Maximum Coverage Heuristics (MCH) for Target Coverage Problem in Wireless Sensor Network

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***Abstract*— Wireless Sensor Network is useful in broad range of applications such as natural disaster relief, military, environmental and health monitoring. Coverage is one of the fundamental problem and an active research area in wireless sensor network. WSN is an emerging field due to its large contribution in dealing with coverage. It consist of low cost, low power, small size and multifunction sensor nodes. The critical aspect with wireless sensor network is energy conservation. In power constrained WSN, scheduling of sensors to be done effectively and efficiently so as to maximize network lifetime. In this paper we give an introduction to WSN and its fundamental problems that is target coverage problem together with energy constraint. The target coverage problem is proven to be NP-Complete problem by many researchers. We propose a new energy-efficient heuristic for target coverage problem in wireless sensor network to maximize total network lifetime.**
***Keywords:* Wireless Sensor Network, Target Coverage, Energy-Efficiency, NP-complete.**

I. INTRODUCTION

WSN is the collection of sensor nodes. There can be hundreds or thousands of sensors. Wireless sensor networks constitute a platform in variety of domains such as military applications, natural disaster relief, environmental and health monitoring. Each sensor has one sensing and communication unit that is capable of collecting and transmitting the sensed data to the base station (may be a desktop computer or a laptop). Sensor deployment strategy can be done in two efficient ways (deterministic and random) depending upon the application and environment: Deterministic deployment is also called structured deployment and random deployment is also called unstructured deployment. In deterministic, sensor placement is done in predetermined manner. The location of sensors is known with an advantage that fewer sensors can be placed with less cost of maintenance and management. In random, sensor placement is done randomly. So sensor density cannot be guaranteed as some area may contain more sensors than other areas. Network maintenance is complex in terms of connectivity and fault or failure detection. Each sensor can collect data by monitoring usually a small area that it is in its sensing range means that sensor provides coverage to this area. Depending upon the application, a sensor can either collect the data continuously or periodically. Each sensor node has the ability to sense the environment, monitor the targets, collect the data from the targets and communicate the sensed data with the neighboring node. Since sensors in sensor network have limited batteries, so energy conservation is critical aspect of wireless sensor network. Management of available energy resources done in an energy-efficient way has direct impact on the network lifetime and application performance. Sensor node can be in three modes: Active, Sleep, off mode. In Active mode, sensor can sense and communicate the data. Energy of sensor in active mode is consumed. In Sleep mode, energy of sensor is not consumed. In Off mode, either the sensor is turned off permanently or battery of sensor is finished. An energy-efficient method for managing the power consumption of the sensor nodes is to schedule the sensor nodes in such a way that they alternate between active and sleep mode. This can be done by organizing the sensors into set of sensors (we call these sets as sensor covers) such that every sensor cover is capable of monitoring all the targets. As only a subset of sensors is active at a time for providing coverage to all the targets, helps in reducing power consumption. The aim of this paper is to propose an energy-efficient method of scheduling sensors activity for target coverage problem in WSN. The rest of this paper is organized as follows: Section 2, describes different types of coverage. Section 3, we describe the review of all the papers that we studied in context of target coverage problem. In Section 4, describes the problem definition. In Section 5, we present proposed algorithm. Section 6 , experiment analysis for performance evaluation. Finally, conclusions and future work are given in section 7.

II. COVERAGE

The Coverage is the key research issue in WSN. It is the measure of the Quality of Service (QOS) that is how well the targets are being covered by the deployed set of sensors. The aim of coverage is that each object in the physical space of interest must be within sensing range of at least one sensor. Factors those are considered while developing a plan for coverage in a sensor networks depends upon the requirements of the application. The coverage problem is classified into an area coverage problem and a target coverage problem.

A. Area Coverage

Objective of the sensor network in area coverage is to cover a given area completely by battery powered sensors and each point of the area need to be monitored to extent network lifetime. Area is divided into number of fields such that each field is covered by a subset of sensors. Area coverage problem aims at determining the sensor covers that covers the entire area collectively. In Area coverage problem, network lifetime can be extended by selecting an appropriate distributed and localized protocol to select set of active sensors. The network activity is divided into rounds such that before each round decision is made about which sensors will be in sleep mode.

Slijepcevic et. al. [1] proposed an energy-efficient algorithm for dealing with the area coverage problem. The field is considered as a collection of points. If two points are monitored by the same set of sensors then it can be said that the points belongs to same fields. Fields are the areas obtained from the intersection of the sensing limits of the sensor. Each sensor can cover more than one field and each field is to be covered by at least one sensor. The most-constrained least constraining algorithm produce maximum number of disjoint sensor covers by selecting sensors that cover the critical field and gives priority to sensors that cover more uncovered fields. Cardie et. al. [8] Model disjoint sets as disjoint-dominating sets in an undirected graph and a graph coloring mechanism is proposed for computing the maximum number of disjoint dominating sets. Cardei et. al. [3] proposed (MC-MIP) heuristics that transform the coverage problem into maximum flow problem. The result of maximum flow problem is solved using mixed integer programming to compute maximum number of disjoint sets covers.

B. Target Coverage Problem

Target coverage problem is all about maximizing network lifetime of wireless sensor network with power scarcity by monitoring a set of targets continuously for the maximum duration. Since the sensors are battery powered, they can neither be renewed nor replaced. So conservation of energy is an important issue in WSN. The battery consumption of the sensors needs to be managed efficiently to extend the network lifetime. Energy-efficient monitoring of targets can be achieved by dividing the sensors into subsets called sensor cover responsible for covering all the targets for certain period of time. Sensor cover is the subsets of sensors that cover all the targets. Here, objective is to schedule the sensor covers in such a way that only one cover is active at a time to cover all the targets. So, instead of activating all the sensor covers, a subset of sensors is active, thus reducing power consumption and extending network lifetime. Coverage objective is to maximize the number of cover sets with maximum aggregated lifetime or minimize the required number of deployed sensors.

III. RECENT WORK IN TARGET COVERAGE PROBLEM

There is lot of work has been done in this field. Various algorithms have been proposed based on coverage problem. This section outlines the existing algorithms that were designed by the researchers in context of energy-efficient target coverage problem in wireless sensor networks.

A. Disjoint and Non- Disjoint Algorithm

In Disjoint approach, sensors are divided into disjoint subsets called disjoint cover set where a sensor can participate only in one sensor cover. Only one disjoint sensor cover is active at a time [3, 8 and 1]. In non disjoint, sensors are divided into non disjoint cover sets where a sensor can participate in more than one cover set thus extends the total lifetime of the network. It will produce more cover sets as compared to disjoint ones. The algorithms discussed in [2, 4, 5 and 7] have high degree of complexity.

B. Centralized and Distributed Algorithm

In Centralized approach, monitoring scheduled is calculated at the base station and then the result is sent to rest of the sensors. Algorithm is always executed at the base station and result is scattered to the sensor nodes. In Distributed, decentralized decision making is involved as the number of sensor nodes are involved in executing the required task and then the result is scattered to rest of the sensors10, 11 and 12].

Cardei et. al. [2] models the random target coverage problem as MSC (Maximum Set Cover) problem and proposed a LP and Greedy solution. It designs energy-efficient target coverage heuristics for computing non disjoint sets efficiently using greedy and LP approach. It allows the sets to operate for different time interval. The greedy algorithm is called Greedy-MSC and linear programming is also called LP-MSC. In Greedy, sensor cover is formed by selecting the sensors covering the critical target. Then the sensor with maximum battery life and cover more uncovered targets is selected. Greedy approach has lower complexity and running time as compared to LP approach.

Zorbas et. al. [4] proposed a centralized greedy heuristic algorithm to produce non disjoint sets for power efficient monitoring of targets. Sensors are categorized into four classes depending upon the coverage quality: ***best, good, ok, poor***. This categorization is based on their coverage status of already and uncovered targets and flexible enough to avoid double covered critical targets. While generating non disjoint cover sets, it tries to select a sensor first from best class. If no more sensors in best class then it tries from good class and so on. So sensor selection is based on classes, coverage of critical targets and number of available sensors.

Zorbas et. al. [7] presented a detailed description of greedy heuristic algorithm and maximize network lifetime by presenting an energy-efficient centralized static and dynamic heuristics that produce both disjoint and non disjoint cover set. The strategy to select sensor for sensor cover based on cost function managing the coverage status of the sensors and their relation with the critical targets and remaining battery life. The heuristic is flexible enough to avoid double covering of targets. Dynamic-CCF has higher complexity due to neighbor-set recalculation and critical node task management.

M. Chaudhary et. al. [5] proposed a centralized energy-efficient approach to produce non disjoint cover sets where heuristic gives priority to sensors with maximum residual battery life and which covered at least one uncovered target. The priority of sensor reduces once it is included in the sensor cover to avoid generation of same sensor covers. This algorithm generates non minimal sensor covers which are later minimized to extend the total network lifetime.

C. Target coverage with adjustable sensing range

Target coverage problem is based on multiple sensing ranges of the deployed sensors. Each sensor in WSN has P sensing ranges and based on the coverage requirement, at a time one sensing range is chosen by sensor.

Cardei et. al. [9] improves wireless sensor network lifetime through power aware organization by scheduling the sensors and their sensing range. This paper proposed two algorithms: centralized greedy and heuristic algorithm named CGH & a distributed localized greedy and heuristic algorithm named DLGH. In CGH, priority is to select a sensor with greatest contribution (in terms of coverage). Because of large contribution of some sensors, they die out early. In distributed DLGH, since the local information of sensors is used so it may result in many redundant sensors in each round too.

D. Target Coverage Problem under QOS Constraint

Target Coverage Problem deals with maximizing network lifetime satisfying Q-Coverage requirement [6]. Q-Coverage requirement is that all the targets are covered by at least Q-sensor. There are set of a sensors and set of targets. Target is covered if it falls within sensing range of at least Q number of sensor.

M.Chaudhary et. al. [6] Concerned with maximizing the network lifetime while monitoring a set of targets for maximum duration. It uses greedy heuristics to generate Q-Cover by selecting a sensor with higher residual battery life. Instead of consuming total lifetime of the sensor, it allows the sensor to participate in more than one sensor cover thus generating more cover sets.

E. Incorporating connectivity in the target coverage problem.

A network is said to be connected if any node can communicate with any other node. A sensor can collect the data either periodically or continuously and send collected data to the connected base station. Objective is to maximize the network lifetime by selecting minimum number of nodes to provide initial coverage and connectivity.

Jaggi et. al. [10] authors goal is to increase the network lifetime to achieve both coverage and connectivity requirements. It proposed a connected cover set generation algorithm with the consideration that all the cover sets are disjoint and they try to maximize their number, while computing a shortest path tree to select the minimum number of relay nodes that manage to retain coverage and connectivity in the network.

Cardei et. al. [11] author proposed centralized algorithm using integer programming and greedy technique and distributed algorithm for the computation of the connected cover sets (CSC) problem with an objective to find maximum number of sensor cover such that each sensor node to be activated is connected to the base station.

Zamanifar et. al. [12] author discuss the variant of target coverage problem that is target connected coverage where all the sensors are connected to the base station with the help of relay nodes.

IV. PROBLEM DEFINATION

Let the n sensors $s_1, s_2, \ldots s_n$ and m targets $t_1, t_2, \ldots t_n$ be randomly deployed. Each sensor s_i has a battery life of $b_{i,}$ initially all the sensors s_i has battery life b_i and at any stage $b_{i\ is}$ the residual battery life of the sensors. Sensor s_i can cover target t_j if t_j falls within the sensing range of $s_{i.}$ Sensor cover is the set of sensors covering all the targets. The maximum allowable lifetime to the sensor cover is the smallest lifetime of its sensors.

V. PROPOSED HEURISTIC

In this section, based on above analysis we put forward a new heuristic to solve the target coverage problem. The granularity parameter $w \in (0,1]$ helps in generating a better approximation of optimal solution. We propose an energy-efficient maximum coverage heuristic (MCH) mainly divided into following steps:

A. Generate a cover

Maximum coverage heuristics generates sensor cover S by selecting a sensor covering the critical target with maximum battery life. It then avoids double covering of critical target. Rest of the sensors is selected from subset of sensors not covering the critical target. So, the sensor with maximum battery life is selected next.

B. Minimalizing sensor cover

Maximum coverage heuristics minimalize the sensor cover C by removing the sensors which are of no use in the cover helps in reducing the wastage of battery life of sensor. By removing a sensor from the sensor cover if the cover still covers all the targets, then the sensor is removed from the current cover and same process is repeated for all the sensors.

C. Assign lifetime to cover

After finding the sensor cover which is also energy-efficient, we decide the lifetime of that cover means for how much time the cover is active. This is denoted by X (C).In this algorithm instead of assigning maximum allowable lifetime, we assign minimum of user defined constant w and the maximum allowable lifetime. By this we improve the efficiency of using the sensors and making the sensors available for other covers.

D. Updating priorities of sensors

After finding the value of lifetime in above step, we will update the battery of all sensor nodes those who are participating in above sensor cover to avoid the generation of same sensor cover in the next iteration. We subtract the value of X (C) from all sensors battery.

```
INITIALIZATION

C=Ø; SENSORS= all sensors
GENERATE COVER

While (all targets are covered)
{
SUBSET=Ø
S= Ø
TARGETS=all targets
Find critical target tk, a target covered by least number of
  sensors.
Select a sensor s with maximum battery life bi from
  SENSORS covering the critical target tk.
S = S ∪ s
SENSORS= SENSORS – s;
For all the targets t covered by s
TARGETS = TARGETS – t;
 SUBSET= set of sensors from SENSORS not
  covering   the critical target tk.
 While (TARGETS ≠ Ø)
 {
Select a sensor s with maximum battery life bi from
  SUBSET that covers at least one uncovered target.
S = S ∪ s
SENSORS= SENSORS – s;
SUBSET= SUBSET – s;
For all the targets t covered by s
TARGETS = TARGETS – t;
While (TARGETS ≠ Ø and SUBSET = Ø)
{
Select a sensor s with maximum battery life bi among
  remaining sensors from SENSORS that covers at least
  one   uncovered target.
S = S ∪ s
SENSORS= SENSORS – s;
For all the targets t covered by s
TARGETS = TARGETS – t;
}
}
 Minimalize S
 If S ≠ NULL
 C = C ∪ S
 X (C)← min (w, maximum - lifetime (C))
 For all si ∈ S,
Update bi = bi - X (C)
If bi =0, then SENSORS = SENSORS – si
 Else return
}
```

VI. EXPERIMENTAL RESULTS

Our heuristic is implemented in c language for experimental study. In this section, we evaluate the performance of greedy [2] and HEF [5] with maximum coverage heuristics (MCH). We simulate a stationary network with sensors and targets points randomly located in area with coordinates [300m, 400m] and [400m, 300m]. We assume all the sensors are homogeneous and equal sensing range for all the sensors.

A. Experiment 1

We experimented for fixed 60 targets points randomly distributed and vary number of sensors between 30 and 100 with an increment of 10, when sensing range r is 50. Average lifetime is calculated for 5 random problem instances. Both greedy [2] and maximum coverage heuristics are experimented with value of w as 0.37 to find out the heuristic solution.

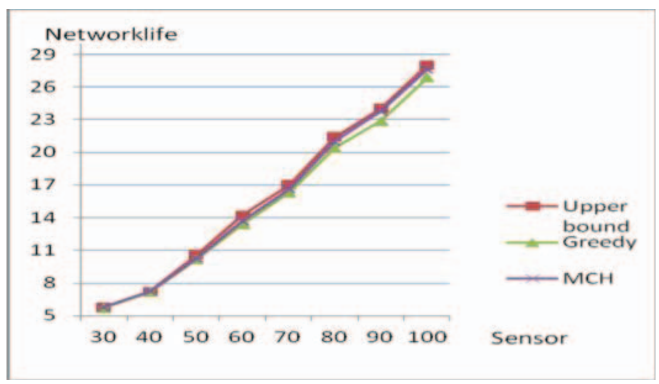

Fig 1: Network lifetime with number of sensors when r = 50

B. Experiment 2

We experimented for fixed 50 sensors points randomly distributed and vary number of targets between 20 and 100 with an increment of 10, when sensing range r is 50. Average lifetime is calculated for 5 random problem instances. Both greedy [2] and maximum coverage heuristics are experimented with value of w as 0.25 to find out the heuristic solution.

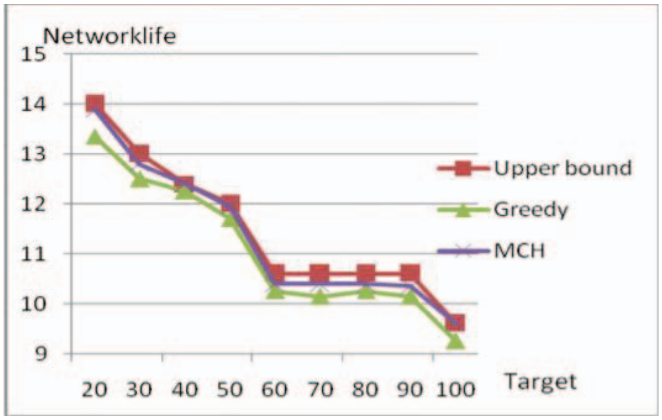

Fig 2: Network lifetime with number of targets when r = 50

C. Experiment 3

We experimented for fixed 60 targets points randomly distributed and vary number of sensors between 30 and 100 with an increment of 10, when sensing range r is 50. Average lifetime is calculated for 5 random problem instances. Both HEF [5] and maximum coverage heuristics are experimented with value of w as 0.37 to find out the heuristic solution.

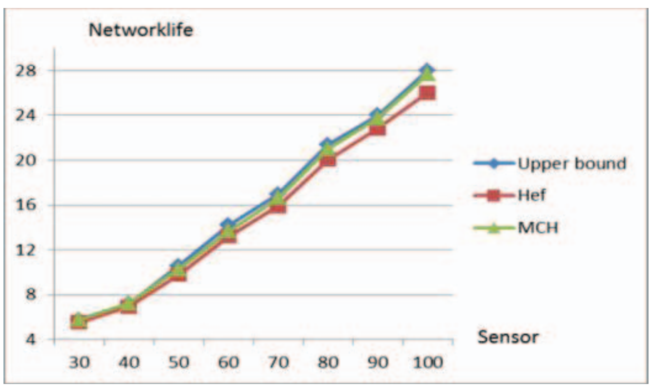

Fig 3: Network lifetime with number of sensors when r = 50

D. Experiment 4

We experimented for fixed 50 sensors points randomly distributed and vary number of targets between 20 and 100 with an increment of 10, when sensing range r is 50. Average lifetime is calculated for 5 random problem instances. Both HEF [5] and maximum coverage heuristics are experimented with value of w as 0.25 to find out the heuristic solution.

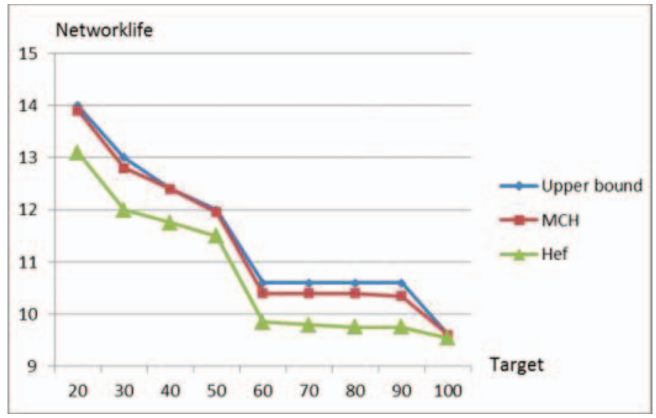

Fig 4: Network lifetime with number of targets when r = 50

Heuristics depends upon number of sensors and number of targets. Network life results increases as the sensor density increases. When more sensors are deployed, targets are covered by more number of sensors. So, more covers are generated. Network lifetime tends to decrease as the number of targets increases for specific number of sensors.

VII. CONCLUSION

In this paper we have mainly presented a brief description of the work that has been done in the field of TARGET coverage in wireless sensor network. We proposed energy-efficient target coverage heuristic to improve total network lifetime. Our simulation results shows that proposed algorithm (MCH) is performing better than two of the existing algorithms in terms of total network lifetime. In future scope of work, we will be designing some more energy-efficient algorithm for various variants of target coverage problems in WSN.

REFERENCES

[1]Jeffrey S. Slijepcevic, M. Potkonjak,(2001) "Power efficient organization of wireless sensor networks", Procof International Conference on Communications (ICC), IEEE, pp 472–476, 2001.
[2] M. Cardei, M. T. Thai, Y. Li, and W. Wu,(2005) "Energy-efficient target coverage in wireless sensor networks", In Proc. of IEEE Infocom.
[3] Boehm, .M. Cardei, D.-Z. Du, (2005) "Improving wireless sensor network lifetime through power aware organization", ACM Wireless Networks vol. 11, pp: 333–340.
[4] D. Zorbas, D. Glynos, P. Kotzanikolaou, C. Douligeris, (2007) "B {GOP}: An adaptive algorithm for coverage problems in wireless sensor networks", 13th European Wireless Conference, EW.
[5] M.Chaudhary , A.K.Pujari, (2011) "High-Energy-First(HEF)Heuristics for Energy-Efficient Target Coverage Problem", International journal of AdHoc,Sensor&UbiquitousComputing(IJASUC),Volume 2,Number 1, March 2011.
[6] M.Chaudhary, A.K.Pujari, (2009) "Q-Coverage Problem in Wireless Sensor Networks, ICDCN, LNCS 5408, pp. 325–330, 2009. © Springer-Verlag Berlin Heidelberg 2009.
[7] D. Zorbas, D. Glynos, P. Kotzanikolaou, C. Douligeris, (2010) "Solving coverage problems in wireless sensor networks using cover sets", Elsevier, Ad Hoc Networks, Volume 8, Issue 4, pp. 400-415, 2010.
[8]. M. Cardie, D. MacCallum, M. X. Cheng , M. Min , X .Jia, D .Li and D. Z. Du (2002) "Wireless sensor networks with energy efficient organization" Journal of Interconnection Networks, vol.3, no.3-4.pp.213-229, 2002.

[9]. M. Cardei, J. Wu, N. Lu, M.O. Pervaiz, (2005) "Maximum Network Lifetime with Adjustable Range", IEEE Intl. Conf. on Wireless and Mobile Computing, Networking and Communications (WiMob).
[10]N. Jaggi, &, A. A. Abouzeid, (2006) "Energy-efficient connected coverage in wireless sensor networks", 4th Asian International Mobile Computing Conference (AMOC), pp 77–86.
[11]. I. Cardei, M. Cardei, (2008) "Energy efficient connected coverage in wireless sensor networks*",* Int. J. Sen. Netw. Vol. 3, pp 201–210.
[12]. A. Zamanifar, O. Kashefi and M. Sharifi, (2009) "An Efficient Approach to Restore Actor-Actor Connectivity in Wireless Sensor and Actro Network", International Journal of Computer Networks & Communications (IJCNC), Vol.1, No.1.