

SOLVING TARGET COVERAGE PROBLEM IN WIRELESS SENSOR NETWORKS USING GENETIC ALGORITHM

BY

RAVI KUMAR SINGH (108CS045)

ANSHUL PANDEY (108CS078)

Under the Guidance of

Prof. B.D. SAHOO



Department of Computer Science & Engineering

National Institute of Technology, Rourkela

Rourkela-769 008, Odisha, India



CERTIFICATE

This is to certify that the thesis entitled, “**SOLVING TARGET COVERAGE PROBLEM IN WIRELESS SENSOR NETWORKS USING GENETIC ALGORITHM**” submitted by **Ravi Kumar Singh (108CS045) & Anshul Pandey (108CS078)** in partial fulfillment of the requirements for the award of **Bachelor of Technology degree in Computer Science & Engineering** at National Institute of Technology Rourkela is an authentic work carried out by them under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any University/Institute for the award of any Degree or Diploma.

Prof. B.D. Sahoo

Department of Computer Science & Engineering

National Institute of Technology

Rourkela-769008



ACKNOWLEDGEMENT

We avail this opportunity to extend our hearty indebtedness to our guide Prof. B.D. Sahoo, Computer Science Engineering Department, for his valuable guidance, constant encouragement and kind help at different stages for the execution of this dissertation work.

Ravi Kumar Singh (108CS045)

Computer Science & Engineering, 2012

Anshul Pandey (108CS078)

Computer Science & Engineering, 2012

NIT Rourkela

ABSTRACT

The past few years have seen tremendous increase of interest in the field of wireless sensor network. These wireless sensor network comprise numerous small sensor nodes distributed in an area and collect specific data from that area. The nodes comprising a network are mostly battery driven and hence have a limited amount of energy. The target coverage deals with the surveillance of the area under consideration taking into account the energy constraint associated with nodes. In nutshell, the lifetime of the network is to be maximized while ensuring that all the targets are monitored. The approach of segregating the nodes into various covers is used such that each cover can monitor all the targets while other nodes in remaining covers are in sleep state. The covers are scheduled to operate in turn thereby ensuring that the targets are monitored all the time and the lifetime of the network is also maximized. The segregation method is based on Maximum Set Cover (MSC) problem which is transformed into Maximum Disjoint Set Cover problem (MDSC). This problem of finding Maximum Disjoint Set Cover falls under the category of NP-Complete problem. Hence, two heuristics based approach are discussed in this work; first Greedy Heuristic is implemented to be used as baseline. Then a Genetic Algorithm based approach is proposed that can solve this problem by evolutionary global search technique. The existing and proposed

algorithms are coded and functionality verified using MATLAB R2010b and performance evaluation and comparisons are made in terms of number of sensors and sensing range.

Contents

ACKNOWLEDGEMENT.....	iii
ABSTRACT.....	iv
LIST OF FIGURES.....	ix
LIST OF TABLES.....	x
1. Introduction.....	1
1.1.Introduction.....	1
1.2.Wireless Sensor Network.....	3
1.3.Motivation.....	4
1.4.Objective.....	6
1.5.Related Work.....	7
1.6.Organization of the Thesis.....	7
2. System Model.....	8
2.1.Assumptions.....	8
2.2.Target Coverage Problem.....	9
2.2.1. Remarks.....	10
2.3.Problem Definition.....	11

2.4.	Conclusion.....	12
2.5.	Summary.....	13
3.	Existing Heuristics.....	14
3.1.	Greedy Algorithm Based Heuristic.....	14
3.1.1.	Introduction.....	14
3.1.2.	Algorithm Description.....	17
3.2.	Simulation.....	19
3.3.	Inference.....	20
3.4.	Conclusion.....	20
4.	Genetic Algorithm for Disjoint Set Cover Problem.....	21
4.1.	Introduction.....	21
4.2.	Genetic Algorithm based MDSC Components.....	23
4.2.1.	Representation.....	23
4.2.2.	Fitness.....	24
4.2.3.	Reproduction.....	24
4.2.4.	Genetic Operators.....	25
4.2.5.	Distribution.....	25
4.3.	Simulation.....	27
4.4.	Inference.....	30
4.5.	Conclusion.....	31

5. Conclusion and Future Work.....32

REFERENCES.....33

List of Figures

2.1. A Deployment of Wireless Sensor Network.....	11
2.2. Bipartite Graph G based on given WSN.....	12
4.1. Representation of a chromosome.....	23
4.2. Single Point Crossover.....	25

List of Tables

4.1. Genetic Algorithm Parameters.....26

1. Introduction

1.1 Introduction

Recent years have seen tremendous advancement in wireless sensor networks due to reduction in development costs and improvisation in hardware manufacturing. Past two to three decades have been marked with rapid use of wireless sensor networks in various fields. Wireless sensor networks are now used, other than in military surveillance, in habitat monitoring, seismic activity surveillance and are now even used in indoor applications. These wireless sensors have provided us the tool to monitor an area of interest remotely. All one is supposed to do is to deploy these sensors, aurally or manually, and then these sensors which form the nodes of the network gather information from the area under investigation. The information thus obtained is relayed back to the “main server” or “base station” where the information is processed. The base server is sometimes connected to Internet which then relays the processed information via satellite to the main station or control center for further processing and analysis. Very little or no processing is done while information is transferred from nodes.

Sensor nodes which constitute the wireless network are autonomous nodes with a microcontroller, one or more sensors, a transceiver, actuators and a battery for power supply. These nodes, sometimes also referred motes, are also equipped with analog to digital converter and/or digital to analog converter. These sensors have very little memory and perform little amount of processing with the information obtained. Now apart from monitoring, collecting and transmitting data from one node to another and to the base station, these sensors communicate with other nodes following certain communication protocols moreover the processing unit

regulates and controls functionality of other components of the sensor node. Nevertheless the memory operation is an overhead too. This is because the sensors are equipped with a battery which often is non-replaceable. Thus increase in processing would imply more energy is being consumed and hence sensor lifetime would decrease thereby affecting the lifetime of the network. As mentioned earlier the relaying of information is done by following a certain communication protocol. However this facility is achieved by the communication unit of the sensor. Usually the sensor has a transceiver that can act as both transmitter and a receiver. The transmitter and the receiver hardware are not kept separate in order to save space and energy. These days, sensors can communicate through transmission media ranging from vast electromagnetic spectrum.

A wireless sensor network is deployed in one of the two ways: planned and unplanned. In the planned method of deployment a specific number of sensors are placed in strategic points in predetermined manner. Here it should be noted that the area to be monitored can be accessed physically thus the cost is not a factor under such conditions. These nodes are placed using a predetermined algorithm such that the area to be covered is maximized placing less overhead on transmission and battery thereby enhancing the network lifetime.

The wireless sensor network faces various issues one of which includes coverage of the given area under limited energy. This problem of maximizing the network lifetime while following the coverage and energy parameters or constraints is known as the Target Coverage Problem in Wireless Sensor Networks [4]. As the sensor nodes are battery driven so they have limited energy too and hence the main challenge becomes maximizing the coverage area and also ensuring a prolonged network lifetime.

The work has been done to address this problem but mainly as the challenge by default comprises time constraint, hence the problem becomes time dependent [4], which in turn is non-polynomial in nature [4]. Now even non-linear problems belong to the NP-Hard class [4] thus only a few heuristics have been proposed to address the Target Coverage Problem if not in optimal, then near optimal or suboptimal time. One of such algorithm is discusses in further section which is used as a baseline against our proposed algorithm. In this work one of the proposed algorithm is analyzed which divides the sensors into various covers. These covers are then scheduled for activation one after another after a specific, fixed, time quantum. A new algorithm is further proposed which outperforms the existing algorithm in finding the number of covers. Since the number of covers of sensors in a particular wireless sensor network is maximized, the lifetime of network is also maximized.

1.2 Wireless Sensor Network

Wireless sensor network consists of large number of distributed nodes which are used for monitoring or surveillance of physical area [8]. The information thus gathered is relayed back to a base station or main server. Wireless network has many applications and depending upon the type of use, the quality of service differs. For one application, the quality of service depends upon how information is transferred from one node to another while for others the delay in transmission has to be minimized. The quality of service parameter here is that the target points in the area under surveillance are to be maximized while taking in account the limited energy supply of the sensor. Basically, it is ensured that every sensor monitors at least one target and that they operate in covers. Each cover is scheduled to work in turns while other sensors remain

in sleep mode. Thus when a particular cover runs out of energy, other cover is activated which monitors the area and hence the network lifetime is maximized.

Network Lifetime: Network lifetime is the amount of time each target is covered by at least one sensor, obtain data and transmit them back to the base station. The main concern or the bottleneck is the limited amount of battery available since there are various situations in which the sensors are deployed in hostile situation where it is very difficult to replace the battery. The objective is to maximize the number of targets monitored before the sensors consume their energy. The second factor can be assigned to cost which might not be as great constraint as that of energy. But as the sensing range increase the number of targets monitored will also increase.

1.3 Motivation

The last ten years have seen the requirement for Wireless Sensor Networks based applications grow sharply. Given their extensive requirement and use a lot of research is now being done in these areas. But this relatively new field still suffers from some fundamental challenges. Firstly it is the problem from the limited energy source equipped with every sensor that is from the battery source. Secondly it is the problem of covering a non-uniform target area in most of the situations [9][10]. Then cost minimization becomes a serious issue. It has already been pointed out about the various aspects of quality parameters in the earlier section and so it is worthwhile to mention that meeting even a single quality parameter presents a problem and needs appropriate analysis and observation to answer it.

If the operation of a wireless sensor network is taken in account, then the question which comes first is that of deployment so that the target nodes are fully covered[2]. Once this problem is dealt with, the second question which arises is that of surveillance and operation of the network in a way so that the energy consumption is less and also the network can meet certain quality of service standards. Usually the scenario is that, there are a number of sensors with limited energy that is required or used to monitor a given number of target nodes. In such a case, one thing that is to be taken into account is the time for surveillance i.e. the duration of time under which each target is observed. This sometimes is loosely related to the lifetime of the network. However one such scenario can be to observe the seismic activity in an area. The sensors deployed there can monitor occurrence of any faults or fractures in the surface. Any unusual activity can be used to alarm the concerned local authority moreover the time taken for those faults to occur and develop is also of interest which fortunately is monitored by the sensor nodes.

This issue of maximizing network lifetime while taking into account the limited power supply is called Target Coverage Problem. It is later shown that this problem is inherently time dependent in nature and therefore cannot be solved in polynomial time. It will be later shown that the problem falls under the category of NP-complete problems[5] and only a few heuristics have been proposed which offer the solution in near polynomial time. This is use as the foundation of this work. An existing heuristic is used to serve as a baseline against our proposed algorithm which seeks to maximize the network lifetime.

1.4 Objective

The present work involves the Target Coverage Problem in wireless sensor networks, which seeks to maximize the network lifetime under energy and coverage parameters [4]. The problem is addressed and quantified first and the mathematical model for the problem is made following which one of the conventional or used heuristic is simulated. The central objective is to modify the existing approach to maximize the network lifetime.

1.5 Related Work

Wireless Sensor Networks have been witnessing tremendous applications in varied fields. As such the issues associated with them have attracted worldwide attention. [1] lists out the target coverage problem with wireless sensor network and attempts to address it using the energy constraint as the objective function and aims at maximizing the network lifetime.

The central idea of this work has been laid out in [2]. This work aims at dividing the sensors into a number of set covers and aims at maximizing the number of set covers thus found. The problem of maximum set cover is transformed into disjoint set cover by quantifying the time quanta associate with each cover and the sensor as well. The work also explains the bottleneck of the problem by giving an elegant proof that finding maximum set cover fall under the category of NP-complete and thus cannot be computed under polynomial time. There are various heuristics proposed to address the maximum set cover problem. One such has been laid out in [3]. In this a greedy approach is used in computing the maximum set cover[5] presents a genetic approach to the topic of maximum set cover but concerns with directional sensors i.e. multimedia sensors. It uses the technique of evolutionary algorithm to solve the problem. In [6], the authors present a

probabilistic model of the wireless sensors and also use genetic algorithm heuristic to find the maximum set cover.

1.6 Organization of the Thesis

This thesis is divided into five chapters. The first chapter gives a detail of the sensor nodes and Wireless Sensor Networks, and the corresponding problems associated with it. The second chapter is about the assumptions on which this work has been based and goes onto constructing a mathematical model for the problem. It also introduces a disjoint set cover model based on Euclidean distance using which the existing heuristic is compared with the proposed heuristic. The third chapter starts with an existing heuristic which computes maximum covers that can be found in network in sub optimal polynomial time. The main objective in using the existing heuristic is to compute the covers in polynomial time and then use the heuristic to use as a baseline for comparison against our proposed algorithm. In fourth chapter genetic algorithm based approach to solve MDSC Problem is presented. A heuristic function, Distribution is developed to distribute genes to different groups to search for more number of cover. This chapter is concluded by providing a simulation of GA based approach and Greedy Heuristic. The work concludes in chapter 5 by drawing inferences from the simulations done using the Greedy based and Genetic Algorithm based heuristic.

2. System Model

This work deals with Target Coverage Problem in wireless sensor network. The target coverage involves maximizing the coverage of an area taking into consideration the energy constraints. Firstly the given problem is formulated and then a mathematical model is proposed. Following which the greedy approach proposed in [3] is formulated and simulated. The central idea is to modify the existing heuristic and find a better solution to the problem.

2.1 Assumptions

There are various assumptions made while formulating the model for the used system. Firstly it has been assumed that the targets and the sensors are static. Secondly, it is assumed that the targets to be monitored are discrete i.e. there are individual locations in the area that is to be monitored. Next it is assumed that the sensors are deployed in large numbers so that they cover the all the targets irrespective of the fashion they are placed. The sensors deployed are assumed to be in two states: Active and Sleep mode. In active mode the sensor can be in either of the following modes, receiving, transmitting and idle. It has been proved in [1][2][3] that the nodes consume much less energy when they are in sleep mode than they are in idle mode. Thus the covers which are not monitoring the targets at present are in sleep mode and are scheduled to be in active state when the current cover exhausts its energy.

2.2 Target Coverage Problem

Assume that n sensors s_1, s_2, \dots, s_n are deployed in territory to monitor m targets t_1, t_2, \dots, t_m . A target is said to be covered by a sensor if it lies within the sensing region of the sensor [1][6]. The sensor network lifetime can be extended by finding the maximum number of disjoint sensor covers or set covers.

Let us set an upper bound p for the number of set-covers [1]. The DSC problem is formulated as follows.

Given:

set of n sensor nodes $C = \{s_1, s_2, \dots, s_n\}$

a set of m targets $T = \{t_1, t_2, \dots, t_m\}$

the relation between sensor and targets, that is, for each sensor which is the set of targets it covers, this is represented as each element present in C depicted as a subset of the finite set T .

Let us define [1]

$C_k = \{i \mid \text{sensor } s_i \text{ covers target } r_k\}$

Variables:

x_{ij} , boolean variable, for $i = 1..n$ and

$j = 1..p$; $x_{ij} = 1$ if sensor s_i is in the set cover S_j , otherwise $x_{ij} = 0$.

$t_j \in \mathbb{R} \ 0 \leq t_j \leq 1$, for $j = 1..p$, represents the time allocated for the set cover S_j .

The optimization problem can be written as:

Maximize: $t_1 + t_2 + \dots + t_p$

subject to:

$$\sum_{j=1}^p x_{ij} t_j \leq 1 \text{ for all } s_i \in C$$

$$\sum_{i \in C_k} x_{ij} \geq 1 \text{ for all } t_k \in R, j = 1, \dots, p$$

where $x_{ij} = 0, 1$ ($x_{ij} = 1$ if and only if $s_i \in S_j$)

2.2.1 Remarks:

- the first constraint, $\sum_{j=1}^p x_{ij} t_j \leq 1$ for all $s_i \in C$ guarantees that the time allocated for each sensor s_i , across all set covers, is not larger than 1, which is the life time of each sensor.
- the second constraint, $\sum_{i \in C_k} x_{ij} \geq 1$ for all $t_k \in T, j = 1..p$, and $j = 1, \dots, p$ and $C_k = \{ i \mid \text{sensor } s_i \text{ covers target } t_k \}$ guarantees that each target t_k is covered by at least one sensor s_i in each set cover S_j
- For Disjoint Set Cover Problem $t_j \in \{0, 1\}$ so that the covers found are disjoint and lifetime of network is total no. of disjoint covers formed multiplied by average lifetime of one sensor.

2.3 Problem Definition

Definition (Disjoint Set Covers Problem) [2][5]: Given a collection S of subsets of a finite set T , find the maximum number of disjoint covers for T . Every cover C_i is a subset of S , $C_i \subseteq S$, such that every element of T belongs to at least one member of C_i , and for any two covers C_i and C_j , $C_i \cap C_j = \varphi$.

That is, let T be the set of the targets, t_1, t_2, \dots, t_m , sensor s_i can be represented by a subset, denoted as S_i , of T , where $t_j \in S_i$ if and only if t_j lies within the sensing region of sensor s_i . Thus, S is a collection of subsets representing sensors and a cover C_i represents a sensor cover.

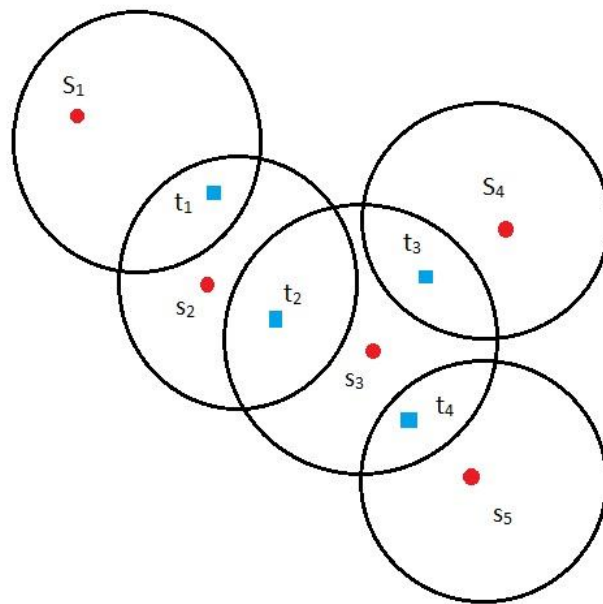


Fig. 2.1. A Deployment of Wireless Sensor Network

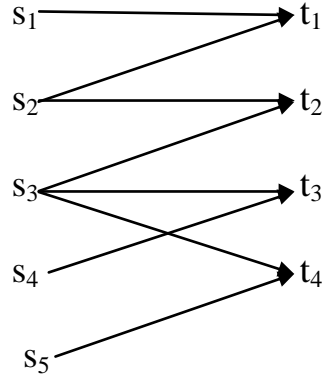


Fig. 2.2 Bipartite Graph G based on WSN in Fig. 2.1. Link between s_i and t_i means t_i lies within the sensing region of s_i .

In Fig.1, $s_1, s_2, s_3, s_4,$ and s_5 as five sensors, and $t_1, t_2, t_3,$ and t_4 as four targets are depicted [2]. In this example, $S_1 = \{t_1\}, S_2 = \{t_1, t_2\}, S_3 = \{t_2, t_3, t_4\}, S_4 = \{t_3\},$ and $S_5 = \{t_4\}$. Two disjoint covers are, $C_1 = \{S_1, S_3\}$ and $C_2 = \{S_2, S_4, S_5\}$. Thus, in the given figure, maximum number of disjoint covers is 2.

2.4 Conclusion

Computing maximum disjoint set cover is NP-Complete problem. The heuristic aims at finding the near optimal solution to the problem. The maximum disjoint set cover approach ensures that all the targets in the given area are monitored all the time and each cover gets to monitor those targets. The covers are active for a discrete time quantum after which the next cover becomes active and the previous one goes into sleep mode. Alternating between sleep mode and active mode ensure that the energy of the sensors is used judiciously and thus the network lifetime is maximized.

2.5 Summary

This chapter lays down the groundwork for determining the number of maximum set cover in a given network and presents a mathematical model which can be implemented find the maximum number of disjoint cover for given number of sensors. Static deployment of sensors is considered to monitor a certain number of discrete targets. The maximum number of covers that can be computed is the number of sensors which monitor certain critical targets. The targets are determined to be within the range of the sensor is by calculating the Euclidean distance between each other. The covers thus found then operate for discrete time intervals to monitor the targets. It has also been discussed that the sensors operate in active and sleep mode and by switching alternatively between these two modes the sensor's lifetime can be maximized.

3. Existing Heuristics

3.1 Greedy Algorithm based Heuristic

3.1.1 Introduction

This section describes the details of the greedy algorithm devised to solve the Disjoint Maximum Set Cover Problem (DMSCP). It is similar to one proposed in[1]. Greedy Algorithm goes on in iterative way to find disjoint covers i.e., it decides one cover per round.

The Greedy Heuristics discussed here takes three parameters C -the set of covers, R -the number of targets, and S -the number of sensors and returns i the number of disjoint cover sets C_1, C_2, \dots, C_i formed.

3.1.2 Algorithm Description

Greedy-MSC Heuristic (C, T, S)

```
1: set lifetime of each sensor to 1
2: SENSORS = C
3: i = 0
4: while each target is covered by at least one sensor in SENSORS do
5: /* a new set cover  $C_i$  will be formed */
6: i = i + 1
7:  $C_i = \emptyset$ 
8: TARGETS = T
9: while TARGETS =  $\emptyset$  do
10: /* more targets have to be covered */
11: find a critical target  $t_{crit} \in TARGETS$ 
12: select a sensor  $s_u \in SENSORS$  with greatest contribution, that covers  $t_{crit}$ 
13:  $C_i = C_i \cup s_u$ 
14: for all targets  $t_k \in TARGETS$  do
15: if  $t_k$  is covered by  $s_u$  then
16: TARGETS = TARGETS -  $r_k$ 
17: end if
18: end for
19: end while
20: for all sensors  $s_j \in C_i$  do
21: SENSORS = SENSORS -  $s_j$ 
22: end if
23: end for
24: end while
25: return i-number of set covers and the set covers  $C_1, C_2, \dots, C_i$ 
```

The Greedy Heuristics builds set covers iteratively[1], from lines 5 to 19. The set *SENSORS* maintain the list of sensors that are not part of any set cover, and these sensors can participate in additional set covers. The set *TARGETS* contains the targets that still have to be covered by the current set cover C_i .

In Step 11, critical target is selected to be covered; critical target is defined as the target covered by least number of sensors. This means when the energy of the sensors that cover the critical target is completely exhausted, the target cannot be covered anymore and hence the network lifetime is terminated. As a result, any cover set must contain the sensors monitoring the critical target. Once the critical target is selected, the heuristic selects the sensor with the greatest contribution that covers the critical target. Various sensor contribution functions can be defined. For the given heuristic a sensor has greater contribution if it covers a larger number of uncovered targets. Once a sensor is selected, it is added to the current set cover in line 13, and all additionally covered targets are removed from the *TARGETS* set. When all targets are covered, the new set cover is formed. The condition in line 4, that each target is covered by at least one sensor in the set *SENSORS*, guarantees that a new set cover will be formed in lines 5 to 19. After a set cover C_i has been formed, the sensors forming that cover are removed for set of available sensors *SENSORS* to find disjoint set.

The lifetime of WSN depends on the number of Cover Sets C_i found.

The complexity of Greedy Heuristic is $O(|S| \times |T|)$, where $|S|$ is the number of sensors and $|T|$ is the number of targets.

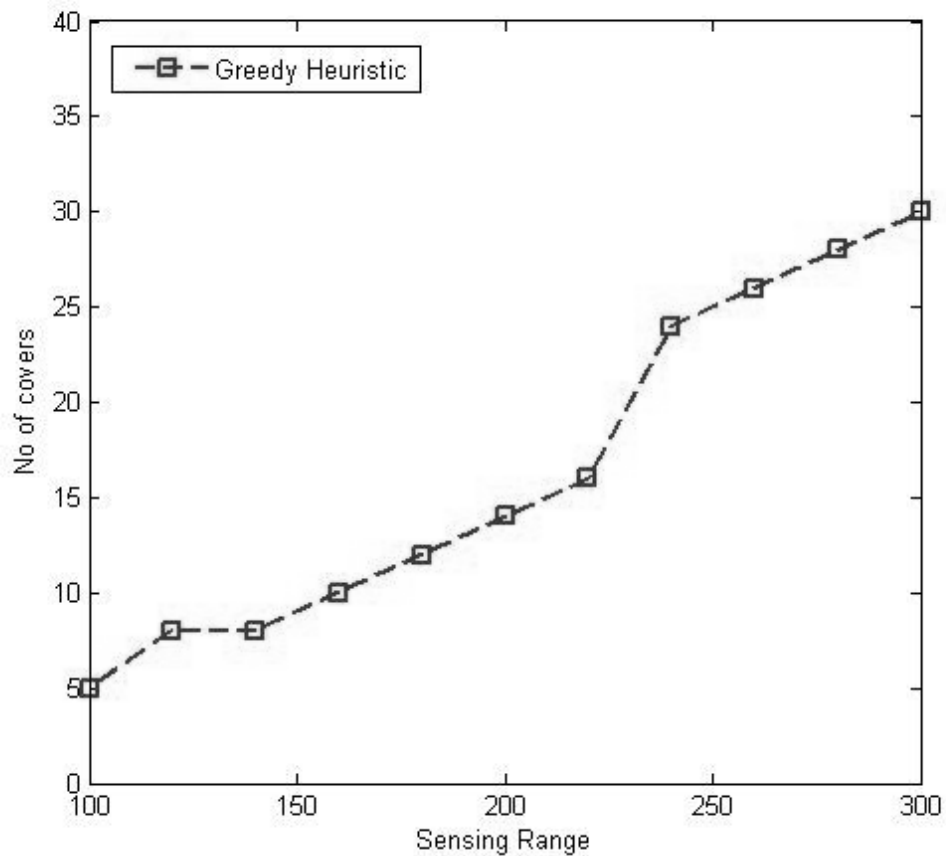
3.2 Simulation

A stationary network spanning an area of 500m by 500m with a fixed number of targets and sensors randomly deployed around the targets is simulated. The range of each sensor and life time is considered equal. The main objective is to study increase in number of cover sets as sensing radius and number of sensors increase. More the no of cover sets found, more is network lifetime.

Simulation 1: Adjusting the Sensing Radius

In the first simulation, 90 sensors and 10 targets are deployed.

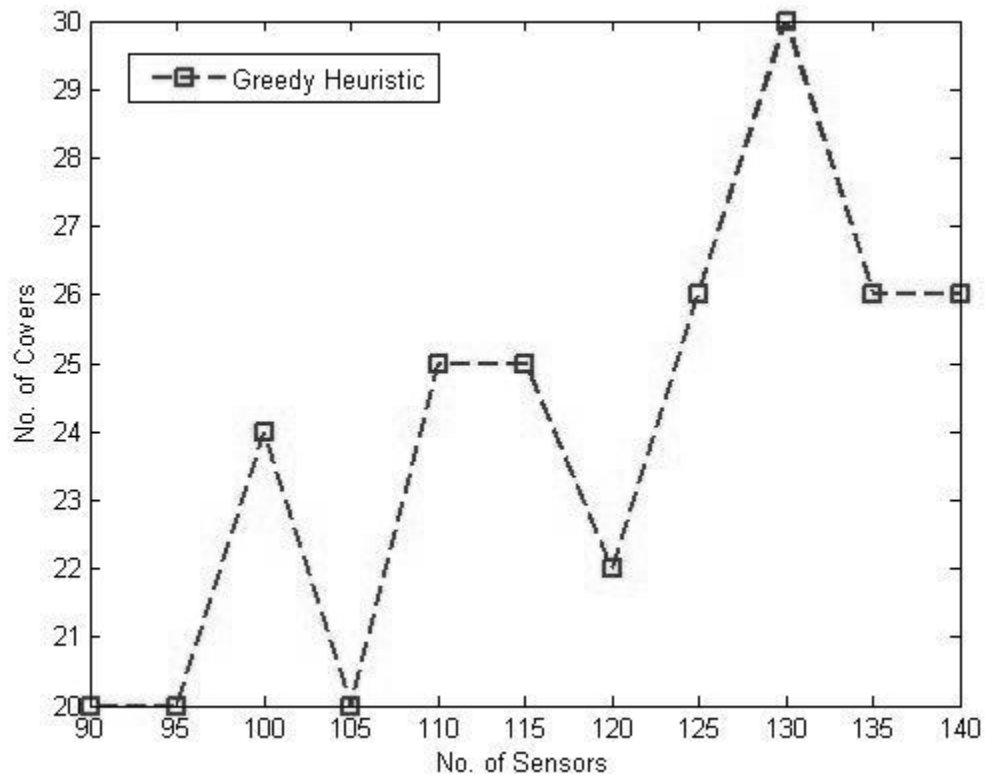
And the sensing radius of each sensor is increased from 100 to 300 by 10 for observing performance of given algorithms.



Graph. 3.1 No. of Covers with Sensing Range

Simulation 2: Controlling the number of Sensors.

In the second simulation, the sensing radius is fixed at 220 and sensors are randomly deployed from 90 to 140 increasing by 5 to cover 10 targets.



Graph. 3.2 No. of Covers with No. of Sensors

3.3 Inference

The inferences drawn from given simulations are:

1. Slope of curve gives the degree of optimization of the network lifetime.
2. For a specific number of targets, the network lifetime output increases with the number of sensors and the sensing range.
3. A better algorithm will have greater slope than one presented in this section.

3.4 Conclusion

In this section Greedy Algorithm based heuristic [1] is discussed to solve the MDSC problem. Even if this approach finds the cover sets to maximize the network lifetime of a WSN in polynomial time, its performance is very sensitive to how close an initial candidate is to an optimal solution. Thus, the approach can lead to a local maximum solution due to its heuristic search. A more sophisticated method to solve the MDSC problem is required. In the next section, a Genetic Algorithm based approach to solve MDSC problem is discussed to find the optimal solution by evolutionary global search. In this work, the Greedy Algorithm based approach is used as a baseline for comparison.

4. Genetic Algorithm for Disjoint Set Cover Problem

Genetic algorithm is a search heuristic that mimics the process of natural evolution. GA proceeds by creating successive generations of better solutions by applying genetic operations [4]. The main advantage of genetic algorithms is that genetic algorithms improve the chance of reaching the global optimum and also help in avoiding local optima [7].

4.1 Introduction

Simple Generational Genetic Algorithm procedure [11] is given:

1. Choose the initial population of individuals
2. Evaluate the fitness of each individual in that population
3. Repeat on this generation until termination (time limit, sufficient fitness achieved, etc.):
 - a. Select the best-fit individuals for reproduction
 - b. Breed new individuals through crossover and mutation operations to give birth to offspring
 - c. Evaluate the individual fitness of new individuals
 - d. Replace least-fit population with new individuals

The modeling of genetic algorithms for a given problem includes four basic steps [4]:

Representation - a candidate solution is represented by a chromosome and an element of the candidate solution is encoded into a gene. Each chromosome can be thought of as a point in the search space of candidate solutions.

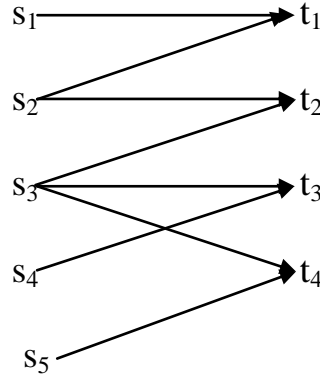
Fitness - The performance of each chromosome is measured by the fitness function.

Reproduction - The evolution of genetic algorithms processes populations of chromosomes, successively replacing one population with another by reproduction.

Genetic operators such as crossover, mutation, etc., are used to generate a better chromosome in the next generation.

For finding Maximum Disjoint Set, heuristic operator - Distribution is applied to the offspring after mutation.

4.2 Genetic Algorithm based MDSC Components



1	2	1	2	2
s ₁	s ₂	s ₃	s ₄	s ₅

Fig. 4.1 The value of gene in a chromosome represents the group that a sensor joins to be checked to form a cover.

s₁ and s₃ join the group 1, and s₂, s₄, and s₅ join the group 2. Both the groups 1 or 2 can fully cover the targets, forming 2 covers. Thus, the fitness of the chromosome is 2.

4.2.1 Representation

In given GA, integer representation is used to encode chromosome [2]. Each gene in the chromosome is mapped to a sensor and the gene's value indicates the group any sensor is included in to form a cover. Each chromosome can be represented as

$$C_i = \{g_{i1}, g_{i2}, \dots, g_{in}\}$$

Where, $g_{ij} \in \{1, 2, \dots, cb\}$, represents sensor S_j's group, $j = 1, 2, \dots, n$, n is the total number of sensors in target area and $i = 1, 2, \dots, npop$ is total population.

A chromosome is initialized with gene values randomly generated between the range from 1 to cb , where cb (critical bound) is the number of sensors covering the most sparsely covered target t_{CRIT} . All the genes in a chromosome having same random number are grouped to check if they form a cover, i.e. the value of a gene indicates the index of the group that the sensor joins.

Additionally, this type of encoding enforces that covers are disjoint since no sensor can join more than one group simultaneously.

4.2.2 Fitness

The fitness of a chromosome is calculated as the number of disjoint covers that can be found by the groups represented by genes in a chromosome. Fitness value is given by the number of groups that can form covers. For checking that a group of sensors form a cover, it is checked that the sensors belonging to that group has all targets within their range. This is done for all the groups to find fitness of a chromosome.

4.2.3 Reproduction

In the reproduction process, selection mechanisms are used to organize a new population from the current population [4]. For this approach Rank based Roulette wheel selection scheme is used to form new population.

4.2.3.1 Roulette wheel: The selection of chromosomes from the current population depends on the proportion of each chromosome's fitness to the total fitness, i.e. chromosomes with high fitness are copied to the population of the next generation at a higher rate. In rank-based fitness assignment, the associated probability of selection with each individual chromosome is based on rank of chromosome sorted by fitness value. The fitness

assigned to each individual depends only on its position in the individuals rank and not on the actual objective value [4][7].

4.2.4 Genetic Operators

The variation operators for integer-based GA are applicable. In this simulation, one-point crossover and uniform mutation is adopted.

In One-point Crossover, single crossover point on both parents' organism strings is selected. All data beyond that point in either organism string is swapped between the two parent organisms. Uniform mutation changes each gene of the offspring to a random number varying from 1 *to* *cb* with a given mutation rate.

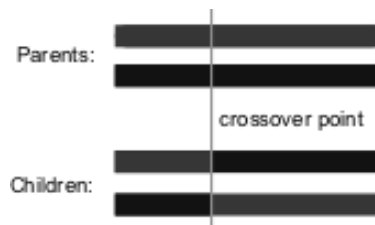


Fig.4.2 Single Point Crossover to generate children from parent chromosome

4.2.5 Distribution

Distribution is a heuristic operator used to distribute genes to different groups to search for more number of cover. Distribution has 2 functions:

1. Critical distribution - is used to distribute critical sensors to different groups. Critical Sensors are the sensors covering the most sparsely covered target. If they join the same

group, then at most only one cover can be found. Thus, the critical sensors need to be “distributed” to different groups to prevent them from joining the same group. This operator checks genes corresponding to critical sensors to find the genes with repeated values. For genes with repeated values, genes are replaced with other values from 1 to cb such that all genes corresponding to the critical sensors have different values.

2. Redundant distribution – is used to distribute redundant sensors from a cover set to a different group. A random sensor is selected, if the sensor is redundant to given cover set, the value of gene is changed randomly to a group that is not yet a cover set.

Distribution is applied on the offspring soon after mutation.

Parameter	Values in GA
Representation	$\{1, 2, 3 \dots \dots cb\}^{ S }$
Parent Selection	Roulette Wheel Rank based selection with Selection Rate = 0.5
Crossover	Single Point Crossover
Mutation	Uniform mutation Mutation Rate = .05
Heuristic	Distribution
Population Size	20
Stop Condition	300 Generations

Table.4.1 Genetic Algorithm Parameters

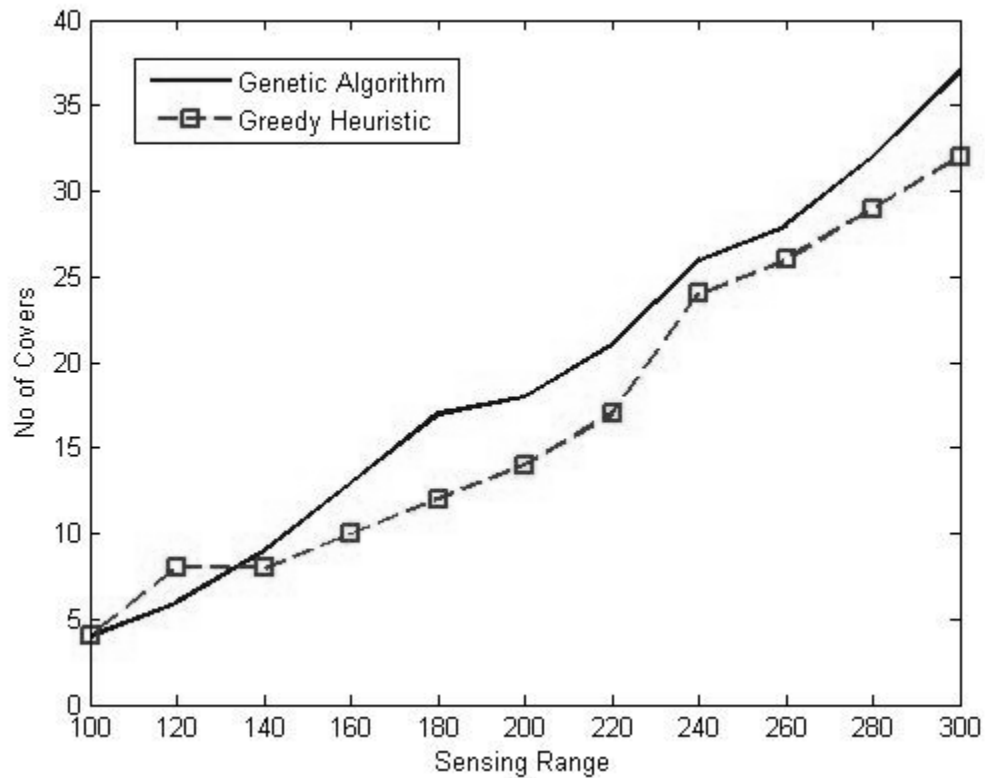
4.3 Simulation

The simulation is based on the same network as given in earlier section. A stationary network spanning an area of 500m by 500m with a fixed number of targets and sensors randomly deployed around the targets are simulated. The range of each sensor and life time is considered equal. The main objective is to study increase in number of cover sets as sensing radius and number of sensors increase. More the no of cover sets found, more is network lifetime.

Simulation 1: Adjusting the Sensing Radius

In the first simulation, 90 sensors and 10 targets are deployed.

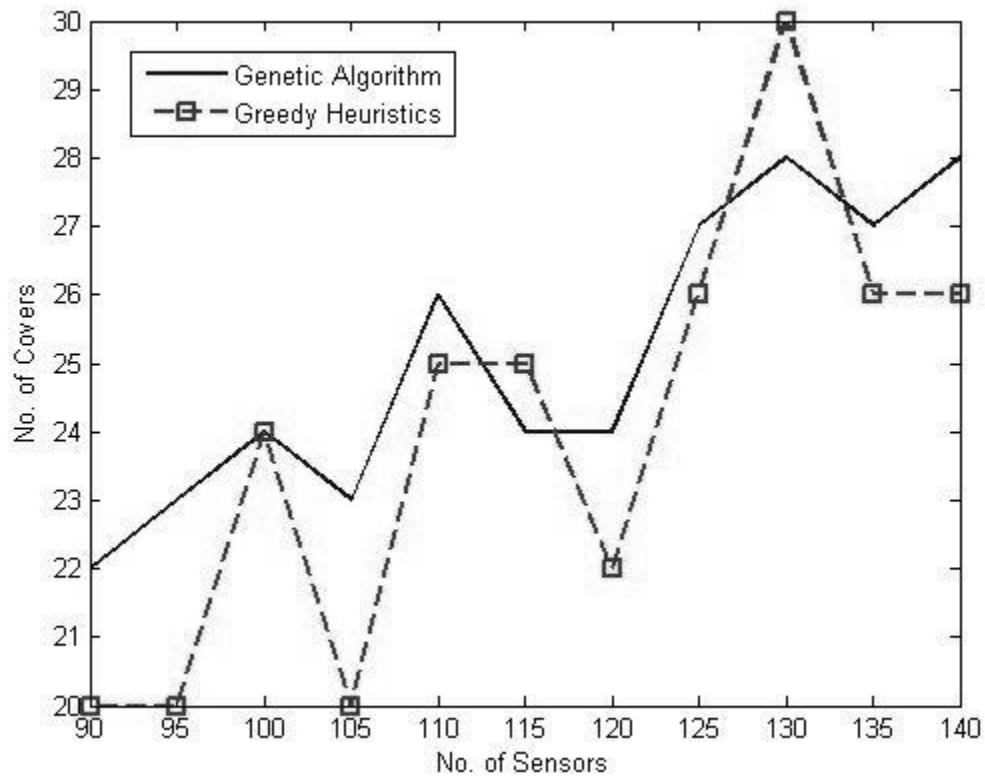
And the sensing radius of each sensor is increased from 100 to 300 by 10 for observing performance of given algorithms.



Graph. 4.1 No. of Covers with Sensing Range

Simulation 2: Controlling the number of Sensors.

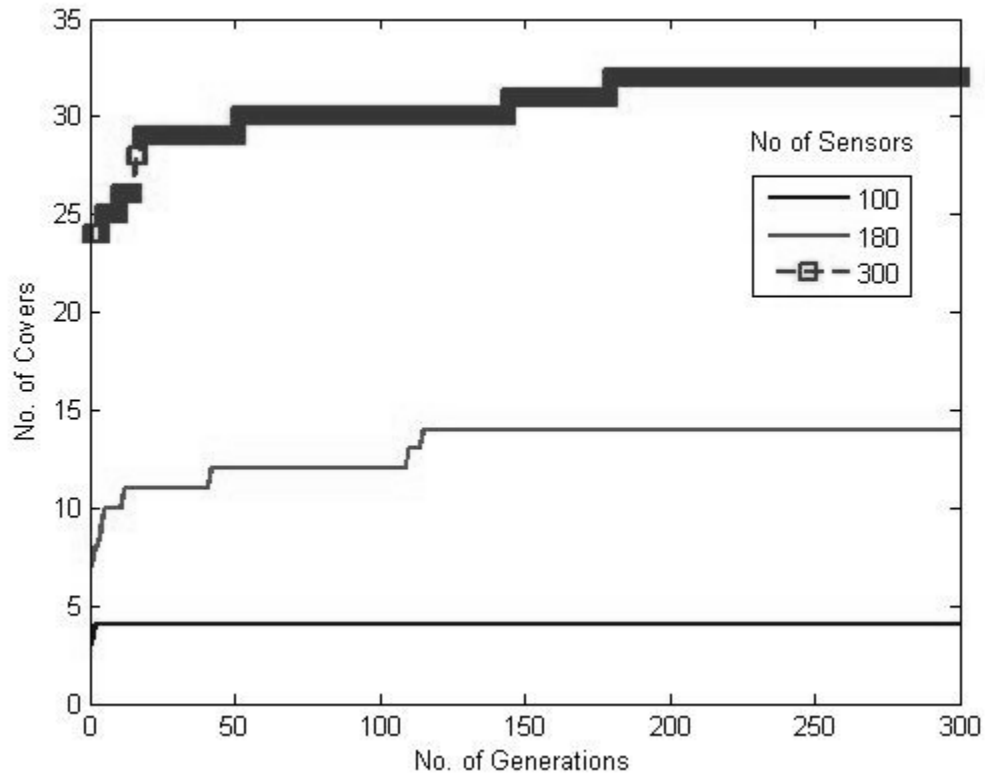
In the second simulation, the sensing radius is fixed at 220 and sensors are randomly deployed from 90 to 140 increasing by 5 to cover 10 targets.



Graph. 4.2 No. of Covers with No. of Sensors

Simulation 3: Controlling the number of Generations

In the third simulation, 90 sensors and 10 targets are used and varying the sensing radius from 100 to 180 and then to 300 to see the no. of generations it takes to find a cover



Graph. 5.3 No. of Covers with No of Generations

4.4 Inference

The simulation results can be summarized as follows:

1. For a specific number of targets, the network lifetime output increases with the number of sensors and the sensing range, as expected.
2. The value of slope of Genetic Algorithm based approach is greater than Greedy heuristic. Thus, GA based approach achieves a longer network lifetime than the Greedy heuristic does.

3. For target coverage problem with higher number of covers more generations are needed in genetic algorithm.

4.5 Conclusion

In this section Genetic Algorithm based approach for solving Maximum Disjoint Set (MDSC) Problem is discussed and basic GA parameters are formed. In addition, heuristic function Distribution is applied to distribute genes to different groups to search for more number of cover. Finally simulation is done using Greedy Heuristic as baseline to show that Genetic Algorithm based approach is better for finding more number of disjoint cover sets.

5. Conclusion and Future Work

This work discussed the target coverage scheduling for WSNs where the coverage constraint is that all targets must be covered. An important scheme for extending the sensor network lifetime is dividing sensors into maximum disjoint sensor covers and letting the sensor covers work by turns. The more sensor covers can be found, the more network life time can be prolonged. This problem can be solved by transformation to a combinatorial optimization problem; disjoint set covers (DSC) [5].

In this work two target scheduling algorithms are presented, the greedy heuristic and the genetic algorithm-based approach, to solve the DSC problem that is known to be NP-complete [5]. Simulations were done for different numbers of sensors, and various sensing ranges to investigate the effect on the performance of the given algorithms. Simulation results showed that the schemes can find the cover sets monitoring all the targets in an energy-efficient way. They also showed that, by an evolutionary global search technique, the genetic algorithm-based DSC can find more number of covers achieving a longer network lifetime than the greedy algorithm-based scheme does.

As our future work, the possibility of reaching closer optimum by combining Genetic Algorithm MDSC with local search techniques can be investigated. Another direction is to derive a parallel genetic algorithm to distribute the computation load evenly to each sensor for further prolonging the network lifetime.

REFERENCES

- [1] M. Cardei, My T. Thai, Y. Li, W. Wu “*Energy-Efficient Target Coverage in Wireless Sensor Networks*”, INFOCOM’05, IEEE press, 2005
- [2] C. Lai, C. Ting, R. Ko, “*An Effective Genetic Algorithm to Improve Wireless Sensor Network Lifetime for Large-Scale Surveillance Applications*”, IEEE press, 2007
- [3] J. Gil, Y. Han, “*A Target Coverage Scheduling Scheme Based on Genetic Algorithms in Directional Sensor Networks*”, Sensors press, 2011
- [4] R. L. Haupt, S. E. Haupt, “*Practical genetic Algorithm*”, 2nd edn., Wiley Press
- [5] M. Cardei, D. Z. Du, “*Improving Wireless Sensor Network Lifetime through Power Aware Organization*”, Wireless Network ’11, pp 334-340, Springer press, 2005
- [6] J. Chen, Y. Wen, D. Zhao “*Modeling and Extending Lifetime of Wireless Sensor Networks Using Genetic Algorithm*”, ACM press, 2009
- [7] S. Sivanandam,S. Deepa. “*Introduction to Genetic Algorithms*”; Springer: New York, NY, USA, 2008.
- [8] J. Yick, B. Mukherjee, D. Ghoshal “*Wireless sensor network survey*”, Elsevier press, 2008

- [9] C. F. Huang, Y. C. Ting, "*The Coverage Problem in a Wireless Sensor Network*", WSNA'03, ACM press, 2003
- [10] M.T. Thai, F. Wang, D. Z. Du "*Coverage Problems in Wireless Sensor Networks: Designs and Analysis*"
- [11] Wikipedia, http://en.wikipedia.org/Genetic_algorithm