[1.]Omid HAJFATHALI, [2.]Ali NAJARI, [3.]Mehdi HOSSEYNZADEH

TREE-BASED ROUTING PROTOCOL IN WIRELESS SENSOR NETWORKS USING OPTIMIZATION ALGORITHM BATCH PARTICLES WITH A MOBILE SINK

[1.]Qazvin Azad University, Department of Electrical Engineering and Industrial Informatics, Qazvin, IRAN
[2.]Sapienza University of Rome, Department of Computer, Control and Management Engineering, Roma, ITALY
[3.]Iran University of Science and Technology, Department of Electrical Engineering and Industrial Informatics, Tehran, IRAN

Abstract: Wireless sensor networks include a large number of sensor nodes that are distributed over a given range. To improve energy efficiency and delay, which are two important criteria in wireless sensor networks, tree-based routing protocols are common. In this paper, we present a minimally invasive veneer tree using the particle optimization algorithm for routing wireless sensor networks with a moving sink. This algorithm is population-based, and population members try to find a tree that has less energy and latency by sharing routing information. The proposed algorithm was compared in terms of energy consumption, distance, and the number of steps with previous algorithms. The simulation results showed that the improvement of the proposed protocol compared to the MWST method is on average in energy, distance, and step 30, 40, and 36 percent, respectively.

Keywords: Wireless sensor networks, tree-based routing protocols, optimization algorithm, MWST method

INTRODUCTION

Recent progress in digital circuit technology leads to the appearance of low cost and energy node sensors that have small sizes. Since the energy of the sensors in the sensor's network is limited and their battery is not rechargeable, finding an optimum routing based on this energy network is one of the most important problems [1-2]. Moreover, in the applicable program like physical penetration recognition systems, a low delay time is as important as energy consumption. It can be said that one of the most important benefits of using a tree as a routing topology are routing in a straightforward way since the path between each node is unique, and data aggregation can be done to decrease the amount of data by combining related data [3]. To save the energy in the communication link and decrease the bandwidth, the compressed-sensing methods are using in the system identification and controller paradigms [4]. Despite wired communications the time/frequency-based methods [5-8] are not sufficient to guarantee the link performance.

In [9], a routing tree is showed based on the spanning tree with the mobile Wiener index. In this paper, the simulated annealing method has been used to produce a tree. In [10], routing trees for sensor networks with fixed sink has been demonstrated based on a minimum spanning tree (MST) and the shortest unique path tree (SPT). MST protocols connect the network's nodes together like a tree using the prim's algorithm, and routing has been done based on this tree. In [11] a protocol for minimum spanning tree named PEDAP is proposed. This protocol increases the longevity of the network while reduces energy consumption. Routing information is calculated using the prim's optimum spanning tree algorithm.

In [12], a new routing protocol named DCMST with a fixed sink is demonstrated. This protocol is based on a hierarchical tree and uses degree limitation as a routing tree. Sensors are categorized into different clusters, and in each cluster, a routing tree for sending data is being made. In [13], asynchronous dissemination protocol with minimum energy consumption named SEAD, which is using a low-cost-weighted-Schneider tree for routing steps, is proposed. In SEAD, a mobile sink is considered.

In this paper, we have demonstrated the spanning tree with a minimum Weiner index, which is using particle swarm optimization (MWST-PSO) as a routing topology in wireless sensor networks as well as using a mobile sink. The proposed protocol tries to have less energy consumption and delay compared to the previous works. In [9], the simulated annealing method has been used to produce a tree.

The paper has three sections: In section two, the proposed method with considering the definition of Weiner index spanning tree with minimum Weiner index, particle swarm optimization is explained. Evaluation and simulation results are also demonstrated. The conclusion has been shown in Section three.

THE PROPOSED ROUTING PROTOCOL BASED ON TREE USING PARTICLE SWARM OPTIMIZATION

In this section, the required concepts for solving the problem like the Weiner index, the tree with minimum Weiner index, and particle swarm optimization algorithm are explained. Then, the method to obtain the spanning tree with the minimum Weiner index using the PSO algorithm is represented. In the end, the results of the simulation are depicted.

— Tree with the Minimum Weiner Index

For a specific graph $G=(V(G),E(G))$, the distance $d_G(v,u)$ between two nodes $v,u \in V(G)$ is defined as the shortest path from u to v in the graph G. The Weiner index from graph G is defined in equation (1):

$$\frac{1}{2}\sum_{u\in V(G)}\sum_{v\in V(G)}d_G(u.v) \quad (1)$$

The problem of MWST is defined by finding a spanning tree from a weighted tree. The weights of the graph's edges are defined by Euclidean distance. In graph G, the problem of MWST is represented by finding a spanning tree t^* from all the spanning trees t in graph G so much so that $\sigma(t^*)\le\sigma(t)$. The Spanning tree t is a tree that includes all the nodes and is a subset of graph's edges. In fact, we have these two conditions in a spanning tree: $E(t)\subseteq E(G)$ and $V(t)\subseteq V(G)$.

— Particle Swarm Optimization

The PSO algorithm was proposed by James Kennedy and Eberhart in 1995 [14]. The PSO algorithm has been inspirited by the social behavior of a group of birds. Since PSO is working in a group manner and has a fitness function, it is like an evolutionary algorithm, but the main difference is that each member gets benefits from their past information, while there is no such behavior in evolutionary algorithms. In PSO, any member of the population can change its own position based on personal and population experiences. Sharing social information between members of a society can lead to evolutionary benefits and this assumption is considered as a basis of the PSO algorithm. In this algorithm, each bird is a possible solution in a problem searching space, which is named a particle. At first, the PSO is initialized with assigning random values that are generated in the problem space and then searching for finding the best solution is started. In each iteration, the particle moves toward the better position and the next position for each particle is obtained by considering two values: the first value is the best position that the particle has had up to that moment (Pbest) and the second value is the best value that all the particles have obtained. In fact, it is the best Pbest in the whole population (Gbest). This process is continued until obtaining a desirable solution. Considering the P_{best} and G_{best}, each particle uses equation (2) and (3) to obtain the next position:

$$v_i(t)=wv_i(t-1)+\rho_1c_1^*(P_i-X_i(t-1))+\rho_2c_2^*(P_g-X_i(t-1)) \quad (2)$$

$$X_i(t)=X_i(t-1)+v_i(t) \quad (3)$$

ρ_1 and ρ_2 are the random parameters in [0,1]. c_1 and c_2 are defining as learning parameters for P_{best} and G_{best} and should always observe $c_1+c_2\le 4$. w is a parameter that controls the inertia of particles' moving. Researches show that the best value for it is a value between 0.4 and 0.7. P_i is the P_{best} of the particle i and P_g is the G_{best}. $X_i(t)$ and $v_i(t)$ show the current location and the velocity of the particle i respectively [15].

— The Spanning Tree with Minimum Weiner Index Using the Particle Swarm Optimization Algorithm

In this paper, the object of obtaining the spanning three with minimum Weiner index is actually finding a tree with low energy consumption and steps for routing in a connected graph G. To find this tree; particle swarm algorithm is used. The optimization using the particle swarm algorithm is initialized using a collection of random solutions. Here, each solution is equal to a spanning tree. Then the solution tries to optimize itself. The criterion that shows which solution is better is the Weiner index. In fact, when the Winer index of the next solution is less than the current solution's one. Figure 1 shows the flow chart of the proposed algorithm.

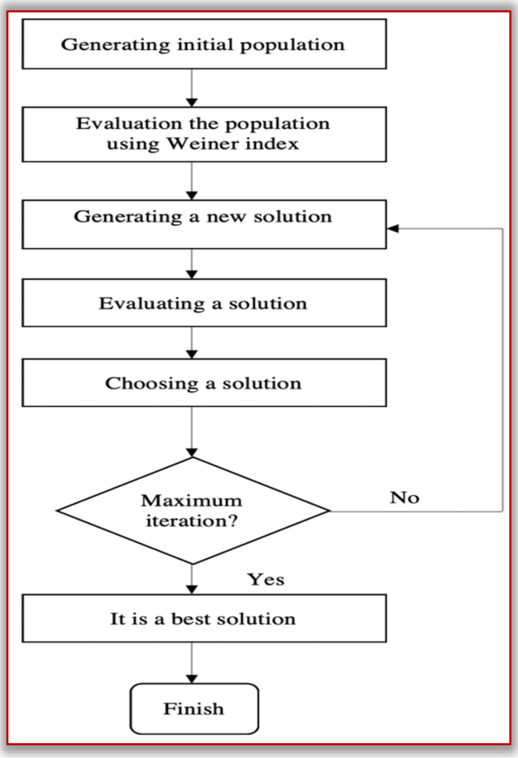

Figure 1. The proposed algorithm

The MWST-PSO can be defined with these steps:
1-Generating a collection of random trees as an initial papulation
2-Evaluation the initial population using Weiner index
3-Obtaining Pbest and Gbest
4-Updating current solution using the PSO algorithm
5-Evaluating the new solution using Weiner index
6-If Wiener index of the new solution is less than the current one, replace the current one with the new one
7-Continue steps 4 to 6 until reaches the maximum iteration
8-Peak the best solution which is the same Gbest

The time complexity of the proposed algorithm is O(n^3) which n is the number of nodes. Since the proposed algorithm is being executed in the sink, the overflow computation of the tree obtaining has been neglected.

— Function evaluation

In this section, we want to evaluate the function of three algorithms MST, MWST, and MWST-PSO with transfer distance, the average of steps, and energy consumption criteria using MATLAB simulation. In the simulation, the homogenous simulation environment is considered for all sensors, and the energy loss due to collision and eavesdropping is not considered. The Network's field is 200 by 200 meters, and 40 to 150 random nodes are positioned inside it. It is assumed that the initial energy of each node is 2 Joule, and each node generates the fixed-length 1000 bits data. The required energy for data transferring when one node sends k bits package of data to its 4-meter distance node can be obtained by equation 4:

$$E_{TX}\left(k,d\right)=E_{TX}\times k+\varepsilon_{amp}\times k\times d^{2} \quad (4)$$

The required energy for receiving the data can be calculated by equation 5:

$$E_{RX}\left(k\right)=E_{RX}\times k \quad (5)$$

Hence, the required energy for transmitting and receiving k bits package of data between two nodes, which are located in the 4-meter distance of each other, is equal to the summation of equations 4 and 5. The simulation results are obtained by taking an average from fifteen execution of the algorithm [16-17]. The parameters for an energy-consumption model are demonstrated in table 1.

Table 1: Parameters in the energy-consumption model

Parameter's name	Value
Energy for sending data	50 Nano Joule per bit
Energy for receiving data	50 Nano Joule per bit
Energy to support sending	100 Pico joule per bit per meter square
Height and width of the filed	200 * 200
Initial energy	2 Joule
Packet size	1000 bits

In the simulation, it is assumed that three random sinks have been positioned in the environment and each sink is moving with the velocity of 10 meter per each round and its direction is considered 10 percent of each sink randomly. Each simulation lasts for 360 rounds. In this paper, it is assumed that all nodes have information about the structural connection of the network. It is also assumed that nodes transmitter sensors are aware of the location of the target sink and the steps of routing to the nearest sensor to the sink. Because of the tree structure, there is a unique path between each couple of nodes and the packets are sent to the sink using a routing path between a source node and the nearest node and eventually packets can reach to the target sink using the nearest node to the sink named the gate node. Figure 2 shows an example of this process that node n is the nearest node to the sink b.

In the simulation, the packet's transfer distance is calculated with the summation of the transfer distance for all the packets in the 360 rounds execution. Figure 3 shows the packet's transfer distance when the number of sinks is three. As we can see from figure 3, the packet's transfer distance of MWST-PSO is less than MWST and MST and when the number of sensors increases, the difference between transfer distances is also increased. The improvement of transfer distance in the proposed protocol is about 40 percent comparing to the MWST protocol.

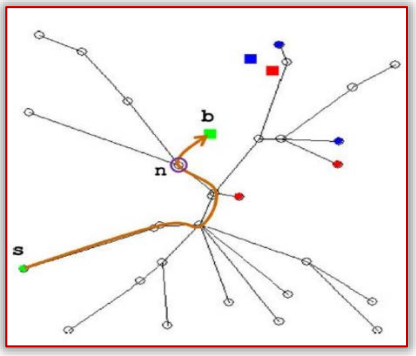

Figure 2. Sending a packet from a source s to the mobile sink b using the nearest neighbour sensor [4]

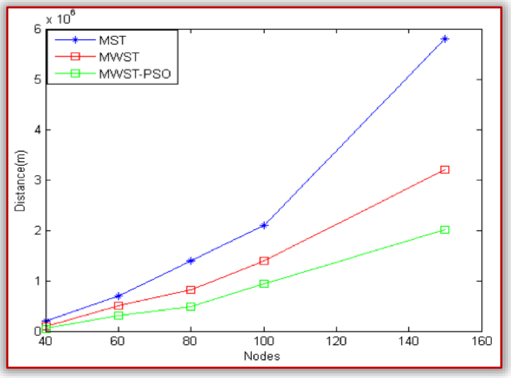

Figure 3. Transfer distance comparison with different sensors' numbers

Figure 4 shows the comparison of energy consumption for all three trees. Consumed energy is equal to the summation of the energy which is consumed by all sensors during the 360 rounds of transmitting and receiving the data. The improvement of energy consumption in the proposed protocol is about 30 percent comparing to the MWST protocol.

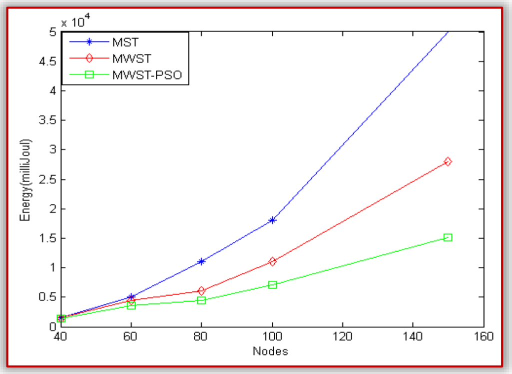

Figure 4. Energy consumption comparison with different sensors' numbers

Figure 5 shows the average number of steps for three routing trees: MST, MWST, and MWST-PSO. The mean of steps' number is the average of the steps for all the packets during the 360 rounds execution. The figure shows that MSWT-PSO outperforms the MST and MSWT in delay time and as it can be seen from the figure it remains constant when the number of sensors and steps increases. The improvement of steps' number in the proposed protocol is about 36 percent comparing to the MWST protocol.

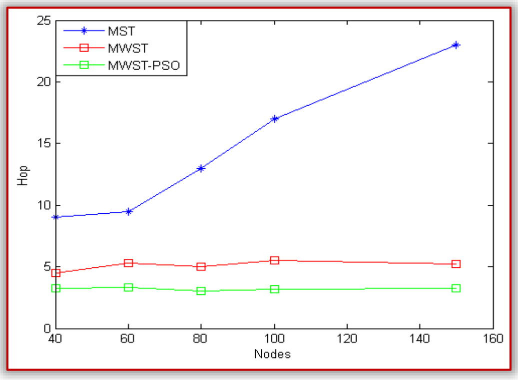

Figure 5. Steps' number comparison with different sensors' numbers

CONCLUSION

In this paper, we proposed a spanning tree with minimum Weiner index for wireless sensor networks with the mobile sink. For a network that sensors are connected completely, finding a spanning tree with the minimum Wiener index is an NP-hard problem. For solving this problem, we proposed a particle swarm optimization. The simulation results showed that the improvement of the proposed protocol in energy, distance, and steps is about 30, 40, and 36 percent respectively, compared to the MWST protocol. So, we can conclude that MSWT-PSO protocol has acceptable properties for being used as a routing tree in wireless sensor networks with multiple mobile sinks, especially in energy consumption and less delay time factors. The MWST-PSO is not appropriate enough for large sensor networks which include hundreds of nodes. Consequently, the more precise algorithm is required for making a tree in a wireless sensor network that observes the given time limitation.

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