Observation on using Genetic Algorithm for Extending the Lifetime of Wireless Sensor Networks

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ABSTRACT

Coverage is one of the main aspects in Wireless Sensor Networks applications like environment, health care, disaster prevention and military etc and is a measure of the quality of service of network. The goal is to cover each and every point in the physical location. Coverage of network is mainly effected by the sensing ranges of sensors in WSN. So, increasing the range of sensor can increase the coverage of network. Coverage can be classified into 2 types, area coverage and point coverage (Target Coverage). In this paper we address the target coverage problem. One of the main aspects of applications of wireless sensor networks is network lifetime. The network lifetime can be highly depends on sensors scheduling because in sensor network energy consumes for both sensing and communication. Coverage problem highly effects on network lifetime i.e. network functions until each target is covered by at least one sensor in network. Forming the sensors into maximal set covers is one of the efficient methods to extend the sensor network lifetime, in which the sensors presented in particular cover are activated and remaining sensors are in sleep mode. This paper proposes a modified genetic algorithm to increase the network lifetime by solving the coverage problem. Here we are forming disjoint set covers that is the sensors covered in one cover cannot be repeated. Experimental results are shown to verify our approach.

Keywords – Wireless Sensor Network (WSN), Modified Genetic Algorithm, Coverage, Disjoint set covers problem, redundancy, Integer Programming, Linear Programming.

1. INTRODUCTION

A wireless sensor network consists of a large number of tiny sensor nodes to accomplish a sensing task. Sensor nodes are small devices equipped with one or more sensors, one or more transceivers, processor, storage resources and power source [2]. Sensor network has a feature that sensor nodes can work cooperatively and the sensor node has a capability of processing and transmits the locally computed data. The information gathered from interested region by sensors in the network is transferred to sink node. These are two types 1) On demand, that is the sink node will send the request for data, 2) event-driven, that is the sensors will send the data to the sink nodes whenever an event occurs. Because of these features sensor network has many applications. Some of the application areas are health, military, and home. In military application, for example, the rapid deployment, self-organization, and fault tolerance characteristics of sensor networks make them a very promising sensing technique for military command, control, communications, computing, intelligence, surveillance, reconnaissance, and targeting systems. In health care applications, sensor nodes can also be deployed to monitor patients and assist disabled patients.

In wireless sensor networks, sensors are dumply deployed. The number of sensors deployed is generally more than the required number of sensors, because there is no prior knowledge of sensor placement, especially when the interest region is inaccessible. Thus it is possible to turn some sensors to cover the uncovered regions. Due to the size of the battery the important issue in WSN is to increase the network lifetime. The mechanisms which optimize sensor energy utilization will greatly impact to prolong the network lifetime. The techniques to save the power of a sensor can be classified into two categories [3]: scheduling the sensors from active to sleep mode and from sleep to active mode, and adjusting the transmission ranges of sensor nodes. Here we are forming the maximal set covers that is the sensors present in the cover are activated and remaining sensors are in sleep mode, and only one set cover will be executed at particular time.

One of the objectives of coverage problem is to increase the network lifetime. Coverage problem has many types [1] based on objects to be covered. There is 1) area-coverage [13],[7],[14], that is the interest region to cover is area, and 2) target-coverage [6],[5],[9], that is the interest region to cover is point. In WSN basically the coverage is caused by three main reasons; random deployment, limited sensing ranges and not presented the enough number of sensors to cover the targets.

In this paper we address the Target Coverage Problem to increase the network lifetime, deployed for monitoring a set of targets. The rest of the paper is organized as follows: In section II we present related work on coverage problems. Section III presents Integer Programming and Linear programming formulations. Section IV presents problem definition. In Section V present modified genetic algorithm. In section VI we present the simulation results and Section VII concludes the paper.

2. RELATED WORK

In this paper we address the target coverage problem. In [15] S. Meguerdichian, the coverage is measure of quality of service of the sensing function of sensors. Coverage problems have been formulated in other fields, such as the Art Gallery Problem, ocean coverage and coverage in robotic systems. In Art Gallery problem [16], coverage is to determine the number of observer and their placement, necessary to cover an art gallery room such that every point is seen by at least one observer. This visibility problem has many real world applications, such as placement of antennas for cellular telephone companies, and placement of cameras for security purposes in banks and supermarkets.

In WSN, coverage is one of the main factors to be considered to increase the sensor network lifetime. The method used is scheduling some sensors to be in active mode and the remaining sensors are in sleep mode. The sensors in sleep mode are activated after the energy of activated sensors completed. Here the sensors which are activated should cover all the targets and the sensor should not be included in more than one set as the covers are disjoint. Dividing the sensors for maximum number of covers has been modeled as an NP-complete problem- the Set K-Cover problem [8] that is to find the maximum K number of covers from the given set of covers.

Slijepecevic and Potkonjak [8], proposed a greedy heuristic. Here the WSN lifetime as the Set K-Cover problem, and proved the problem as a NP-complete problem by reduction it to the minimum cover problem. Cardei and Du [6] proposed maximum covers using mixed integer programming to find the maximum number of disjoint complete set covers to cover the targets and, Cardei and T.thai [9] formulated Disjoint Set covers (DSC) problem, which is identical to the Set K-cover problem and proved that the Maximum Set Cover problem is NP-complete.

In [3], M. Cardei and jie Wu, maximum set cover problem solved by Adjustable Range Set Covers (AR-SC) problem. Here by using the sensing ranges of sensors, a sensor can participate in multiple sensor sets that is non-disjoint sets are using to solve the maximal set cover problem.

In [5], M. Cheng coverage breach problem has introduced, sensors formed into disjoint set covers and the overall breach of network is minimized. The overall breach is measured as the number of uncovered targets by the sensors in sensor network.

Lai et al. [11], proposed an integer-coded Genetic Algorithm (GA) to address the Set K-Cover problem and obtained satisfactory results. This approach needs an upper bound for the number of covers and for chromosomes integer representation is used. In [10], C.-C.Lai, C.-K. Ting integers are used for chromosome representation and even the chromosomes are represented with different values then so there is no guarantee for complete coverage.

Chien Liao [12], instead of integer representation to eliminate the upper bound on maximal set covers and keep the advantage of GA for solving the Set K-Cover problem.

In Xiao Hu, Henry chung [12] proposed an enhanced GA to maximize the network lifetime while solving the disjoint set cover problem.

OTHER PARADIGMS: The paradigms which are used to maximize the network lifetime by solving the target coverage problem are Integer Programming Formulations [3][9], Linear Programming Heuristic [3][9], Greedy Heuristics [3][9[18], Lagrangean Heuristics [18] and Branch and Bound Approach [19] .

Now we are Using Genetic Approach [11][12] to maximize the lifetime of network. We have adopted integer and linear programming formulations to solve the coverage problem using genetic approach. Different formulations are proposed by Mihaela Cardei et al [3] [9] and Ionut Cardei [4].This method does not need any assumptions and upper bound for maximum number of covers.

TABLE I
NOTATIONS

Symbol	Description
S	Set of the sensors deployed
S_i	Sensor i
N	Total number of sensors
r	Sensing range of sensor
k	Maximum number of disjoint set covers
E	Initial energy of sensor
C_i	Chromosome i
g_{ij}	Jth gene of chromosome C_i
r_1	Number of sensors selected in the initialization
g_{imax}	Maximum gene value in the chromosome C_i
c_i	Number of Disjoint Covers in i^{th} chromosome

3. INTEGER AND LINEAR PROGRAMMING FORMULATIONS

Coverage problem has been modeled as an interger programming problem [3][4][9]. Set Covers with Ranges problem is the maximum number of covers sholud be formed and the sensors in the each cover set should cover all targets and sensing ranges of sensors may not be equal i.e. sensing ranges of sensors can be adjustable. This problem can be solved by integer programming (IP).

Variables:

- a_{ipj} is a coefficient 1 if sensor s_i with range p covers the targer T_j.
- b_k, boolean variable 1 if the particular kth is activated, otherwise 0.
- x_{ikp} is 1 if sensor s_i is presented in k^{th} cover with p^{th} sensing range.

3.1 Integer Programming:

We consider integer programming formulations from [3] for Target Coverage problem. i.e.

Maximize $c_1 + ... + c_K$

subject to the following constraints:

$\sum_{k=1}^{K}(\sum_{p=1}^{P} x_{ikp} e_p) \leq E$ for all i=1….N

$\sum_{p=1}^{P} x_{ikp} \leq c_k$ for all i=1….N, k=1…K

$\sum_{i=1}^{N}(\sum_{p=1}^{P} x_{ikp} * a_{ipj}) \geq c_k$ for all k=1….K,j=1….M

$x_{ikp} \in \{0, 1\}$ and $c_k \in \{0, 1\}$

3.2 Linear Programming:

IP in NP-hard problem, so to solve this Problem relaxation and rounding mechanisms are used. First IP is relaxed to Linear Programming (LP) [3], now LP can be solved in polynomial time in order to get feasible solutions for IP we need to round the solution.

Relaxed LP:

Maximize c1 + ... + cK

Subject to

$\sum_{k=1}^{K}(\sum_{p=1}^{P} x_{ikp}\, e_p) \leq E$ for all i=1….N

$\sum_{p=1}^{P} x_{ikp} \leq c_k$ for all i=1….N, k=1…K

$\sum_{i=1}^{N}(\sum_{p=1}^{P} x_{ikp} * a_{ipj}) \geq c_k$ for all k=1….K,j=1….M

$0 \leq x_{ikp} \leq 1$ for all i = 1…N , k = 1…K and p = 1…P

$0 \leq c_k \leq 1$ for all k = 1…K

4. PROBLEM DEFINITION

In WSN, assume there is a set of N sensors S= {s_1, s2 …sN} are randomly deployed to cover set of M targets t_1, t2…t_M. Initially all sensors having same energy. We are forming set covers with minimum number of sensors which covers the total number of targets. We are solving target coverage problem to increase the network lifetime by forming disjoint complete cover sets, T_1, T2….T_k. To increase the lifetime of the network the disjoint cover sets should be maximized.

Disjoint set cover [12] is, the sensors belongs to one set cannot be covered in another set, that is

$$S_i \cap S_j = \emptyset$$

Where S_i is the set of sensors in i^{th} cover.

S_j is the set of sensors in j^{th} cover.

and i≠j, i,j=T_1,T_2,……T_k.

Target coverage problem [3]:

In WSN with N sensors and M targets, schedule the sensors activity such that all targets should be covered continuously and increase the network lifetime.

TABLE II

Symbol	Description
$C_i = (g_{i1}, g_{i2}, \dots g_{iN})$	Genetic representation of Candidate solutions
m	Population size
$f_i = c_i + p_{c_i+1}$	Evaluation function
r_0	Recombination operator
µ	Mutation operator
G_m	generation gap

5. PROPOSED METHOD

This paper proposes a modified GA to maximize the coverage of the network. We first introduce chromosome representation, fitness function followed by GA operations adopted from Xiao-Min Hu [12].

5.1 Chromosome representation:

Each gene in the chromosome represents sensor in the network and the value of gene represents scheduled activated number of sensor.

The representation of chromosome in the population is

$$C_i = (g_{i1}, g_{i2}, \dots g_{iN}) \quad (2)$$

Where $g_{ij} \in \{1,2 \dots k+1\}$ represents sensor S_j's scheduling number, j=1,2…N, N is the total number of sensors in the network, i=1,2…m and m is the number of chromosomes in the population. The sensors with the same scheduling number in the chromosome are formed cover set and formed cover set is disjoint. Initially for all chromosomes in the population the gene values are assigned to 1, i.e., C_i=(1, 1, …, 1), i=1, 2, …, m, meaning that initially all sensors are activated. If the initial schedule covers all the targets, then without any effect on coverage percentage the redundant sensors can be turned off to sleep mode. This procedure can be done randomly i.e select r_1 genes i.e. predefined value, if the selected genes are redundant then increase the schedule number. After resetting the generated initial population is C_1, C_2….C_m.

Here g_{imax} is the maximum schedule number in the i^{th} chromosome, which decides the number disjoint cover sets for particular chromosome. That is if the sensors with $g_{i\ max}$ number cannot completely cover all the targets, the number of disjoint cover sets in the chromosome C_i is

$$c_i = g_{i\ max} - 1 \quad (3)$$

Otherwise, the number of disjoint cover sets in the chromosome C_i is

$$c_i = g_{i\ max} \quad (4)$$

5.2 Fitness function

The fitness function of each chromosome C_i in population is

$$f_i = c_i + p_{c_i+1} \quad (4)$$

Where c_i is the number of disjoint complete covers and $p_{c_i} + 1$ is the coverage percentage of incomplete cover set.

Fig1 shows an example of a wireless sensor network with 9 sensors and 5 targets. Fig2 shows the coverage relation between the sensor nodes and targets. Assume the initial population is 5 i.e. C_i, (i =1, 2… 5) and r1 is 4. Each C_i has 9 genes i.e., the network has 9 sensors and initially the C_i, (i = 1, 2 …5) is initialized with 1.

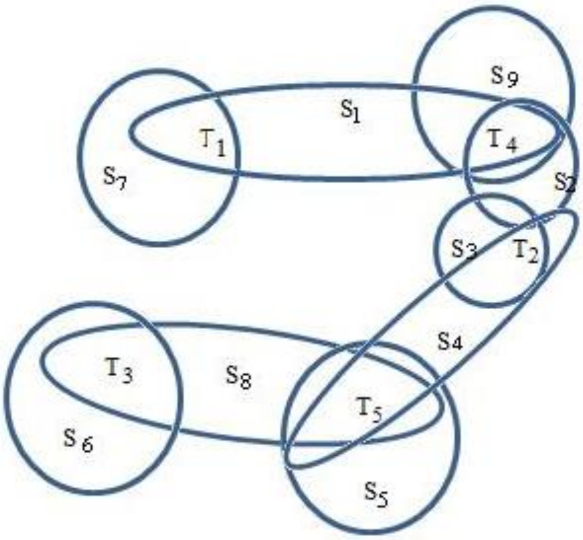

Fig1: an example of wireless sensor network

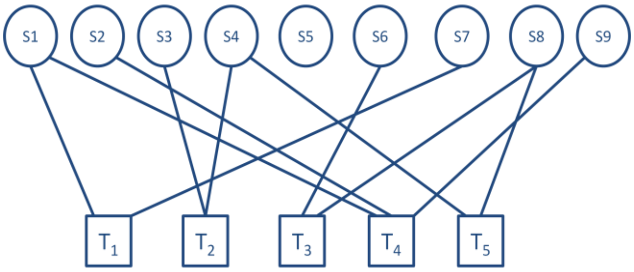

Fig2: Relationship between sensor nodes and targets

From above Fig 2. One of chromosome representation in the population is C={1,2,1,2,3,2,2,1,3}, here the scheduled numbers with 1 and 2 forms complete disjoint covers and scheduled number with 3 forms incomplete set cover with 0.4 coverage. Therefore the fitness value for above chromosome is 2.4 gives the best coverage.

5.3 GA Operations

1) Crossover

Crossover operates works as recombination of parental information to produce the new offspring. The new offspring generated by combining the genes of two parents with probability 0.5. Here parent chromosomes are selected randomly.

The algorithm in Fig 3 is adopted from [12]. Here after recombination, the fitness of the newspring C_p is calculated using (4) and compared with its parents. If the fitness of the offspring is not worse than parents is considered into population and is replaced by one of the parents which has lowest fitness than offspring.

But in our model, fitness of the offspring not only compared with parents and also compared with the fitness of remaining chromosomes in the population. If any one of the chromosome fitness value is lowest than the generated offspring, the new offspring replaced with that chromosome.

Here we are eliminating the chromosome which has the less fitness value than the generated offspring.

Step 1: Choose the parameters, i.e. selection operator C_i, population size m, crossover probability P_c=0.5, mutation rate μ=0.5 and the number of generations $G_{m.}$ Initialize the chromosome with 1, means initially gene values of all the chromosomes in the population are 1.
Step 2: select the sensors randomly in all chromosomes in population and increase the gene value if those are redundant.
Step 3: calculate the fitness value for all the chromosomes in population.
Step 4: select 2 chromosomes from population and perform crossover. And calculate the fitness of the generated new origin.
Step 5: If fitness is greater than the parents, replace it with the parent chromosome which has less fitness, otherwise replace it with the chromosome which has less fitness value.
Step 6: repeat the above step 4 and step 5 for G_m generations.
Step 7: perform mutation operation.
Step 8: calculate mean number of covers.

Fig3: General Genetic Algorithm.

This way we are reducing the chance to select the parent chromosome which has low value to generate the offspring for the next generation.

2) Mutation

Performs reverse operation that is Sensors are added into complete cover set from incomplete cover set after certain number of generations. It is an important operation to eliminate the search bias.

6. SIMULATION RESULTS

We simulate a stationary network with sensor nodes and targets randomly located in 100m × 100m area. We assume the sensing range is equal for all sensors in the network. In the simulation we consider the following tunable parameters:

- N the number of sensor nodes. .
- M the number of targets to be covered.
- P sensing ranges r_1, r_2… r_p.
- Population size m.
- Mutation rate is μ

In Fig 4 the maximum number of complete cover sets formed by the MGA when the number of targets is fixed as 10 targets, population size m=3, the number of generations for performing mutation is G_m=100, the mutation μ=0.5, and the parameter r_1=4. The numbers of number of complete covers formed by MGA are greater than GA.

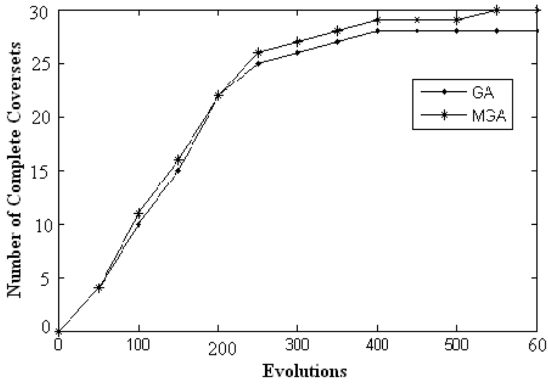

Fig 4: Number covers formed for increasing the evolutions for both GA and MGA

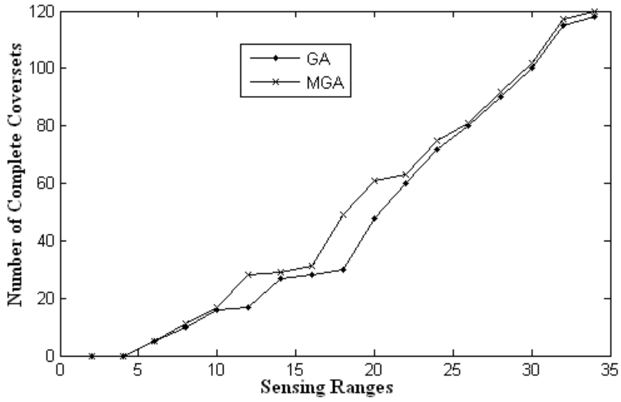

Fig 5: Number of Disjoint Covers from ranges 1 to 34 with 400 Nodes using GA and MGA

The network Lifetime can be influenced by sensing ranges, when the number and position of the sensors are fixed. In sensor network 400 sensors are deployed using 1 to 35 sensing ranges. Fig 5 compares the results generates by MGA and GA. For smaller sensing ranges there are no cover formed. ranges between 10 to 15 the covers formed in both MGA and GA are equal. R increases the covers formed in MGA slightly greater than GA.

7. CONCLUSION

One of the best solutions to utilize the energy of sensor network is coverage problems. We are solving this by partitioning the sensors into set cover and each cover set should cover all targets with minimum number of sensor nodes .In this paper, Modified GA to solve the coverage problem and increasing the network lifetime. Network lifetime is increasing by forming the sensors into disjoint set covers and each cover set covers all the targets in physical space. In this approach, the coverage chromosome participated in recombination process is always better to generate new population. The simulation results show that the numbers of covers formed by the proposed algorithm are more than the number of covers formed by the GA.

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