Dynamic Multi-Swarm-Particle Swarm Optimizer (DMS-PSO) for Time and Energy Efficient Cluster Head Selection in WSN

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Abstract- ***Wireless sensor networks comprise several sensor nodes being supported by limited capacity battery source. The network hierarchy may be chosen as per required applications, such as clustered arrangement. Cluster heads play a major role in clustering Wireless Sensor Network. Particle swarm optimization (PSO) is one of the swarm based intelligence methods for locating optimum solution by imitating the behavior of flocks of birds and fish schooling. PSO is based on the movement and intelligence of swarms. Social learning factor can achieve better convergence speed and particle reselection mechanism reduces the chances of being trapped in local maximum. In this paper cluster head selection based on DMS-PSO approach is proposed. The performance of the proposed approach is compared with low energy adaptive cluster Hierarchy (LEACH). Simulation result shows that proposed approach outperforms LEACH in terms of first node died (FND), total data received by base station and energy consume per round. The simulation has been carried out over different network size and with different number of cluster heads and it is clearly seen from the results that the proposed approach outperform LEACH in large network size also.***

Keywords*:* Cluster Heads, PSO, LEACH, WSN, FND.

1. Introduction

A wireless sensor network comprises sensor nodes, which are distributed in a specified region to sense the particular information/data and then transmitting the gathered information to the other nodes or to the base station depending upon the network architecture. Wireless Sensor Networks (WSNs) are used for a variety of purposes like habitat monitoring, military surveillance, forest-fire detection, temperature monitoring etc. The sensors have limited computation capability, small battery size and small memory storage. The prime concern of the WSN is the energy conservation as there is always scarcity of power, thus energy consumption to be reduced by allowing only a few nodes of the network, generally called cluster heads, to communicate with the base station [1]. Cluster based hierarchical routing protocol is an energy efficient routing protocol where sensor nodes are grouped into clusters. Each cluster has a node that acts as the CH (Cluster Head). The CH will collect the data sensed from all the nodes which belong to the same cluster [5].The CH transmit the collected data to the BS (Base Station). Although clustering can reduce energy consumption, it has some problems. The main problem is that energy consumption is concentrated on the cluster heads.

LEACH (Low Energy Adaptive clustering Hierarchy) is a clustering protocol designed to achieve prolonged network lifetime. In LEACH, the CHs are elected based on the probability model. The algorithm runs periodically and the probability of becoming a cluster head for each round is chosen to ensure that every node becomes a cluster head atleast once within 1/P rounds, where P is the predetermined percentage of cluster heads.

The LEACH protocol does not guarantee energy efficiency because each CH is selected on the basis of the probability model. There is a possibility that elected CHs maybe concentrated in a particular region or may be located at the boundaries of the network.

The particle swarm optimization (PSO) is a simple, effective and computationally efficient optimization algorithm. PSO is one of the swarm based intelligence methods devised to find optimum solution by imitating the behavior of flocks of birds and fish schooling as shown in figure 1. It works through initializing population of random solutions and searching for the optima by updating generations [13].All particles have a fitness value that is evaluated with help of the fitness function, and have a velocity that direct the movement of the particles [16]. It has been applied on WSN to overcome a number of issues such as optimal deployment, clustering, node selection and data aggregation. The application of PSO algorithm to solve the problem of sensor network clustering has already been proposed [4]. Attempts have been made to equalize the number of candidate cluster heads to minimize the energy expended by the nodes and prolong the life of the network. In this paper a DMS-PSO based approach has been proposed in which effort has been done to choose the optimal nodes as cluster heads along with a reselect mechanism to extend the network lifetime.

Figure 1: Coordinated collective behavior exhibited by birds or fish

2. Related Work

PSO (Particle Swarm Optimization)

A computational approach that optimizes an issue by an attempt to improve a candidate solution iteratively with regard to a given measure of quality is known as Particle Swarm Optimization (PSO) [12].A problem is optimized by PSO by including dubbed particles, which is the population of candidate solutions here, and moving these particles based on an uncomplicated mathematical formulae over the location and velocity of the particle in the search-space [17]. The movement of each particle is affected by its best known local position but is also directed towards the positions that are best known in the search-space, which are recorded and updated as improved positions and discovered by other particles [11]. This is expected to move the swarm towards the best solutions. As energy is the major concern in WSN, PSO provides us an optimal selection of cluster heads i.e. scarce distribution of cluster heads over the network [15].

2.1. Basic Swarm Based Routing for WSN

The PSO has been applied with success in WSN in on stationary nodes [4]. Its optimization procedure can be easily implemented to a swarm based routing algorithm for WSN. A basic implementation of particle swarm optimization algorithm on WSN can be described as follows.

1. Randomly initialize all the particles in a network space with an initial energy as E_0 and initial velocity as 0.
2. Calculate fitness function for each particle using the formula: fitness $=\alpha f_1 + (1-\alpha) f_2$
Where α is a constant value and f_1 & f_2 are functions that can be calculated using the following formula:

$$f_1 = \sum_{i=1}^{n} E(n_i) / \sum_{m=1}^{M} E(CH_m) \quad (2)$$

$$f_2 = \max_{m=1,2,..M}\{\sum_{i\in m} d(n_i, CH_m)/|C_m|\} \quad (3)$$

Where f_1 is the energy representative part, and it is equal to the sum of all member node energy $E(n_i)$ (not including CH) divided by the sum of all CHs (Cluster Heads) energy $E(CH_m)$. f_2 represents the density and it is equal to cluster with highest average distance between CH and joined member nodes $d(n_i, CH_m)$ divided by the total member nodes in the same cluster $|C_m|$.
3. Each particle updates its global and local best.
4. Update position and velocity for each CH using the equations:

$$v_{k+1} = wv_k + C_1 r(p_k - x_k) + c_2 r(P_G - x_k) \quad (4)$$

$$x_{k+1} = x_k + v_{k+1} \quad (5)$$

Where, w is the inertia weight for particle; C_1 is the cognition learning factor; c_2 is the social learning factor; r is a random number distributed between [0, 1].
5. Repeat steps 2-4 until maximum number of iterations are reached.
6. The optimal cluster heads are then broadcast.

2.2. LEACH Protocol

LEACH (Low Energy Adaptive Clustering Hierarchy) is one of the most popular hierarchical clustering algorithms. The idea behind LEACH is to form cluster heads on the basis of the probability model. Some of the nodes are randomly chosen as the cluster heads (CHs) and all the nearby nodes are associated with the CH to form a cluster. CHs have to do a lot more work than the normal nodes because they collect data from all the nodes in that cluster and then transfer the data to the Base Station (BS), hence they dissipate a lot more energy and may die quickly [7]. In order to maintain stability in the network, CHs keep on rotating, in every round. So, a node which had become CH may not get an opportunity to become CH again before a set of rounds based on the probability model. The major drawback of LEACH protocol is that there is a possibility that elected CHs maybe concentrated in a particular region or may be located at the boundaries of the network.

2.3. DPSO Based Single Hop (DSPOCA)

In DSPOCA the energy dissipation such as data packet processing, transmitting, receiving and fusing in the transceiver are considered [2]. It consists of mobile nodes and the position of a sensor node that can be found with the help of GPS. A sensor node n is decided to become a DSPO agent for a particular round on the basis of a threshold formula.

$$T_{h1}(n,r) = \begin{cases} \frac{PN}{N_{active}} & \text{if } PN/N_{active} < 1 \\ 1 & \text{if } PN/N_{active} \geq 1 \end{cases} \quad (6)$$

In DPSO there is a comparison based on the inertia w, where w lies between 0.4 to 0.9. The disadvantage of this protocol is that the cluster heads are selected on the basis of the position rather than on the basis of energy, hence it can be said that the protocol is not energy efficient.

2.4. Energy-Aware Clustering

Energy-Aware clustering [3] consists of stationary nodes, to ensure that only nodes with sufficient energy are elected to be cluster heads, average energy is calculated from all the nodes and the nodes with energy level higher than average energy are eligible to become cluster heads. The base station then runs PSO algorithm on the eligible nodes and nodes with minimum cost form the cluster heads [14]. The basic disadvantage of this protocol is that after a number of iterations when the particles have achieved their global best, the cluster heads become stagnant and do not change till their energy is drained.

2.5. Clustering Strategy Based on DPSO (CS)

Clustering strategy based on DPSO (CS) proposes an algorithm to avoid premature stagnation by providing mixed inertia weight and mutant strategy [6]. Mixed inertia weight is proposed by the formula:

$$w = w_{max} - (w_{max} - w_{min}) \times \frac{iter}{maxiter} \quad (7)$$

Mutant strategy is when the global best keeps unchanged for maximum 10%iterations; half of the normal nodes are reinitiated. An optimal function is used in order to keep the distance between CH and normal nodes as small as possible and distance between each normal node and CH should be approximately equal [6]. When a selected CH satisfies both the conditions mentioned above an even cluster is formed. The optimal function can be given as:

$$F = \min[mean(\sum_{i=1}^{m} D_{ij-j_{ch}}) \times mean(var(\sum_{i=1}^{m} D_{ij-j_{ch}}))] \quad (8)$$

In CS strategies are presented to avoid premature stagnation whereas stagnation at a later stage is not covered.

2.6. Double Cluster-Head Clustering (PSO-DH)

PSO-DH [8] proposes a double cluster head algorithm using PSO. The selection of cluster heads is relies on considering the optimized selection and node energy equilibrium. The data is received and aggregated by Master Cluster Head (MCH) and then it is sent to the Vice Cluster Head (VCH). VCH receives the aggregated data and transmits it directly to the sink. MCH is the current global best of a cluster and VCH is the previous global best. Since the MCH does not interact directly with the sink, energy is saved resulting in prolonged lifetime of the network. The disadvantage of PSO-DH [8] is that there is no mechanism to avoid premature stagnation of cluster heads.

2.7. Adaptive Particle Swarm (APSO)

Adaptive particle swarm (APSO) conducted particle swarm algorithm at the base station for cluster head selection [10]. An adaptive inertia weight function is proposed in the paper that will consider not only the iteration cycle, but also the ratio of the particles' local best over global best. APSO achieves a prolonged network lifetime over LEACH which can be demonstrated by the simulation results.

2.8. Cluster Head Distribution via Adaptive PSO (CHD)

For CHD [9] the cluster head selection takes place according to PSO algorithm in [4].The velocity calculation is given as equation (7).The value of the constants c1 and c2 is calculated from the formula:

$$C_1 = C_2 = 2 - \exp\left(\frac{\frac{P_i}{P_G}}{iteration}\right) \quad (9)$$

A reselect mechanism is proposed in CHD to overcome stagnation in the CH selection [9]. If global best does not change after a number of iterations, 25% particles from the worst set will be re-selected. Simulation results demonstrate that CHD achieves better energy consumption and a prolonged lifetime over LEACH.

3. Energy Model Analysis

The energy dissipation model as used in the proposed approach is shown below in figure 2. Each sensor node consists of a transmitter and receiver having some transmitter and receiver electronics. Energy is dissipated when nodes transmit and receive data.

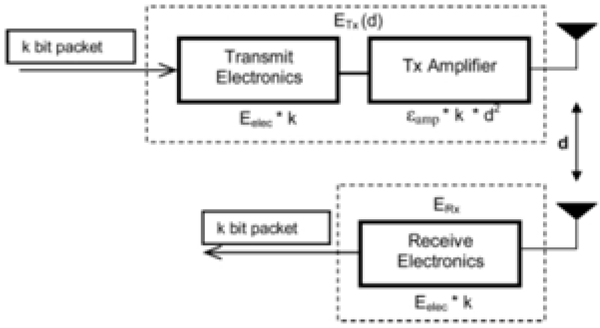

Figure 2: Energy dissipation diagram

When the sensor node transmits k-bit data by its transmitter, the energy dissipation is:

$$E_{Tx}(k,d) = E_{elec} * k + \epsilon_{fs} * k * d^2 \ \ if\ d < d_0 \quad (10)$$
$$= E_{elec} * k + \epsilon_{mp} * k * d^4 \ \ if\ d \geq d_0 \quad (11)$$

When the sensor node receives k-bit data packet, the energy dissipation is

$$E_{Rx}(k) = E_{elec} * k$$

Eelec is the energy dissipated to run the electronics circuits

- k is the packet size
- Efs and Emp are the characteristics of the transmitter amplifier
- d is the distance between the two communicating ends.

The radio characteristics and energy due to electronics are –

Eelec = 50 nJ/bit
Efs = 10 pJ/bit/m2
Emp = 0.0013pJ/bit/m4

In addition to above energy dissipations, CHs also dissipates energy in data aggregation. The data aggregation energy EDA has the value of 5nJ/bit/signal.

4. Proposed Approach

PSO (Particle swarm Optimization) algorithm has been applied in solving various optimization problems effectively. In the proposed approach PSO helps in cluster head selection whereas the normal nodes are allocated to the cluster heads with the help of LEACH protocol. Flowchart for Basic PSO in wireless sensor network for CH selection is shown in figure 3.

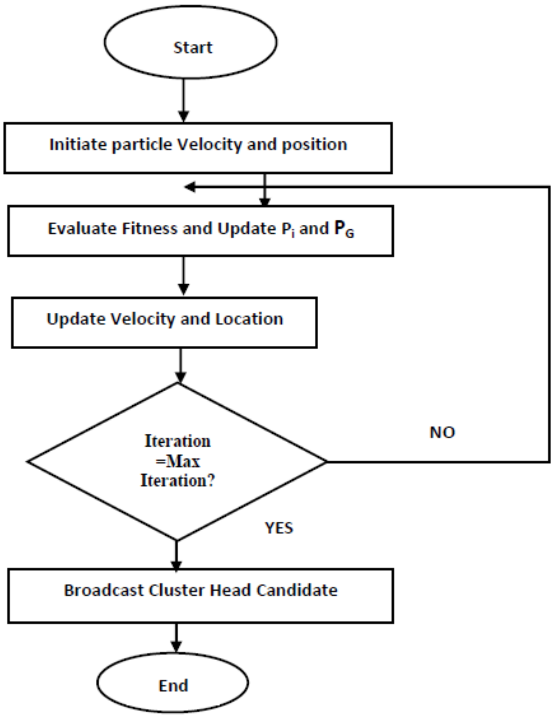

Figure 3: Flow Chart of Basic PSO

In the proposed approach DMS-PSO (Dynamic Multi Swarm Particle swarm optimization approach) is used to find out the Cluster Heads (CHs) and LEACH protocol is used as a basis for transmitting data from the sensor node to the base station. The concept of a reselect mechanism is derived from CHD [9] where 25% particles from the worst set will be re-selected if the global best does not change for a number of iterations. Whereas in the reselect mechanism proposed in our approach states that if the position of cluster heads remains same for some fixed number of iterations, the cluster heads are assigned to the position of the nearest sensor node and the velocity of that particle is changed to 0. This assures that the former cluster head has to travel again to find its global best and hence does not get stuck at a particular position. The particle now updates its position and velocity using equations (4) and (5) after every iteration to acquire its global best position. Figure 4 shows the Flowchart for the proposed approach. The simulation result is carried out for the homogenous environment where all the sensor nodes have the same initial energy. The steps below need to be follow for the implementation of proposed approach.

1) Particle Initialization: All the sensor nodes are initialized with an initial energy E0 and an initial velocity 0.
2) Fitness evaluation: Calculate fitness of each particle using a fitness function Equation (1).
3) Update Local and Global Best: Every particle updates their local best Pi and global best PG on the basis of the fitness function.
4) Reselect mechanism: If the position of cluster heads remains same for some fixed number of iterations, in our case it is five, the cluster heads are assigned to the position of the nearest sensor node and the velocity of that particle is changed to 0.
5) Velocity and Position Update: Every particle updates their position and velocity according to equation (4) and (5).The value of constants c1 and c2 used in equation (4) is calculated by the formula:

$$c_1 = c_2 = c_{initial} + random(0,1) \quad (13)$$

Where $c_{initial}$ is 2 and the value of $c_1 \& c_2$ lies between 2 3.The value of inertia can be calculated from the following equation:

$$w = w_{initial} + \frac{random(0,50)}{100}$$

Where $w_{initial}$ is 0.4. Hence we can see that the value of inertia ranges between 0.4-0.9.

6) Repeat steps 2-5 until maximum no. of iterations are reached.
7) Broadcast CH candidates: Eligible CH candidates are broadcasted by the Base Station.

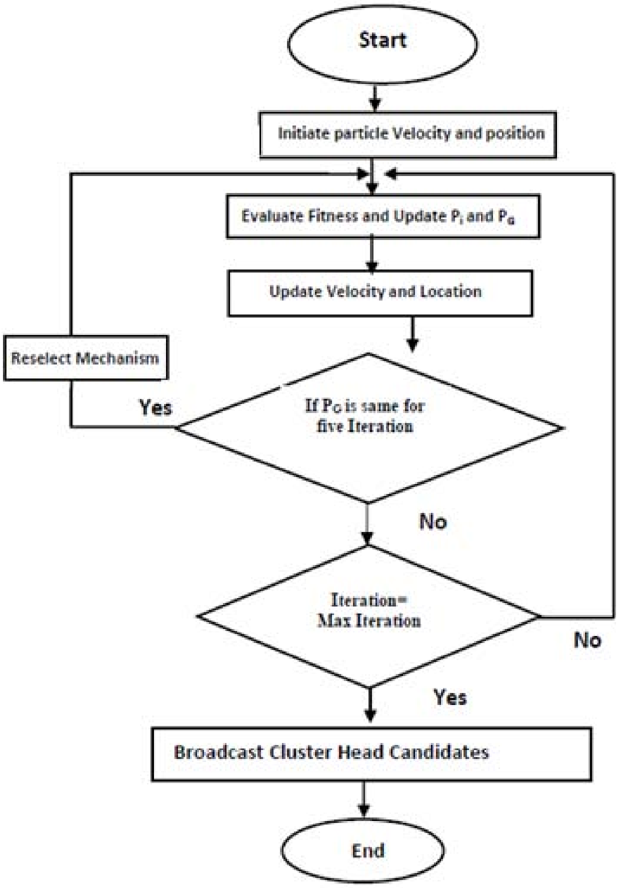

Figure 4: Flowchart of Proposed Approach

5. Conclusion and Future Work

Optimization is a mathematical technique that is used to find out the maxima or minima of functions in some feasible region. A variety of optimization techniques participate for the best solution. Dynamic Multi Swarm Particle Swarm Optimization (DMS-PSO) is a relatively latest, topical and potent method of optimization that is broadly used to uncover the global optimum solution in a complex search space proposed framework is cluster based technique in which respective cluster heads are chosen according to particle swarm algorithm based on re-selection mechanism. Proposed approach is able to give best results as proved in simulation results. In this paper data is directly transmitted to base station by the Cluster Head. In future works, we would try to apply an algorithm for selection of optimized path to transmit the data from cluster head to base station to further increase the energy efficiency. We can apply the Ant colony optimization method to route the data packets from cluster head to Base Station to transmit the data packets through an optimal path to save the energy and to prolong the network life time of wireless sensor network.

The proposed approach is carried out in homogeneous environment where all the sensor nodes have the same initial energy level; we can also simulate the proposed approach in heterogeneous environment to check the applicability of the proposed approach in the presence of different level of initial energy of sensor nodes.

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