Particle Swarm Optimization Algorithm Based Zone Head Selection In Wireless Sensor Networks

A. Prasanth, S.Pavalarajan, M.Karthihadevi, G.Sasi

Abstract: Maximizing the network lifetime and energy consumption are the significant factors for improving the performance of mobile sink based Wireless Sensor Network (WSN). In WSN, the sensor nodes are widely distributed in a terrestrial area to sense, supervise and monitor the physical entities. But, the key problems like Zone Head (ZH) election, and optimal zone count have a direct influence on the network lifetime of WSN. This paper proposes the efficient ZH election using the Particle Swarm Optimization algorithm in which fitness value is acquired based on three parameters such as residual battery energy, a number of the neighbor sensor node and the distance (Euclidean) to the center of the node deployment area. Subsequently, the performance results confirm that the proposed model enhances the network lifetime compared with an existing model.

Keywords: Network lifetime, Particle Swarm Optimization, Wireless Sensor Network, Zone Head

1. INTRODUCTION

Wireless Sensor Network (WSN) is a category of the wireless network, which consists of a huge amount of tiny sensor nodes with single or multiple sink nodes that are deployed in the geographical area to monitor the physical environmental conditions such as temperature, vibration, and pressure. Besides the arrival of the Internet of Things (IoT) and Smart city, WSN has become more idolized. In the current scenario, WSN has been preferred in miscellaneous areas such as military applications, environment, security, surveillance, tracking down, and agriculture[1]. Furthermore, WSN will be endowed to monitor and formulate prompt alert of avalanches, forest fires, hurricanes, tectonic-plate movements, tsunami etc. WSN has been implemented for highly monitoring purposes, for instance, to monitor the climate, environment, personal health, water networks, and greenhouse. Likewise, WSN validated as an enormous tool for automation, especially for industrial automation and home automation[2]. The sensor node and sink node are the key components of WSN. The main aim of the sensor node is to collect the sensed data from the monitoring environment to sink node by transferring the data via multi-hop network There upon the sink node will further notify the user or supervisor through the internet for taking relevant action[3].Eventually, the sensor nodes in WSN are typical with less power, less energy and very small memory[4]. In many cases, the deployment of sensor nodes is very difficultattain in the sensing areas where replacement or recharge of batteries is not feasible. The sensor nodes have inadequate battery energy compared to the sink node which is mostly driven by batteries with a limited lifetime.

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Therefore, energy consumption is a major constraint in WSN due to the limited battery level of sensor nodes. Energy consumption is acquired through effective utilization of the existing battery energy level, which aids to extend the lifetime of the network.Typically, energy consumption can be achieved by clustering or zone formation approach[5]. In the zone approach, the sensor networks are separated into multiple zones. In addition, one sensor node is selected as Zone Head (ZH) and the ZH selection has a direct influence on the energy consumption of WSN. Consequently, the felicitous attention should be given during ZH selection for acquiring energy efficiency and also increasing the node reachability within the zone. In our proposed work, an efficient ZH selection can be carried out by using the Particle Swarm Optimization algorithm.The rest of this paper is as follows. Section 2 depicts the related works. Section 3 defines the proposed PSO-ZH in detail. The performance results are established in section 4. The conclusion is described in section 5.

2. RELATED WORK

This section particularly discusses about various characteristics and aspects of some widely preferred ZH selection algorithms in WSN. In addition, it provides attributes, metrics, advantages and drawbacks of corresponding ZH selection algorithms. Low-Energy Adaptive Clustering Hierarchy (LEACH) [6] is one of the major clustering routing algorithms in WSN. The key knowledge of LEACH is a motivation for many consequent clustering routing protocols. The major aim of LEACH is to create clusters depends on the received signal strength and select local ZHs that doing as routers and transmit sensed data to the sink node. LEACH randomly elects some nodes as ZHs and rotates this ZH role to consistently spread the energy consumption between the sensor nodes in the network. However, there evidently be a few demerits in LEACH. Primarily, owing to one-hop topology, LEACH algorithm is not appropriate to large-scale networks. ZHs are expected to have a high communication range, thus this algorithm can breed much battery energy. Next, ZHs are chosen without energy considerations, therefore LEACH, can simply lead to unbalance energy consumption in the network. Hybrid Energy-Efficient Distributed clustering

(HEED)[7] is a multi-hop topology method in WSN and can offer an energy-efficient routing with clear energy consideration. In HEED, selected ZHs have comparatively large average residual battery energy compared to other sensor nodes. Moreover, a significant objective of HEED method is to attain even-distributed ZHs throughout the whole networks. But, there are some drawbacks in HEED. Initially, the system of ZH selection in terms of probabilities does not recognize real uniform distribution of ZHs in the WSN. In HEED, distributing ZHS uniformly in the WSN is one significant aim in order to recognize load balancing and henceforth higher the lifetime of network. Furthermore, HEED method suffers from a resulting overhead since it requires numerous iterations to create clusters and many data packets are propagate at every iteration. Finally, some ZHs, particularly close the sink, may die prior, and the hotspot problem will arise into being in the WSN. The Distributed Weight based Energy Efficient Hierarchical Clustering (DWEHC) method is proposed[8]. The major intent of DWEHC method is to enhance ZH election via constructing a balanced zone sizes along with optimize the intra-zone topology using position awareness of the ZMs. Each sensor node executes DWEHC method individually and the algorithm ends once several iterations which are executed in a distributed manner. In DWEHC, the only locally computed parameter weight is stated for ZH selection.The following is the features of DWEHC method: (1) It is a fully distributed zone formation approach which is based on a role of the node's battery energy reserve and the closeness to the neighbors for ZH selection; (2) While considering energy reserves in ZH selection, DWEHC method makes more balanced ZHs distribution and attains considerably lesser energy consumption. Some limitations of DWEHC are summarized as follows: (1) DWEHC method utilizes single-hop communication from ZHs to the sink. As a result, DWEHC acquires larger amount of energy consumption, and is not preferred to large scale WSNs; (2) In the process of zone formation, DWEHC methods generate a large control message overhead compared to other methods. To protect node energy, power efficient gathering in sensor information systems (PEGASIS) is introduced which creates a chain of sensor nodes by using greedy algorithm[9]. A sensor node which is close to the sink is elected as chain leader node to send the fused data to the sink. It increases energy consumption, yet not possible for large network as it will arise transmission delays owing to long chains. Furthermore, sensor nodes closer to sink are selected as chain leader that arises early energy drop causing in network partitioning. Another chain based data protocol is proposed, in which the high transmission delays of PEGASIS was enhanced[10]. The entire network is separated in to cells and cell head is elected which is answerable for sending data to sink. All cell heads are related to create chain and leader having large residual battery energy is elected as chain leader. In chain based techniques, there is always a chance of electing such a sensor node that is far away from sink that may arise early drop of battery energy causing in falling network lifetime and high transmission delays.

3. PARTICLE SWARM OPTIMIZATION ALGORITHM BASED ZONE HEAD SELECTION

Particle Swarm Optimization (PSO) is a swarm intelligence optimization algorithm that associates a type of artificial intelligence. PSO is a widely adopted optimization algorithm for many real-time problems viz., multimodal problems[11]. Moreover, PSO is an efficient algorithm to solve EHP because of its higher efficiency. Henceforth, the arrival of the PSO algorithm can highly enlarge the WSNs performance in terms of energy consumption, coverage, connectivity, load balance, etc. PSO has no crossover and mutation operators in which the potential results termed particles that fly through the search space. In each iteration phase, the particles are updated by using two extreme results: one is the local result and the next one is the global optimal result [12]. Additionally, each particle stores both its position as well as velocity inside the search area where it acquires a decision based on a fitness function of the particles. Initially, the sensor nodes detect the unexpected event in each zone. Subsequently, ZH node collects the detected data, aggregate it and forward to the sink node. The main persistence of ZH is to gather data from the non-ZH members, aggregating the gathered data, and transmitting aggregated data to the central sink node. PSO algorithm is implemented to select the ZH (PSO-ZH) in which fitness value is acquired based on three parameters such as residual battery energy, a number of the neighbor sensor node and the distance (Euclidean) to the center of the node deployment area.Procedure steps for selecting ZH using PSO algorithm is demonstrated below,

Input 1: The K sensor nodes are distributed in the sensing field and it is represented by,

$$SN = \{s_1, s_2, ..., s_K\}. \quad (1)$$

Each sensor node s_i is indicated by

$$s_i = (pos_i , res_i , ns_i) \quad (2)$$

where pos_i refers the position of the sensor node i, res_i denotes the residual battery energy, and ns_i intends the number of neighbors sensor node prevailing inside its communication range.

Input 2: A Set of M particles are defined based on the corresponding sensor nodes, which is denoted as,

$$PT = \{p_1, p_2, ..., p_M\} \quad (3)$$

Each particle p_i is represented as,

$$p_i = (V_i, pos_i, pB_i, g_B) \quad (4)$$

where V_i , pos_i indicates the velocity and position of particle p_i respectively, pB_i denotes the present best results of the particle p_i has attained and g_B refers the global best result within the search space. Output: Among M particle the fittest particle will act as ZH, although its position guarantees the performance of the network in terms of lifetime, coverage and connectivity.

Step 1: The fitness value for each particle F (p_i) is computed by using the following equation,

$$F(p_i) = \alpha|NS(p_i)| + \beta \sum_{p \in NS(p_i)} p.rep + \gamma d(p) \quad (5)$$

While α, β, γ are the random number which are generated between the range (0, 1), $NS(p_i)$ denotes the neighbor sensor of the particle p_i, the residual battery energy inside a neighbor node $p \in NS(p_i)$ is referred by $p.rep$, d (p) indicate the distance (Euclidean) between the particle's position and the center of the distributed area.

Step 2: Update pBi using following equation,

$$pB_i = \begin{cases} p_i & F(p_i) > F(pB_i), \\ pB_i & otherwise. \end{cases} \quad (6)$$

Step 3: Choose the optimized pB_{p_i} value among the entire particles to update the gB using below equation,

$$g_B = \max\{pB_p \mid p \in PT\} \quad (7)$$

Step 4: Compute the new velocity for each particle using,

$$V_i(t+1) = \omega V_i(t) + c_1 * ra_1 * [pB_i - V_i(t)] + c_2 * ra_2 * [g_B - V_i(t)] \quad (8)$$

where ω be the weight factor, c_1 and c_2 designates the learning factor, ra_1 and ra_2 intends the random number which are generated between the range (0, 1) and t refers to iteration counter.

Step 5: After the computation of new velocity, all particle will update its position through the following equation,

$$pos_i(t+1) = pos_i(t) + V_i(t) \quad (9)$$

Finally, the new particle is arrived with new Vi (velocity) and new pos_i (position).

Step 6: Compute the fitness value of the new particles by using equation specified in Step 1.

Step 7: Compare the fitness value of the previous particle with a new particle and the best result is chosen.

Step 8: For each iteration, one best result is chosen as a local best result. The maximum fitness value which particle obtained in the present iteration is chosen as pB result.

Step 9: In every iteration, one local best result is obtained as well as the particle that has maximum fitness value among all local best results is chosen as a global best result (gB). Lastly, the particle which has a gB is selected as ZH.

4. SIMULATION RESULTS

In this following section, the performance results are existing to assess PSO-ZH by comparing it with DIRECT, HEED and LEACH methods in Matlab environment.The simulated network has an area of 100 x 100 m^2, where the sink is situated in the center and the numbers of nodes are taken to be 50, 100,150,200,250, and 300. The initial battery energy of all nodes is taken to be 1 J, the control packet size be 200 bits and the data packet size can be 2,000 bits. Table 1. Shows the Simulation settings of WSN.

Table 1. Simulation setup settings.

Type	Parameters	Value
Network topology	Network size	100 m x 100 m
	No. of nodes	50,100,150,200,250,300
	Channel	Wireless
	Channel type	Bidirectional
	Node deployment	Uniform
	Sink initial position	(50,50)

4.1 Energy consumption analysis

In this following subsection, the energy consumed for ZH selection and communicating the data to the sink node is assessed. Fig. 1 depicts the average energy consumption for all ZH selection algorithms. As realized in this Fig.1, the energy consumption of PSO-ZH is much lesser than those of the remaining three algorithms. The major reason for this transformation is that in PSO-ZH, the efficient sensor node is elected as ZH in the network; consequently the number of broadcast messages reduces. In remaining three algorithms, the number of broadcast messages are high. Henceforth, the energy consumed for remaining three algorithms is higher than our proposed PSO-ZH.

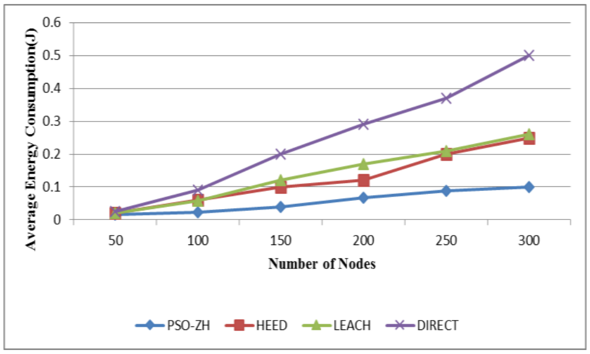
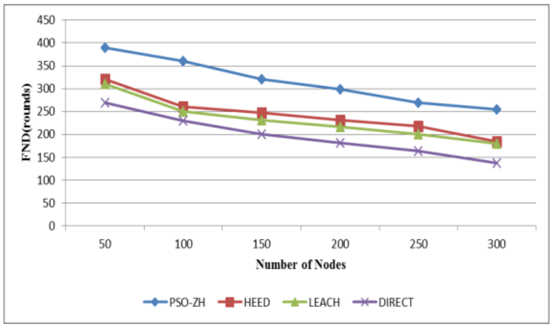


Fig.1. *Energy Consumption Comparison*

4.2 Network lifetime comparison

In order to measure the network lifetime, first sensor node die (FND) metric is performed in simulation environment. The main objective of this paper is to improve the network lifetime by considering the FND metric. As shown in Fig. 2, PSO-ZH outperforms DIRECT, LEACH, and HEED in the FND metric and it has better performance while increasing number of sensor nodes. The above performance results show that the improvements (on average) in FND are 62%, 36% and 30%, as compared with DIRECT, LEACH, and HEED respectively.



From the fig.2 demonstrated in this subsection, it can be determined that PSO-ZH create balanced zones and elects appropriate ZHs leading to the decrease of overall energy consumption. As a result, PSO-ZH algorithm is a suitable for ZH selection and also for prolonging the network lifetime of WSN.

5. CONCLUSION

The major restriction of WSN is energy consumption and the network lifetime, which are general concerns for real-time applications in WSN. By employing PSO-ZH as an efficient approach to improve the network performance of WSN. In this work, the PSO-ZH algorithm is implemented for selection of ZH node in the network. The simulation results are performed in the MATLAB software. The performance of the proposed algorithm is compared with a DIRECT, LEACH, and HEED algorithm. It demonstrates that our proposed work enlarges the network lifetime and decreases the energy consumption in WSN. In future scope, the proposed algorithm will concentrate on heterogeneous network and some real time application like forest fires, tectonic-plate movements, tsunami etc

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