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Minimize Energy Consumption and Improve the Lifetime of Heterogeneous Wireless Sensor Networks by Using Monkey Search Algorithm

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Abstract. Heterogeneous wireless sensor networks consist of various types of sensor nodes with different sensing units. Energy consumption and life time are the most significant concerns in heterogeneous wireless sensor network so that improving the balance in energy consumption increases the network lifetime. In this paper, the evolutionary approach is introduced to minimize the energy consumption and improve the life time of network. Minimizing the run times of algorithm is the major advantage of this approach.

Keywords: Energy consumption, Lifetime, Monkey search algorithm, Heterogeneous wireless sensor network

1. Introduction

Wireless Sensor Networks (WSNs) have rapidly become widely used with low-cost, low-power, multifunction sensors based on development of wireless communication which enable a wide variety of new applications [1]. These applications include pollution monitoring, critical infrastructure surveillance, disaster management and battlefield reconnaissance [2], blood pressure monitoring [3], industrial sensor [4], smart classroom [5] and etc. WSN contains a limited power battery and is constrained in energy consumption, so energy consumption is one of the most important issues in WSN [6]. However, besides energy consumption, hardware complexity is another feature that needs to be considered in network designing [7].

It is assumed that all the nodes within WSN have different amount of energy, provided that the network is heterogeneous which could be the result of reenergizing the sensor networks in order to improve the lifetime of network [8-9]. There are a lot of methods to collect data in heterogeneous WSNs. Direct transmission is one of the simple methods in which sensors forward their collected data to base station directly [10], therefore the nodes which are farthest from the cluster heads spend more energy. This method is called single hop routing [11]. Multi-hoping or indirect transmission is another data collection method in heterogeneous WSNs aimed to reduce energy consumption [12-13].

As presented in LEACH algorithm [14], randomly and periodically rotating the role of cluster head over all the existing nodes ensures that all the nodes run out of their battery almost simultaneously. In this case very low remained energy is wasted at the expiration time of the system [15]. However, disadvantage of applying cluster head role rotation is that all the nodes in the network must be able to act as cluster heads, and therefore should possess the necessary hardware capabilities [16]. This method has some advantages as follows: a cluster head can reduce the number of redundant packets by aggregating data in its cluster [17]. By limiting the domain of inter-cluster interactions to cluster heads, it maintains communication bandwidth [18]. Also, this method can minimize the rate of energy consumption in nodes [10]. In this paper the new method based on MS algorithm is introduced in order to minimize cluster heads and minimize the energy consumption and improve the lifetime of WSNs.

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The rest of paper is organized as follows: Section 2 presents an overview of related works. Section 3 describes the monkey algorithm briefly. Section 4 explains the network model and describes the problem. Then, the proposed method is presented in Section 5. Section 6 provides simulation. Finally, conclusion is presented in Section 7.

2. Related Works

Estrin et al. [20] proposed a hierarchical clustering method focuses on localized behaviour and the requirement for energy conservation and asymmetric communication in sensor networks by applying residual energy level of a node to select cluster head. LEACH-E clustering protocol has been proposed in [21] to select cluster heads according to energy left in each node. A multi-level clustering algorithm to optimize energy in wireless sensor networks has been suggested in [22]. In [23], the authors have considered multi-hop clustered networks and adjust the sensors randomly in order to calculate the optimal values of required parameters. EECS [24] selects cluster heads via local radio communication due to their more remaining energy. In phase of cluster creation, EECS considers the energy usage among nodes and cluster heads. In DEEC [25], selection of cluster heads is based on the ratio between the mean energy of network and remaining energy of each sensor node, where it is more likely that nodes with high remaining energy become head clusters. A distributed low power scheduling algorithm has been presented in [26] by T. Kim et al. to determine active time slots in a TDMA pattern which runs on a CSMA network.

3. Monkey Search Algorithm

The Monkey Search (MS) is a meta-heuristic approach for global optimization [27-28] that invented by Mucherino and Seref in 2008 [30]. It resembles the behaviour of a monkey climbing trees in its search for food. The main assumption in this approach is that a monkey is able to survive in a jungle of trees because it is able to remember food sources previously discovered. When the monkey climbs up a new tree for the first time, it can only choose the branches of the tree in a random way, because it does not have any previous experience on that tree. Upon climbing down the tree, the monkey marks tree branches with respect to the quality of the food available in the subtree starting at that branch. When the monkey climbs up the tree again later, using the previous marks on the branches, it tends to choose those branches that lead to the parts of the tree with better quality of food [29]. MS takes advantage of concepts and strategies from other meta-heuristic methods like Genetic Algorithms, Differential Evolution, Ant Colony Optimization and etc. [29]. Each cycle in MS produces a new generation of possible solutions for a given problem [13]. The main components of the algorithm are Representation of Solution, Fitness Function, Initialization, Exploring, Climb Process, Watch-Jump Process and Termination which described in section 5 [30-32]:

4. Network Model

In this paper, only sensor node-cluster head communications are considered. The topology of network is shown with an undirected weighted graph $G=(V, E, c)$ in the two dimensional surface, where $V=\{n_1,n_2,\dots,n_S,n_{S+1},\dots,n_{C+S}\}$ represents the set of nodes, and E is the set of edges, $E=\{(ni,nj)|dist(ni,nj)\leq Rmax\}$, in which $dist()$ shows the distance function. Where C is the number of cluster head in heterogeneous wireless sensor network and S is the number of sensor nodes that $S<<C$. Sensor nodes include the first C nodes in V, and the cluster heads are the last S nodes. The energy consumption is represented by the cost function $c(u,v)$ for both nodes u and v to create a bidirectional relationship between u and v. A unique id is given to each node which can collect its own position information by using one of the wireless sensor networks localization techniques [33]. By using the maximum transmission range $Rmax$, node s_i can reach a set of neighbourhood nodes [13]. In the next section, a new method based on MS algorithm is proposed to optimize the number of head clusters in WSNs.

5. Proposed Method

In this section, the MS algorithm is proposed to solve cluster head placement problem involved in heterogeneous WSN which is NP-Hard problem as stated in section 4. In the following, we describe eight components of MS algorithm to solve the above mentioned problem.

Representation of Solution: In order to represent the monkey behaviour in this method a binary tree is used. In this representation, at each step two new solutions are generated that the one monkey chooses to climb is considered as a cluster head and the other one, monkey rejects, is considered as sensor node.

Fitness Function: Solutions are evaluated by fitness function and the quality of available food varies with fitness. In this problem, the important factor which requires reducing is the energy consumption. The following combined fitness components are used to evaluate each solution [13]:

$$Fitness = (w \times (D-I) + (1-w) \times (N - S_i)) / 100, \; I = I_n + I_s \quad (1)$$

Where, the total distance of all nodes to the target node is represented by *D*; the total number of nodes is N and w is a weight defined previously. In and Is show the distances from sensor nodes to cluster head and sum of the distances from all cluster heads to target node, respectively; the number of cluster heads is represented by *Si*; all parameters have constant values in a given topology, except *I* and *Si*. When the distance is shorter or the number of cluster heads is lower, the fitness value of solution is higher [13].

The values of weights depend on application that determines the main factor from two factors of distance and cost resulting from cluster heads. The sensor network is optimized only based on the communication distance with a condition of *w=1*; but in *w=0*, only the number of cluster heads optimized [13].

Initialization: The search region of MS algorithm is based on population. The initial population consists of solutions generated in a random way. Based on the number of nodes in the sensor network, the size of population is varied and specified [13]. In this method the population size considered equal to the number of nodes. And here, we consider a region such as hypercube containing potential optimal solutions [32].

Exploring: In this method, at each step, two new branches are created randomly and placed on two nodes of the tree. The monkey selects one branches based on random mechanism to climb. And the random mechanism is mainly based on fitness function values of the solutions. This process continues until reaching top of the tree [29]. By climbing up, monkey builds paths to reach to the top of the tree, then by climbing down it selects solutions with better quality of food based on fitness function.

Climb Process: During climbing, monkey is able to remember food sources traversed before. So, after reaching top of the tree and making the path, it starts to search better food based on fitness function. The fitness function value at the top of the tree is considered as the initial marker value [29]. While climbing down the tree, it marks tree branches according to the quality of solution and compares the fitness function value of that branch with the initial marker. When it finds better quality solution, it remember its position, and continues this procedure until finding the best quality food which is known here as cluster head [29].

Watch- Jump Process: At each step, monkey checks whether there is a higher branch than its current position. If so, it jumps to that branch in order to continue its exploring. In this method, checking is based on monkey's eyesight which indicates the maximum distance it could watch [30-32].

Somersault Process: In this method, in order to explore new regions to find better solutions and avoid getting trapped at local optima, monkeys are able to somersault across a pivot which is created based on a centre of mass of current positions of all the monkeys [30-32]. Also, after finding a cluster head, here it means a food with better quality, the monkey somersault to another region in order to find new head cluster.

Termination Condition: The MS algorithm continues running until no improvement in the value of fitness function is obtained.

6. Experimental Results

Since it is hard to implement the proposed method, we have simulated it with MATLAB software. Simulation results are presented in this section. The area in which sensor nodes are spread is 15 × 15. The number of sensor is 50. The target sensor is located at the (7, 7). We have generated 30 generations in order to optimize the energy consumption in nodes.

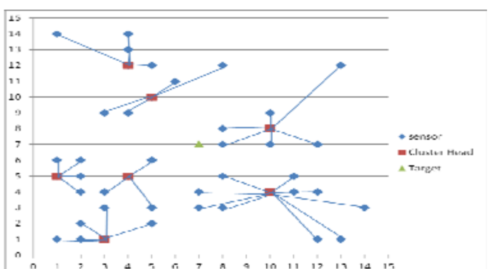

Fig. 1: Schematic of proposed network with w=1

Figure 1 shows the schematic of the network in which sensors are connected to their nearest cluster head with w=1 in order to optimize the network only based on the communication distance in which the number of cluster heads is 7 and the location of target node is in (7, 7).

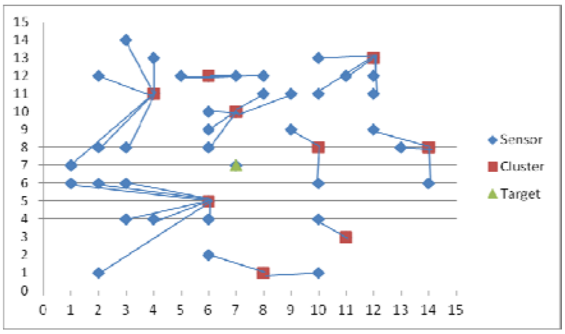

Fig. 2: Schematic of proposed network with w=0

Figure 2 shows the schematic of the network in which sensors are connected to their nearest cluster head with w=0 in which the number of cluster heads is 9 and the location of target node is in (7, 7) in order to reduce the number of cluster heads.

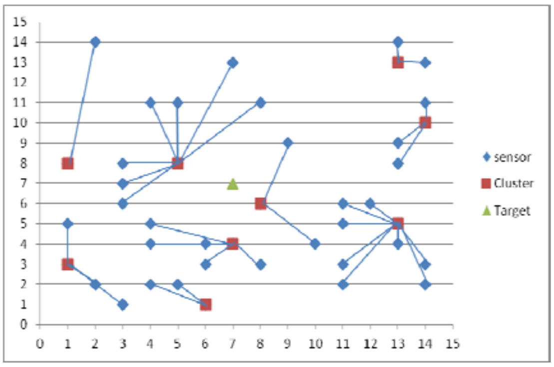

Fig. 3: Schematic of proposed network with w=0.5

Figure 3 shows the schematic of our proposed network in which sensors are connected to their nearest cluster head with w=0.5 in which the number of cluster heads is 9 and the location of target node is in (7, 7) which is a tradeoff between two previous cases. Simulation results show that in our proposed method the fitness is improved in each generation. After some generations the value of fitness is satisfied. So this method minimizes energy consumption and optimizes the life time of network by selecting the best cluster head.

7. Conclusion & Future Work

One of the most important factors in heterogeneous wireless sensor network is energy consumption. In this paper, a new method based on MS algorithm has been introduced to minimize energy consumption and optimize the life time of network by selecting the best cluster head.

As a future research new algorithms can be developed by combining various methods like genetic algorithm, fuzzy logic, harmony search to solve different types of optimization problems.

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