EEPMS: Energy Efficient Path Planning for Mobile Sink in Wireless Sensor Networks: A Genetic Algorithm based Approach

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Abstract. The area of Wireless Sensor Networks(WSN) is continuously researched because of its vast application in various domain. The main constraint of WSN is the energy of the sensor nodes. The use of Mobile Sink (MS) is one of the prominent method to preserve the energy of sensor nodes. Moreover, use of mobile sink is also solving the hot spot problem in the network. In the paper, authors first propose a Genetic Algorithm based approach to plan the path for mobile sink and other algorithm based on Greedy approach. All the basic intermediate operations i.e. Chromosome representation, crossover and mutation are well explained with suitable examples.The simulated result depict the efficacy of the proposed algorithm over existing algorithms.

Keywords: Mobile Sink · energy Efficacy · Wireless Sensor Network · Path Planning · data gathering.

1 Introduction

Wireless sensor networks (WSNs) is the network small tiny devices known as sensor [1]. These sensor nodes have sensing capability, limited memory and computational power [2]. Moreover, the area of wireless sensor networks is continuously researched by the research community due to its vast application in the area of military surveillances, health care, security, habitats monitoring [3–5]. In WSNs, a sensor nodes sense the region for collecting the information. After collecting the information, sensor nodes forward the data to its next hop node towards the base station [6–8]. As the sensor nodes have limited battery, so one of the most important constraint in WSN is energy consumption [9]. Generally,

the energy of sensor nodes consumed due to aggregation of the data, forwarding the data and receiving the data. Moreover, in WSN the energy consumption is quadratic proportional to distance between the sender and receiver [10]. The lifetime of network is dependent upon the backup usage, so for better network lifetime it is necessary that individual sensor node consumes minimum energy for forwarding the sensed data. Moreover, Research scholars have given many mechanisms to improve the network Life such as routing [11, 12], clustering [13].

In WSNs, the sensor nodes near to the sink die quickly because these nodes are overburden as they receive data of such nodes which are so far from the base station. In this situation, there are many cases where nodes near to base station (BS) completely depletes the energy and some node(s) have energy more than 90%. As some node dies then network is partitioned in parts and sensor which has sufficient energy may not able to forward the data to BS. To resolve such kind of issue, several researchers have given the concept of sink which moves [14–16]. An example of WSN with sink that moves has been depicted in figure 1, which as follows: In figure 1, it is clearly seen that there is a sink which

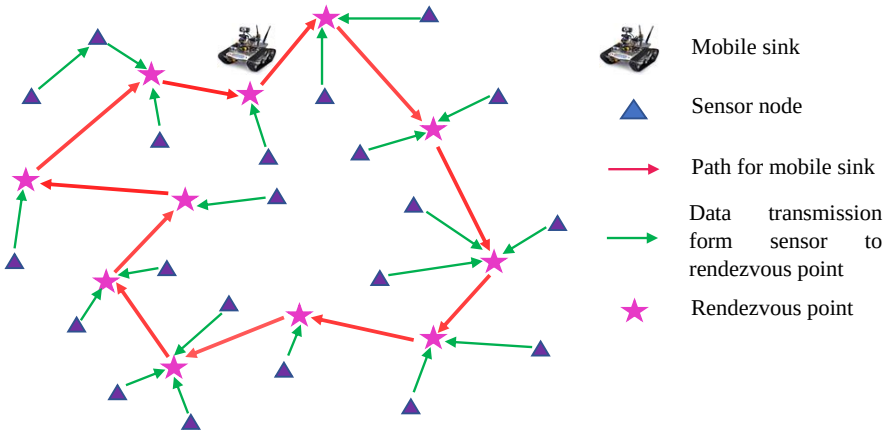

Fig. 1. scenario of wireless sensor networks with mobile sink.

moves over a predefined trajectory over rendezvous points. Generally there are two method to decide the path of mobile sink 1) random and 2) controlled. The random movement of mobile sink leads to uncontrolled behavior as well as buffer overflow. In controlled mobility, some researchers have proposed two methods for collecting the data 1) mobile sink (MS) moves towards the sensor nodes and collect the data. However, in this method the path of mobile sink is too long, further it increases the information delivery time. The other method is sink visits limited number of nodes known as rendezvous points. The sink stops and stay

at rendezvous points (RP) [17] for a predefined time. The sensor nodes either moves information directly to rendezvous points or via multi-hop [18].

In recent past, WSN is continuously researched and researchers have proposed many algorithms for the mobile sink, which may found in [19–21]. The mobility algorithms are categories in random and controlled mobility. The implementation of random mobility strategy is easy as only some of the RPs selected. However, this method increases the delay during the data gathering. In [17], authors presented a novel approach based on the precise mobility. Moreover, the path is static for MS over RPs and SNs are also randomly organized on the basis of RPs. Gafoor et al. [22] have applied one of the popular technique named as Hilbert Curve to prepare the path of MS. In this technique, all the SNs forward the sensed data to RPs in one hope communication. However, length of path is high and this method is not feasible for sensitive application such as Military surveillances. A delay restricted method for mobile sink is presented in [23]. However, disadvantages of algorithm is that it has very high time complexity i.e. $O(n^5)$.

In WSN with mobile sink, there is a big challenge to decide the no of RP as increasing the number of RPs may alleviate the data delivery latency. However, the shorter number of RPs may increase the data delivery latency but there may be a possibility that sensor nodes forward the information to RP using multihop communication. Beacause of multihop communication energy of some of the sensor node(s) deplete quickly. Therefore, while designing the the trajectory it is desired that the length of the trajectory should be minimum and minimum number of sensor node(s) forward the data to RP by multi-hop transmission.

In this article, we address the same issue and propose two energy efficient based on Genetic Algorithm (GA) [24] and greedy approach. In GA based approach, we optimize the number of RPs using some criteria function. The criteria function has three different parameters i.e. the length of the MS tour, minimum number of multi-hop transmission and load of RPs. In GA there are some intermediate steps such as chromosome representation, selection, crossover and mutation. All these steps are well explained with suitable examples. The second procedure is based on greedy method with the same criterion function as used in GA based approach. During simulation, both the algorithms were compared in terms of length of the tour, no of nodes which directly transmit the data to RP, node count which transmit the information to respective RP using multihop and network lifetime.

2 System model and terminologies

In the proposed work, authors have made assumption with network to have formed using homogeneous sensor nodes and these nodes are deployed randomly in the predefined region. There is a sink, which moves in the area and stay at some predefined RPs for a sufficient time for gathering the data. Moreover, the speed of sink is constant. This was also assumed that after the deployment nodes are stationary and communication between the two is possible only when they are in

the communication range of one another. The Network is in functioning condition till some percentage of nodes alive. For the simulation purpose, Authors have considered the energy model discussed in [25]. The terms used in the article is as follows:

- S=$\{s_1, s_2, s_3 \dots s_n\}$: Represents the set of n number of sensor nodes.
- $P = \{p_1, p_2, p_3 \dots p_m\}$: represents the set of m number of potential position which may act as RP and $m \leq n$.
- $DIST(s_i, s_j)$: represents euclidian dist in between node s_i, s_j.
- $Tcost$: Represents the cost of the tour.
- $NW1H$: It represents the numbers of nodes with 1-hop from RPs.
- $LoadRP(i)$: It stores the information that i_th RP receives the information from how many sensor nodes.
- Dif: It represents the difference between maximum and minimum value $LoadRP(i)$.

In this research article, two algorithms is discussed. The detailed explanation about both the algorithm is discussed in following section.

3 Proposed Algorithm

In following subsections first, there is a discussion about algorithm based on the GA. In other section there is a discussion about the Greedy based strategy for the path planning of mobile sink.

3.1 Genetic algorithm based approach

There are mainly three intermediate operations in GA. All these steps are well explained in following sub section.

3.1.1 Chromosomic representation and initial population :

In figure 2, a sub-graph of WSN is shown. There are 23 sensor nodes and out of 23, 11 act a RP. The chromosome representation for this network is presented in figure 3.
In proposed work, the chromosomes are randomly generated. The length of chromosomes is fixed and is same in number as that of sensor nodes. Collection of chromosomes is known as initial population.

3.1.2 Fitness function and Selection :

The performance of chromosome is always judge by using the fitness function. Also fitness function decides that which chromosome is good for the next level operations i.e. crossover, mutation etc. In the proposed work, to design the fitness function three parameters has been used 1) length of the tour of the MS 2) load in RP, it means that RP receives the data from how many sensor nodes and 3)

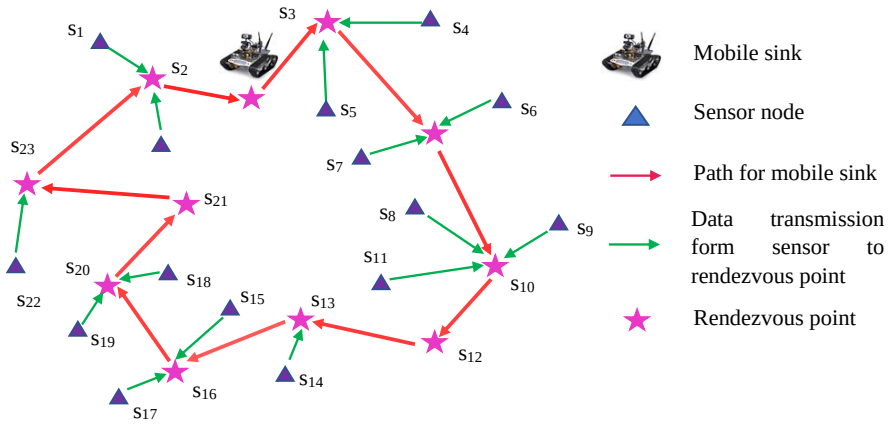

Fig. 2. A sub graph of WSN having 23 number of sensor nodes. Out of 23 11 sensor nodes act as RP.

Sensor node	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23
Gene value	0	1	1	0	0	1	0	0	0	1	0	1	1	0	0	1	0	0	0	1	1	0	1

Fig. 3. Chromosome representation for the graph given in figure 2.

number of nodes which forwards the data to RP using multi hop. The proposed fitness function is represented as follows:

$$Minimize\ F = w_1 \times Tcost + w_2 \times \{n - NW1H\} + w_3 \times Dif$$

where w_1, w_2, w_3 represents the weights and $w_1 + w_2 + w_3 = 1$.
There are many methods for selection operation but in proposed algorithm Roulette Wheel method has been used.

3.1.3 Crossover and Mutation During crossover operation, parent chromosomes interchange the information with each other and form two new chromosome named as child chromosomes. After the crossover operation best two chromosome replace the parent chromosomes. In proposed work, 1-point crossover has been applied which is similar to crossover operation discussed in [26]. During mutation operation, we have tried to minimize the number of RP by flipping the gene value.

3.2 Greedy based approach

The greedy based algorithm for path planning of mobile sink is as follows:

4 Experimental result

The authors of this article have performed rigorous experiments on the Algorithm proposed. The experiment was conducted on MATLAB (version 7.5) with a machine having Processor: Intel Core 2 Duo (2.53 GHz) and Chipset T9400, RAM size as 2 GB running on the MS Windows Vista platform. For the experiments, Authors have taken a WSN scenario assuming that the relay nodes are fixed in 200 200 sq meter span. The position of the sink node is (215,100). Authors have used the same energy model with the similar parameters as that used in LEACH [4]. it was also considered initially 300 chromosomes population. For performing crossover operation, authors have selected the 5 best chromosomes using tournament selection Method. A total of 150 iterations were performed for the proposed algorithm. However, it started showing high-quality results after 30 epochs. The number of relay nodes also varied from 4 to 40 during the run of the algorithm. For the purpose of comparison, MHRM algorithm [14] was also executed, [5] while keeping the same experimental parameters as that int the algorithm proposed . The result of after the simulation of both the algorithms were compared in terms of number of rounds (i.e., network life time) and consumed energy , as shown in Fig. 5.

5 Conclusion

In this article, authors have discussed two algorithms for path planning of mobile sink. One of these is genetic based algorithm and other one is greedy based approach. Both the algorithms are well explained with suitable examples. The fitness function for GA based approach is depend on tour length of MS, number of multi hop nodes and load of RP. Moreover, the same criteria is also used by greedy based approach. For the purpose of result comparison, authors have executed the algorithm in which the arbitrary no of sensors act as a RP and it is observed that the GA based approach outperforms with greedy based and random approach. We are currently working on the node deployment and try to incorporate the issue of mobile sink during the deployment.

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