

GUIDING HYPERPLANE EVOLUTIONARY ALGORITHM FOR OPTIMAL LAYOUT OF WIRELESS SENSORS NETWORKS

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Abstract: *Wireless Sensors Networks are widely used to monitor the areas. In many WSN applications it is important to achieve a good coverage of the observed area while the energetic efficiency and the lifetime of the network are high. The task of placing the sensor nodes while addressing these objectives is known as WSN layout problem. As the optimal sensors network layout can be reformulated as a multiobjective optimization problem, the paper presents a possible use of GHEA technique for solving the considered problem.*

Key words: *optimization, WSN, evolutionary, multiobjective*

1. INTRODUCTION

In many WSN applications the critical issue is the coverage of the monitoring area. Other applications demand an increased network lifetime. Generally, both criteria are fundamental and should be taken into consideration when the WSN is deployed. As the complexity of the problem is high, a metaheuristic option would be appropriate. Evolutionary algorithms are an interesting alternative for solving Optimal WSN layout problem. In (Molina et al., 2008) the problem is formulated as a bi-objective problem which involves the maximization of the network's lifetime, and the minimization of the number of sensor nodes, in order to reduce the network cost. Another work presented in (Jourdan et al., 2004) considered the coverage and lifetime of the network as the objectives of the optimization problem and the solutions are obtained by a popular evolutionary technique for multiobjective optimization: MOGA. Other interesting problems related to the wireless sensor network's issues have been successfully approached by evolutionary techniques: (Yildirim et al., 2008), (Sajid et al., 2008), (Wang et al., 2007).

Recently, our work focuses on solving the optimal layout of the sensors using an original evolutionary technique called Guiding Hyperplane Evolutionary Algorithm. The approach proves itself suitable for the considered problem. Next, we extend our work in a more general case, where the sensing and communication radius of the sensors differs.

2. OPTIMAL WSN LAYOUT PROBLEM

Optimal sensors network layout can be reformulated as a multiobjective optimization problem. The involved criteria are several to be considered: lifetime of the network, communication's efficiency, degree of the connectivity, coverage of the network, and so on. In this paper, we formulate the problem of optimal placement of sensors as a bi-criteria optimization problem, emphasizing the two major objectives which derive from the main functions of the sensors: communication and sensing. Sensor networks represent dense wireless networks of small, low-cost sensors, which collect and disseminate environmental data. Each unit of the network is attached by a battery that provides a limited amount of energy. The purpose of a sensor is to sense or react smartly at a possible event in its neighborhood and to transmit the proper

information to the High Energy Communication Node (HECN) of the network. Given the sensing radius, a sensor is able to gather the right information from its vicinity and further transmit it to the HECN. Data transmission to the special node is done directly or via hops, using nearby sensors. Therefore, each sensor also behaves as a communication relay. The communication between two sensors is possible if they are within a fixed distance. Given the communication radius, two sensors are allowed to communicate if the distance between them is less than communication radius.

The *lifetime* of the entire network is measured by the elapsed time until the first sensor spends the initial allocated energy (*Time to First Failure*). Beyond other tasks, each data transmission accomplished by a sensor decreases its energy, and consequently, the lifetime of entire network. Therefore, the lifetime of the network depends by the maximum number of communication tasks of its nodes. In optimal sensors placement problem, we focus on finding a configuration which does not comprise nodes engaged in too many transmission activities.

The *coverage* of the network represents the other major criteria in optimal placement of the sensors. The coverage of a specific network is given by the ratio between the area of the union of the disks centered at the sensors' positions, of sensing radius and the total area of the region in which the sensors are placed. Better coverage affects in a positive way the quality of the network. Therefore, this objective is maximized.

Another criterion in finding the optimal position of the sensors arises from the connectivity degree of the network. This objective of our problem can be simply reformulated as a penalization of the other two major criteria.

According to the two main functions of a sensor: sensing and communication, two major objectives arise: the first refers to the lifetime of the network and the second one measures the coverage of the net.

3. GHEA FOR OPTIMAL SENSOR NETWORK LAYOUT PROBLEM

In a previous article (Rotar et al, 2009) GHEA technique was successfully applied on the optimal layout of the WSN problem. Then, the sensing and communication radius was set to be equal. Further, we reconsider the problem, taking into account different values for those two parameters of the sensors.

In optimal sensor network placement, a solution is given by any configuration of sensors' locations on the given map. For simplification we consider that the region where the sensors are placed is a 2-dimensional area, and each sensor's location is given by the pair of coordinates (x_i, y_i) . A possible network of n sensors located on the map is represented by the vector: of n pairs of coordinates. In our approach, we consider a homogenous network; each sensor has the same initial energy. One sensor will consume exactly one unit of energy per each transmission it makes. Therefore, if one sensor behaves as a communication relay, and the number of transmission tasks is higher, its lifetime decreases accordingly and further the

lifetime of the network decreases. At one time, a particular network should send data from all sensors to the HECN in an optimal manner. Optimality in this context refers to the problem of finding the minimum paths from the HECN to each sensor. For completing this job, Dijkstra's algorithm is applied. After the minimum paths are found, the number of transmission tasks per sensor is computed. The number of transmission tasks per sensor is measured by the total number of inputs and outputs a sensor has to assure. The standard deviance of these values offers an appropriate measure of the tasks distribution among the network. A smaller value of this metric is preferred, as it denotes the fact that transmissions tasks are uniformly distributed among the network and, therefore, very few sensors are extra loaded and suppressed by too many communications. The connectivity degree of the network is an important issue for the formulation of the criteria. The connectivity can be measured by the number of sensors that are able to communicate to at least another sensor. If the connectivity is less than the total number of sensors, the overall quality of the network decreases.

The second criterion refers to the degree of coverage of the network. As finding the exact value of the area of union of the disks of sensing radius, centered in sensors' locations (x,y) needs high computational costs, an approximation approach of the coverage is chosen. In our approach, we consider a grid which covers the entire map. Each center of the grid's cell could be included or not into at least one disk corresponding to a sensor. If the center of a cell is covered by at least one sensor, we consider that the area corresponding to that cell is covered by the net. The ratio between the number of covered cells and the total number of cells give us a useful measure of the network's coverage ratio. As the GHEA algorithms performs a minimization of the considered objectives of the problem, and the aim is to maximize the coverage and the lifetime of the network, the following functions are considered as objectives for GHEA implementation.

First objective: Considering n - the number of sensors, χ - the number of connected sensors (*connectivity degree*) and σ - standard deviation of the numbers of transmission tasks t_i of the i^{th} sensor: the first objective is formulated as follows:

$$F_1 = \sigma / \sqrt{n} + n - \chi \quad (1)$$

Second objective: Considering the grid with m rows and p columns and g - the number of *covered* cells of the grid, the second objective function is formulated as follows:

$$F_2 = (m \cdot p - g) / (m \cdot p) + n - \chi \quad (2)$$

4. EXPERIMENTS

In our experiments, we tried several scenarios which involve different number of sensors of communication radius R_C and sensing radius R_S . We considered that sensing and communication radiuses are not equal. In our experiment sensing radius is less than communication radius. Regarding the two parameters lifetime and coverage are computed. Therefore, coverage measure takes into account the sensing radius and lifetime is computed accordingly to the communication radius. The area of 500x500 units has to be covered with the given number of sensors in an optimal manner. The High Energy Communication Node (HECN) represents the gateway for external access to the network and it is located in the center of the area. Several scenarios have been taken into consideration. The GHEA algorithm runs for variable number of sensors, with different sensing radius and communication radius. The size of

the population is set to 50 individuals and the maximum number of generations is 100.

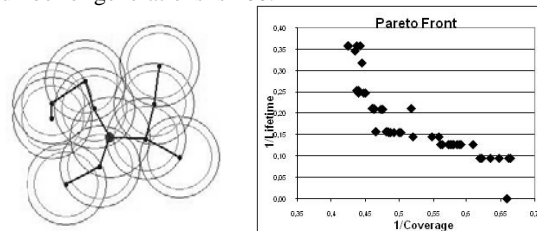


Fig. 1. Best sensors placement regarding the coverage (left) Pareto front after 100 generation (right), 10 sensors with 90 units R_C and 72 units R_S

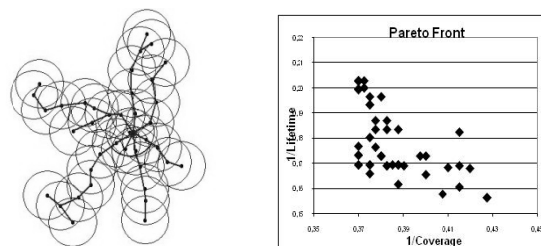


Fig. 2. Best sensors placement regarding the coverage (left) Pareto front after 100 generation (right), 50 population size, 40 sensors with 45 units R_C and 36 units R_S

5. CONCLUSION

Using an ideal hyperplane to guide the population of solutions toward the Pareto front of the considered optimization problem, GHEA offers in many situations better results than the state-of-the-art evolutionary algorithms. The WSN layout problem is formulated as a multiobjective optimization problem, emphasizing two criteria: attaining the maximum area coverage and a maximum lifetime of the network. For the simplified model of 2-dimensional map, having a pre-estimated fixed number of homogenous sensors, GHEA provides the Pareto optimal solutions of the bi-objective problem. The results show that GHEA technique is suitable for optimal WSN layout problem; in all experiments, GHEA offers a good approximation of the Pareto front. As further research, we investigate GHEA's performance for a heterogenous wireless sensors network in a more realistic monitored map.

6. REFERENCES

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