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COMPARATIVE ANALYSIS OF SENSOR PLACEMENT ALGORITHMS IN WIRELESS SENSOR NETWORKS

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ABSTRACT

This paper provides a comprehensive survey on addressing the target coverage problem to maximize the network lifetime by placing the minimum number of sensors and without affecting the quality of monitoring. Energy utilization is one of the important key challenges in the research area of sensor networks. Deployment of sensor nodes should be with extreme coverage and connectivity but with less energy utilization. Coverage and Connectivity is an important performance metric in wireless sensor networks, which reflects how a sensor field is monitored by the deployed WSN. The result shows that Genetic algorithm shows improved performance over Greedy algorithm in maximizing the network lifetime of the sensors in the network.

Keywords: wireless sensor network, target coverage, network lifetime.

1. INTRODUCTION

In recent years, wireless sensor network is widely used in many applications such as area monitoring, vehicle detection, medical and healthcare applications, industrial and border monitoring [14, 16, 17]. Wireless sensor networks consist of distributed sensors which collect data from the environment then compute and forward it to the destination either directly or over a multi-hop path [15]. These sensors are small sensing devices, cost-effective having low power and easy to deploy. Based on the nature of application the sensing nodes may be deployed either randomly or deterministically [11, 12, 13]. There are many sensor placement schemes to precisely identify the sensor location in the field area. The placement scheme is based on location management, routing and power management. Coverage and connectivity are considered as the major issue in the target based wireless sensor networks since the data forwarded from target nodes to base station. Placement of sensors is done in such a way to satisfy the monitoring requirement, to cover the target area and to address to key challenges.

2. CHALLENGES IN SENSOR PLACEMENT

Some of the challenges faced during design and performance in the placement of sensors are connectivity issues in sensor network, data storage, deployment, scheduling, energy efficiency, fault tolerance, communication reliability, and node failure due to environmental condition, localization, energy maintenance, security, low latency, scalability, transmission media, and coverage problem. In addition, the topology issues such as Geographic Routing, Sensor holes, Coverage Topology also exist.

3. ANALYSIS OF GENETIC ALGORITHM

In STHGA [1], a lifetime of sensors is maximized by constructing an energy efficient wireless sensor network using scheduling transition operations. The function of schedule transition operation is to enhance the coverage and to switch the sensors from one cover set to another cover set. Here the author identifies the problem of finding the largest number of a disjoint set of sensors after the random deployment of sensors in the target area. The proposed algorithm finds the highest gene value of each and every chromosome that is constantly increased over quality. It relates to the number of disjoint complete cover sets. The problem depends on the size of the target area, total number of sensors, and sensor location with sensing ranges. Energy consumption of sensors is determined by using the sensors with different sensing ranges to get near-optimal solutions. The work can be extended considering the energy consumption of sensors by using different sensing ranges with different working modes and the lifetime of entire cover sets.

The priority-based target coverage [2], discriminate the limited sensing angle of the directional sensor. In the target coverage set-up, each target is coupled with different priorities. The distance between directional sensors and target are monitored based on the sensing quality. This work considers the minimum subset of directional sensors in the sensor network which monitors the entire target by one or more directional sensors based on the priorities and the quality of monitoring. The work can be extended based on efficient algorithms and decentralized execution in large scale senor networks.

The author in [3] identifies the problem of maintaining the coverage by using the minimum number of active sensors with limited energy consumption in wireless sensor networks. The proposed non-dominated sorting algorithm in a heterogeneous sensor network used to solve the multi-objective optimization of coverage problem in sensor networks. It uses improved binary code which addressed to signify both sensing radius and selection. This proposed centralized algorithm needs to collect the location of all sensors to examine the effect of the coverage rate and energy consumption with different generations. In order to reduce the complexity and to improve the efficiency of an algorithm uses cluster-based architecture and electing the cluster-heads in a distributed manner. The work can be extended to deal with hybrid sensor networks for optimization.

In Schedule Transition Hybrid Genetic Algorithms [4], authors discussed about the coverage and connectivity problem in target based wireless sensor network and the usage of proposed algorithm to solve it. Thus proposed scheme is used to identify the potential set of pre-fixed possible position for placing sensor nodes to accomplish k-coverage to all targets and m-connectivity to each sensor node. The proposed Genetic algorithm is used to solve the optimization problems which defines efficient chromosome representation and proficient fitness function selection cross over and mutation operations. Every individual is evaluated by a fitness function to validate its quality. In this study, the author has not focused on the energy efficiency issues while selecting the possible positions. The work can be extended developing a proficient scheme for routing the sensed data from all the targets in which priority is given for energy balancing and efficiency.

In Heuristic Search method [5], author proposes a scheduling operation to find the maximum number of disjoints sets which also maximizes the network lifetime for the entire region. The proposed algorithm achieves high-quality solutions by sensing multiple target point at fast optimization speeds which are used to find the maximum number of disjoint complete cover sets of sensor for point coverage to maximize the network lifetime. Over the search space initially, members are randomly scattered to provide an optimum solution. The work can be extended to increase the lifetime of sensor networks in coverage problem.

4. ANALYSIS OF GREEDY ALGORITHM

In the Greedy set cover algorithm [6 , 18 - 20], is implemented to satisfy the full target coverage by distributing sensors among disjoints and non-disjoints set cover for TCP in wireless sensor networks. The author addresses the problem of using set cover approach. Target is continuously observed by using scheduling sensors for energy saving. Maximum set cover problem is done by partitioning sensors into a maximum number of set covers. Minimum set cover problem is done by selecting a minimum number of sensors which cover the target. Non-disjoint set covers state that sensors can't be alive if it is supplied more than the initial energy. The provision is given by allowing the sensor to be the member of multiple sets. The proposed sensor scheduling is done by transmitting energy to the number of targets which was covered by multiple sensors. The work can be extended to a k-coverage problem and efficient target coverage by considering connectivity and QoS constraints.

In [7], the authors identify how efficient placement scheme involves in location management, routing and power management. The proposed Greedy Placement scheme is used to achieve near-optimal performance in a linear network. The proposed scheme defines the efficient placement of sensors. To construct a network, parameters needed are initial energy, minimum number of nodes with lifetime and target area. In a linear network, nodes which are closer to the sink node have higher relay loads. In case if we uniformly deploy sensor node, the node which is closer to the sink node consume higher power and die quickly. Thus results in a wireless sensor network that will be disconnected. Data aggregation is considered for the significant enhancement of the coverage area. The work can be extended for placement scheme in planar networks.

In LP-based heuristic greedy algorithms [8], the author identifies the sensor coverage problem in wireless sensor networks by adjustable sensing range. The authors study the problem of target coverage and AR-SC problem. The proposed scheme defines the Adjustable Range set cover problem where a maximum number of set covers and the ranges related with each sensor are found. To monitor the number of targets is done by randomly deploying a large number of sensors with the adjustable sensing range. A greedy algorithm is proposed for computing set covers both in centralized and distributed scenario. The work can be extended by integrating connectivity requirement in sensor network. Among the selected sensors, information is exchanged between sensor and base station by maintaining connectivity.

In [9], the authors study the sensor placement problem as constrained optimization problem to achieve both connectivity and coverage which is based on the confident information coverage model. The grid mechanism is used to discretize the sensing field, in the connected network, by placing the minimum number of sensors to provide the authenticated data coverage for all the grid points. The author propose two heuristic algorithm for finding the estimated solution for the sensor placement problem namely, the connected cover formation (CCF) algorithm and the cover formation and relay placement with redundancy removal (CFRP-RR) algorithm. In CCF, in each and every iteration, it covers the maximum number of uncovered grid points by placing the new sensor at an uninhabited candidate location. In CFRP-RR, without using network connectivity some of the sensors are placed to cover all the grid points. Both of the algorithms are done in a greedy manner.

In [10], authors propose a systematic framework by choosing the minimum number of sensors nodes which are distributed randomly in the sensor network. Optimal placement is implemented by using linear integer programming. The author's main ideas for implementation are that to maximize the area and to minimize the nodes in the sensor network. The greedy algorithm is used to maximize the coverage and minimize the energy utilization. The proposed model and algorithm is used to estimate optimal solutions for the placement of sensors. By using grid topology, initial placement of a sensor in the network is done which is used in the optimal selection, in order to minimize the number of alive sensors nodes. The work can be extended by identify the movement of sensors with communication range and cost.

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5. PERFORMANCE ANALYSIS OF GENETIC AND GREEDY ALGORITHM

Algorithms such as Divide–and–Conquer Approach, Global optimal placement algorithm, MAX_AVG_COV, MAX_MIN_COV, K- means coverage algorithm are some of the algorithms implemented in wireless sensor networks for the sensor placement. The issues related to the comparative algorithms are coverage, connectivity, energy consumption and sensor scheduling. It is required to measure the complexity of a problem. Complexity is measured by the quantity such as time, storage, program, communication by using computational resources to solve particular task. Genetic algorithm and Greedy algorithm were compared with the given issues such as target coverage, connectivity, energy efficiency and sensor scheduling. It was found that Schedule Transition Hybrid Genetic Algorithm [1] perform better than Heuristic Search Genetic algorithm with respect to network lifetime. If target coverage with energy consumption is the primary motive Genetic algorithm [3] offers best option. LP-based centralized and distributed greedy algorithm [8] shows better performance in target coverage problem. The comparison topology of placement algorithms is given in below Figure-1.

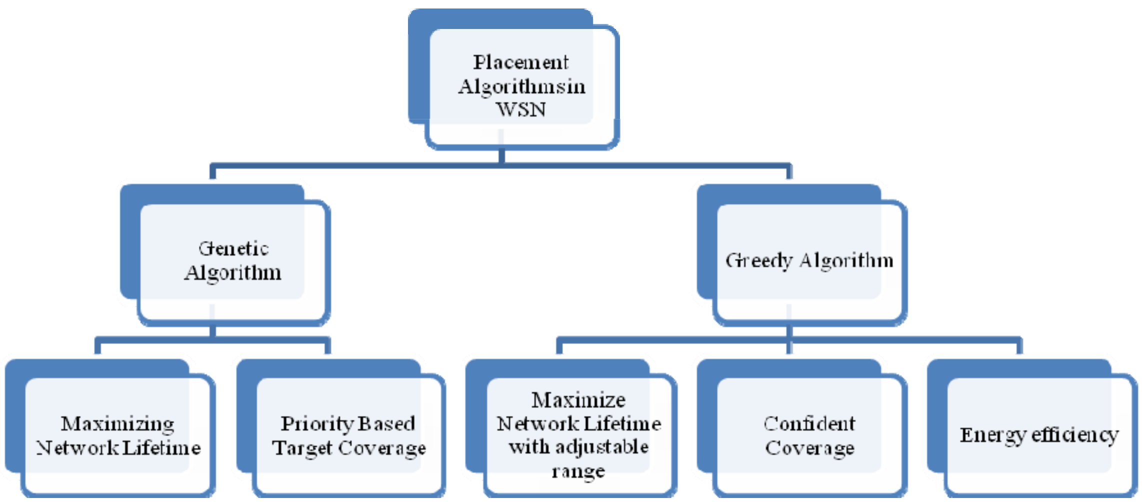

Figure-1. Comparison topology of placement algorithms.

6. COMPARATIVE STUDY

Now we compare the Genetic algorithm with Greedy algorithm depending on different parameters. The comparison between Genetic and Greedy algorithm is given in below Table-1.

Table-1. Comparative analysis of Genetic Algorithm with Greedy Algorithm.

Paper No.	Algorithm used	Paper highlight	Coverage problem	Complexity	Issues handled	Limitation
1	Schedule Transition Hybrid Genetic Algorithms	Maximizing Lifetime of Sensors in WSN	Point-coverage and Area-coverage	NP-Hard	Coverage and Lifetime	Size of target area and sensing ranges
2	Genetic Algorithms	Priority-based target coverage of Sensors in WSN	Directional sensors with different priorities	NP-Complete	Target Coverage	The Distance between the sensor and target area.
3	Genetic Algorithms	Multi-objective optimization for coverage of Sensors in WSN	Target Coverage for Energy Consumption	NP-Complete	Maximum coverage, Least Energy Consumption	Location of sensors
4	Schedule Transition Hybrid Genetic Algorithms	K-coverage and m-connected node placement Data Aggregation	Target Coverage	NP-Complete	Coverage and connectivity	Energy efficiency issues in the location selection.
5	Heuristic Search Algorithm Genetic Algorithm	Maximizing the Lifetime	Point Coverage problem	NP-Hard	Coverage and Lifetime	Coverage
6	Greedy set cover algorithm	Target Coverage Lifetime Management	Target Coverage Problem	Log(m)	Coverage	Energy
7	Greedy algorithm	Lifetime of sensors Total energy constraint	Placement of sensor nodes	-	Coverage distance	Location with parameters like lifetime,etc.,
8	LP-based Heuristic Centralized Greedy Algorithm Distributed Greedy Initialization	Maximum network lifetime with adjustable range	Target Coverage Problem Adjustable Range-Set Cover problem	$O(n3)$ $O(MN^2P\ E/e1)$ $O(W/d\ NMP)$. NP-complete	Energy Efficiency Sensor Scheduling Coverage	Sensing range
9	Connected cover formation algorithm Cover formation and relay placement with redundancy removal algorithm	Confident Information Coverage	Sensor Placement to achieve Connectivity and Coverage	$O(I^2 * J^2)$ $O(I^2 * J^2) + O(I^3) + O(I^2) = O(I^2 * \max \{I; J^2g\})$.	Connectivity Coverage	Energy
10	Greedy algorithm	Maximizing area while Minimizing number of sensors	Optimal Coverage Problem	-	Coverage	Cost

7. CONCLUSIONS

In this paper, optimal placement of sensors is focused, and the comparison of algorithms is done based on the number of sensors placed within the target region to maximize the network lifetime. Genetic algorithm does better optimization compare to the Greedy algorithm in multi-objective optimization and decision making. Future work can be done by improving the order of load balancing, cost and trustworthy connectivity of the network.

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