Deployment of Sensors to Optimize the Network Coverage Using Genetic Algorithm

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Abstract—**Wireless Sensor Networks (WSNs) are commonly used in various pervasive applications. Wireless communication is the fastest growing segment of the communication industry that has captured attention of the media and imagination of the public. The purpose of this study is to develop a Genetic algorithm that provides a proper deployment of sensors in order to optimize the coverage problem. The genetic algorithm optimizes the operational modes of sensors nodes for transmitting signals. In this paper we will present the optimum method for the mobile sensors nodes placement, so that transmission of signals and the field coverage can be improved. One of the critical issues of today's world is to ensure that the quality of services requirement is at an acceptable level and genetic algorithm give the best solution for the above discussed problem. The algorithm has been implemented in MATLAB using its genetic algorithm tool box along with the custom code.**

Index Terms— Wireless Sensor Networks, genetic algorithm, deployment.

I. INTRODUCTION

Wireless Sensors Networks (WSNs) are an emerging technology that has the potential applications in surveillance, environment and habitat monitoring, structural monitoring healthcare, and disaster management. WSN monitors work in an environment by sensing its physical properties. It is a network of tiny, inexpensive autonomous nodes that can acquire, process and transmit sensory data over wireless medium. Final destination is supposed to be the powerful base station. There are so many technical challenges involved in WSN including dense ad-hoc deployment, bandwidth, memory, energy, and computational resources.

Most of the issues in WSN such as node deployment, localization, energy-aware clustering and data gathering often come under the class of optimization problems. These computational techniques require more computational effort, which grows exponentially as the size of the problem increases. These optimization methods produce good and desirable results with moderate computational resources for implementation of individual sensor node.

Distributed Sensor Networks (DSNs) are important for a number of strategic applications such as coordinated target detection and localization. The effectiveness of DSNs is determined to a large extent by the coverage provided by the sensors deployment. The positioning of the sensors effects coverage, communication cost and resource management. In this paper, we are pursuing on sensor placement strategies that maximize the coverage for a given number of sensors. Sensors can be deployed either randomly or deterministically depending upon the application.

Deterministic deployment is preferred in amicable environments. It requires few sensors in node in deterministic deployment than in the random deployment. Network's life time that is also an important parameter to optimize as energy resources in a WSN is limited due to operation on battery. Replacing or recharging of battery in the network may be infeasible, though over all function of the battery may not be hampered due to failure of one or few nodes. Sensors are highly constrained devices that possess limited computing power battery, memory, transmission range. That is why we are considering the network of mobile sensors already deployed in some area of interest. Due to the abundance of cheap sensors scattered, not all of them are actually needed to provide reliable area coverage. Thus, we are establishing the deployment criteria of the sensors in the given field for the uniform network coverage. The key idea in this paper is that the coverage provided by the random deployment can be improved by using the genetic algorithm.WSN deployment problem refers to determining positions for the sensor nodes (or base stations) such that the desired coverage, connectivity and energy efficiency can be achieved with few nodes as possible. Events devoid of an adequate number of sensor nodes remain unnoticed and the area having dense sensor population suffers from congestion and delays. Optimally deployed WSN assures adequate quality of service, long network life and financial economy. Presented genetic algorithm provides the solution to the deployment problem for determining the position of sensors mobile nodes.

Several efforts have been made for solving different problems related to WSN. Bio-inspired optimization methods are computationally efficient alternatives to the analytical methods. Practical swarm optimization technique [8] is a popular multidimensional way. Although different algorithms [7], [11] have been proposed to design optimization of WSNs but many of them failed to address the applications specific issues. Many researchers have successfully implemented GA in a sensor network design [9], [6], which helps in the development of several other GA based application-specific approaches in WSN design. Previous related work for Mobile Sensor Network (MSN) includes dynamic approach where sensors are deployed one at a time given in [2], potential fields to reduce deployment time is discussed in [3], self organization strategies of sensor nodes to cover the field with multiple dynamical changes can be seen in [10]. [5], [4] have provided the approaches related to sensor security to graphic algorithm.

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The rest of the paper organizes as follows. Section II is the problem description and calculates the different parameters for the solution. Section III will provide the description of the genetic algorithm with steps. Section IV will discuss the experimental results and some simulation regarding to the algorithm. Section V will describe the conclusion and then the references.

II. METHODOLOGY

In this paper we are considering L×L Euclidian units in which two types of mobile sensing nodes are placed. These sensing nodes are capable of power controlling and sensing mode selection. Here we are computing four optimizing parameters which help in establishing the strong fittest criteria for the genetic algorithm. These parameters are: quality of service, energy dissipation for data communication operation like transmission and reception, coverage uniformity fitness and field coverage which depend upon the node replacement.

A. Quality of Service(QoS)

In order to determine deployment repositioning of mobile nodes and to improve the network coverage, we define the quality of service as a ratio between the area covered by the sensors and the total area of the given field:

$$\text{QoS} = \frac{A_{cov}}{A_T} \quad (1)$$

This should be equal to 1 ideally A_{cov} depends upon the position of (x and y coordinates) N mobile nodes.

B. Energy Dissipation

We are calculating the amount of energy dissipated during the communication process like data transmission and reception. This is one of the most widely accepted and used models in literature for sensor networks [1]. The energy spent by the sensor node in transmitting the k-bit packet to another node at a distance d meter away is given as:

$$E(k,d) = [\, E_{ele} + E_{amp} \times d\,]\, n \times k \quad (2)$$

Where E_{ele} is the energy dissipated per bit transmission and E_{amp} is the energy required to maintain the signals for the transmission. By using the factor 'n' which is the number of active nodes participated in the field for transmitting the data.

C. Coverage Uniformity Fitness (CUF)

CUF expresses the coverage improvement by filling the coverage holes and maximizing the distance between the active nodes of the field. Since our purpose is to provide the maximum coverage by not using all the sensors, therefore initially we take maximum distance between the sensors and rearrange them according to the network coverage by using the parameter:

$$\text{CUF} = 1 - \frac{1}{E(k,d)} \sum max \sqrt{(x - x_i)^2 + (y - y_i)^2} \quad (3)$$

D. Field Coverage

The effectiveness of a distributed WSN highly depends upon the sensor deployment scheme. By using the randomly selected number of sensor nodes it is highly desirable to deploy these sensors in such a way that the maximum field coverage and high quality communication is achieved. Here a field coverage parameter is defined as,

$$\text{FC} = \frac{(n_x - n_y) - (n_{or} - n_{act}) \times CUF \times k}{N} \quad (4)$$

where,
n_x = number of x sensors
n_y = number of y sensors
n_{or} = number of sensors out of range
n_{act} = number of active sensors

III. INTRODUCTION TO GENETIC ALGORITM

Genetic algorithm (GA) is evolutionary algorithm, it is an stochastic search technique and provides a guide to random search based of the powerful heuristic for solving optimization problems. The GA repeatedly modifies a population of individual solutions. At each step, the genetic algorithm selects individuals at random from the current population to be parent and use them to produce children for the next generation. GA can be applied to solve variety of optimization problems that are not well suited for the standard optimization algorithms. Optimization of the genetic algorithm is based upon the fitness function which is function of environment individuals of genes. Every new generation is obtained by applying the crossover and mutation operator on the old generation. Then new and better population with good genes will give further improvement by using fitness function. Finally after some generation the optimal solution will be attained.

A. Initial Population

We are applying the binary coding in our proposed algorithm and here we are presenting each "individual in the form of chromosome string representing single sensor node's motion vector by 8-bits binary number called gene. It is supposed that the length and width of all sensors in a field is specific". Chromosomes consist of two parts: first binary part is related to X (length of the sensor nodes) and the second part is related to Y (width of the sensor nodes).

B. Fitness Function of Genetic Operator

For above mentioned network and its high quality and performance, the fitness function in terms of GA must include all the important design parameters which affect the quality and performance of the designed WSN.

$$F(x) = \frac{FC \text{ for randomly selected sensor nodes}}{FC \text{ for all of the sensors in the network field}} \quad (5)$$

If the above value is close to 1 then the selected number of nodes will go under the process of crossover.

C. Crossover

Crossover indicates the combination of two parent chromosomes to produce an offspring. We are implementing the crossing method discussed in [12]. In this process we interchange the position of randomly selected slot from parent 1 and parent 2, to get a new offspring.

D. Mutation

Newly reproduced chromosomes are transferred to the mutation pool where the mutation operator mutates them according to the predefined criteria. Similar to crossover mutation, operation may produce an invalid chromosome, which is also fixed using the fittest criteria. The mutation operator can help the optimization problem to jump out of the local optimization and achieve the global optimization. A criterion for mutation is a two point mutation in which we select two random points on chromosomes. One part is for X and the other part is for Y. We flip the randomly selected bits.
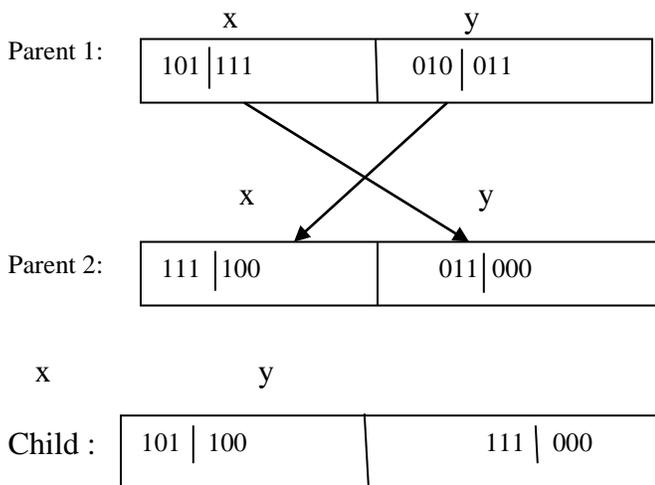

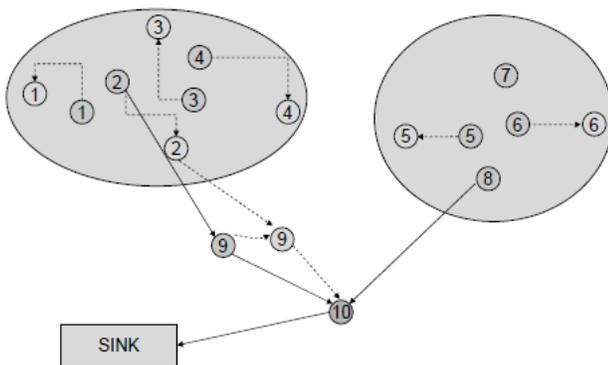
Figure: 1 showing the process of crossover

Figure: 2 New positions of mobile sensors after the application of GA

We have defined the algorithm for optimal deployment of sensor nodes using the GA operators. Genetic algorithm executes in a centralized entity, where it repeats itself upon multiple triggers, which are related to the battery alerts, determining the routes fitness alerts along with the network coverage. Once the optimal fitness is achieved the mobile sensors are instructed to achieve the new position corresponding to their new fitness function. GA optimization procedure highly depends on the crossover and mutation. These methodologies are available in GA tool box of MATLAB like scattered, single point, intermediate and heuristic. However, the two point mutation methodology was used as it gave us optimum performance in terms of time and speed.

IV. EXPERIMENTAL RESULTS

Experimental setup consists of 300 nodes at random position in 200×200 space. First a number of experiments were conducted to determine appropriate population size ranging from 100 to 1000 individuals. Individual node picks up at random coordinate between (0,0) and (200, 200) and assign itself an undecided and undetermined initial distance (UUDI) and a random battery capacity between 1 to 15. For simplicity each node covered an area of 30×30. Once all the nodes have been placed in a listening mode, GA is run with a crossover of 70% with the initial mutation of 10%. The software simulates the sink operation and runs in conjunction. It also calculates the fitness parameter based on the field coverage, energy consumption, and maximum distance between the nodes to have uniform coverage. The data is used to estimate the fitness parameter during the GA as shown in figure 3. All parameters are given in table 1. However, the best performance, by means of maximizing the corresponding fitness function, was achieved with a population size of 300 individuals. GA objectives maximize the network coverage for the optimal deployment of mobile sensor nodes.
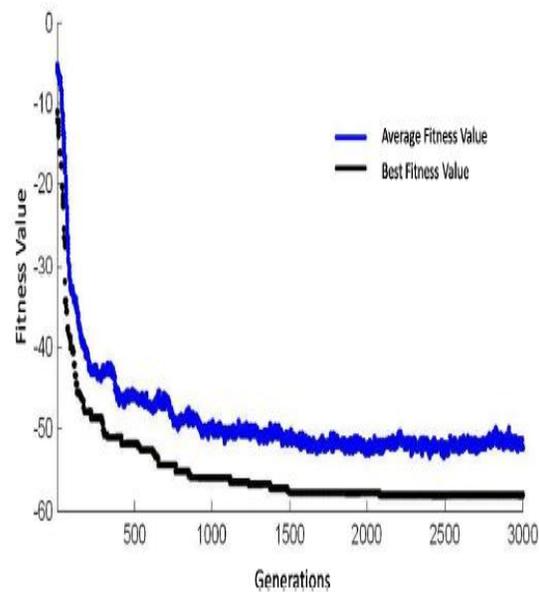

Figure3: Fitness rate according to produced number of generations

Table 1: Simulations Parameter

Description	Parameters	Values
Simulation Area	$M \times M$	300×300
Number of Nodes	N	300
Battery Rang	R_s	1-15
Initial Energy	E	1 Joule
Data Packet Size	K	200 bytes
Electronic Energy	E_{ele}	50 Joule/Bit
Sensors out of Range	n_{or}	10
Field Coverage	FC	4 (optimal)

V. CONCLUSION

In this paper we have presented the use of genetic algorithm for the optimize deployment of mobile sensor nodes for maximizing the network coverage. A network of mobile sensors was considered and GA decided which sensor should participate in data transmission and whether each of the remaining active nodes should have low or medium transmission range. The network lay out was optimized by considering some specific parameters like quality of service, energy dissipation, coverage uniformity fitness, and field coverage. The fitness function depends upon these parameters which have produced good results. During the optimization and the evaluation of network characteristics we can conclude that it should be sufficient if we have a large number of sensors with low energy consumption for transmitting the data as compared to have less number of sensors with consequently high energy consumption. Also the quality of service depends upon the energy consumption of the sensors because of the low powered device, and the sensors with high energy consumption will not be sufficient for long run time.

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