almost uniform in our proposed algorithm.

5.1.3 Lifetime Comparision in Number of Rounds

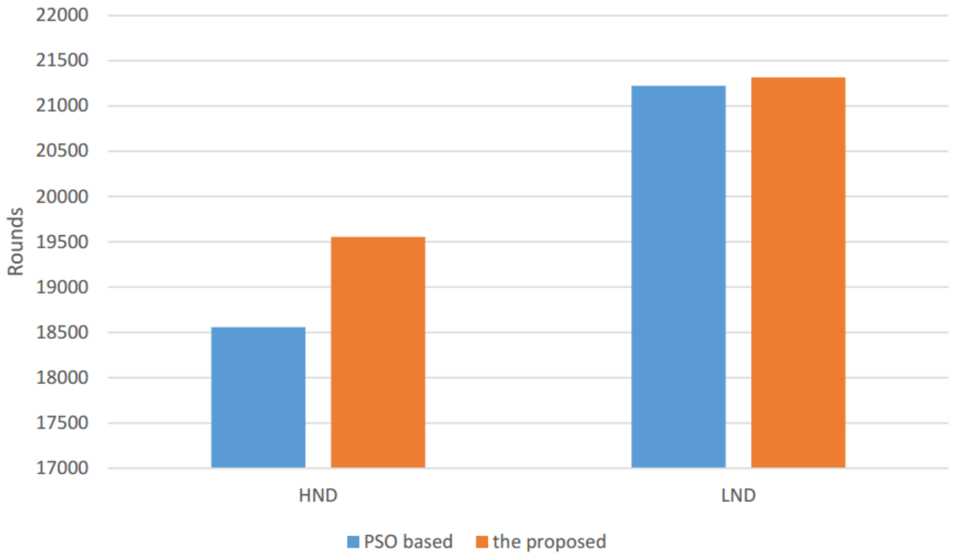


Figure 5.3: Comparision of network Lifetime with respect to number of rounds

The figure 5.3 shows after how many rounds of transmissions half of the nodes die and after how many rounds last node dies. We can see that although our proposed algorithm has been able to increase network lifetime, it has not made that significant improvement in half node dies. The no. of rounds after which last node dies is almost same for both algorithms.

5.1.4 Optimal Number of Cluster Heads

In our proposed approach as well as PSO based approach, initially maximum possible no. of CHs is needed to be specified. If each particle in the swarm is n-dimensional then there will be at best n no. of CHs selected. So in order to attain maximum energy efficiency we need to find out maximum no of CHs. If we specify the number too small, then each CHs will have massive load and will be depleted fast. As a result network lifetime will be reduced. If we let maximum possible no. of CHs larger, that won't be efficient also. Because more CH means more nodes directly communicating with BS. Another reason is redundant data transmission. CHs reduce redundancy from collected data and send to BS. If more nodes are selected as CH redundancy in transmitted data is reduced. The figure 5.4 shows different network lifetimes against different number of CHs. It is seen from the graph that for the scenario we have used for experimentation, we will get optimum network lifetime for 14 CHs.

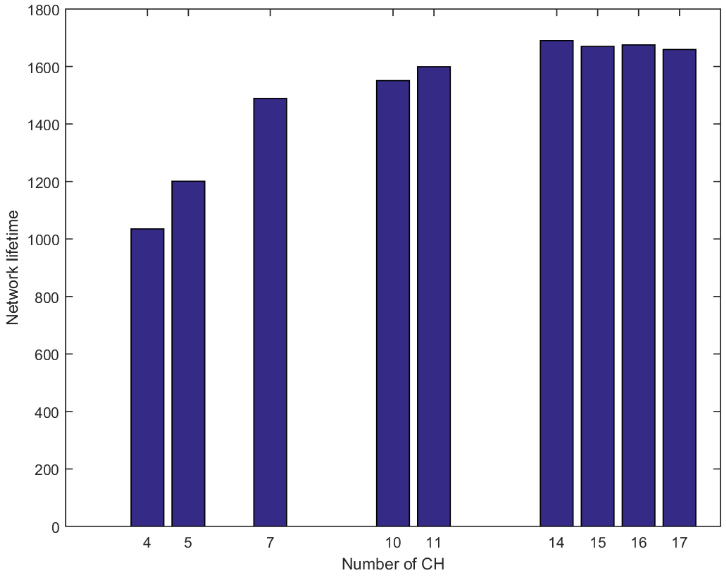


Figure 5.4: Comparision between the proposed protocol and the PSO-based protocol

Chapter 6

Conclusion and Future Works

Considering the intra-cluster distance along with the along with residual energy and distance to the control server increases the network lifetime significantly. To maximize the network lifetime of Wireless sensor network (WSN), our proposed algorithm performs good. The overall observation of the proposed algorithm is that it has higher fitness function value and it reaches much more faster than the existing PSO based algorithm. The proposed algorithm however shows almost similar output when it comes to the network lifetime for half of the nodes in the network and all the nodes. The nodes dies after almost similar number of rounds for both the proposed algorithm and the existing one.

Our future work includes the improvement of the proposed algorithm emphasizing in the better throughput in case of distributing the sensor nodes and enhancing the network's lifetime. Relay nodes can be added to release the extensive pressure on the cluster heads and this can maximize the network lifetime.

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