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REVIEW OF METHODS FOR MAXIMIZING THE NETWORK LIFETIME IN HETEROGENEOUS WIRELESS SENSOR NETWORKS (HWSNs)

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Abstract: In Wireless Sensor Networks (WSNs), prolong network lifetime have been becomes always a very challenging issue. Several methods that exist to address this problem in homogeneous WSNs however research on this problem is less for Heterogeneous WSNs (HWSNs). Because of their wide applications, they have received only little research attentions. In this survey papers presents a detailed analysis of energy efficient methods used for solving of target coverage in HWSN with many sensing units to prolong network lifetime. This paper studies the detailed review of energy-efficient methods for both Homogenous and HWSN. Initially, the lifetime maximization problem is devised as finding the utmost number of disjoint sets of devices with each and every set accomplishing network connectivity and sensing coverage at the same time. Several methods have been proposed in the literature to solve the energy efficient problem; however these methods mightn't issue of connectivity problem. So there is trend to use the evolutionary scheme to address this coverage issue to further enhance the efficiency of the method. The issues of conventional methods are compared to evolutionary scheme. The major aim of these conventional methods is to prolong network lifetime as well as minimize the computational time for both sensing coverage and connectivity of network. An experimental result shows that the optimization methods results quality solutions for WSNs, when compared to conventional methods.

Keywords: Coverage, network lifetime, Wireless Sensor Networks (WSNs), Heterogeneous Wireless Sensor Networks (HWSN).

I. INTRODUCTION

A Wireless Sensor Network (WSN) consists of set of sensor nodes dispersed in a several areas for monitoring substantial variables such as voltage, temperature, humidity, etc. It is applied to different applications such as environment surveillance [1], medical and health monitoring or surveillance [2], system of irrigation [3], manufacturing examining [4] and so on. The major objective of WSN is to maximization of network lifetime with the purpose of the satisfaction of network requirements of application [4]. Studies to extend the network lifetime have become one of the most challenging and significant matter of importance in WSNs, as most of the WSNs devices is powered by non-renewable batteries.

Similarly there is an additional aspect to be taken into account that is the dependency between energy constraints of sensor networks and WSN size. Because of this reason, the authors decided to examine the evolutionary algorithm effectiveness regarding optimization of network lifetime in a limited power supply framework which mainly focuses on strategies of communication [5].

With the continuing advances in network design, gadgets like smart phones, RFIDs and other wireless mobile devices, the objective of optimization in the communication layer is not only to extend the system lifespan, but also to increase integration efficiency, availability and reliability. These coexisting aspects represent a typical multi-objective problem. With an aim of providing solution to this problem, evolutionary algorithms could be utilized as these are population-based heuristic search techniques that can be used to solve general combinatorial optimization problems that are modelled on the concepts of evolution and natural selection or based on cultural and social behaviours of typical swarm intelligence. In the last decades these several kinds of evolutionary algorithms have been received advancement in the optimization of different kinds of engineering problems. These evolutionary algorithms are more utilized to show the strength and a new interface is developed in order to adjust this hybrid algorithm towards WSN domain [6].

Different methods have been proposed for extending the life time of WSNs that is primarily focusing on the issues of data processing [7], methodology of routing [8], device placement [9], topology management [10], and device control [11]. In a WSN sensor deployment is performed which consists of subset of the devices to address network connectivity and coverage problem within sensing range [12].

Among many of the issues, this survey paper deals with sensor node coverage problem. Coverage problem is an essential problem of WSNs. It compact by means of the problems of constructing and executing WSN to cover regions of interest to detect. According to the kind of the regions with the purpose it should be covered, the coverage problem is classified into two problems such as Area Coverage Problem and Target Coverage Problem respectively. The first problem aims at collecting information of entire region. The second problem monitors the state of a set of specific locations in the region. Several numbers of works have been presented in the literature for solving target coverage problem for WSN, but more studies focus on homogeneous WSN by single sensing unit based on centralized policies. However, discovering the maximum number of points in the connected cover set is more complicated task under the Target Coverage with coverage constraints. To solve the problem, it is improbable to have a polynomial time deterministic algorithm. This paper addresses the issues of conventional methods for energy efficient target coverage problem in HWSN. Even though if many algorithms are proposed in the literature for HWSN with multiple sensing units to save the energy and prolong network lifetime. The proposed heuristic methods are more promising to find high quality solutions when compared to other conventional methods that are proposed earlier. The main principle behind this survey is to study of the several methods in HWSN which are the sensing ability and the remaining energy.

The rest of this paper is ordered as follows: Section II classifies the problem dealt in this paper. Both methods for estimating network lifetime under conventional Methods and optimization methods in HWSN that uses the number of connected covers are given in Section III. The motivation from the literature is devoted to the development of HWSN that is defined in Section IV. Section V brings a conclusion and provides guidelines for future research.

II. PROBLEM SPECIFICATION

In this section, the method of finding the utmost number of disjoint set covers in WSN is defined and then introduces a method for computing an upper bound of the number of disjoint set covers.

Problem Definition: Consider an area defined by $\times W$, that have randomly arrange a set of sensors $S = \{ s_1, s_2, s_3, \dots, s_n \}$ to monitor the targets from a set of targets $T = \{ t_1, t_2, t_3, \dots, t_m \}$. All these sensors have both sleep mode and active mode. During the active mode sensors can sense information of target, and assumes sensors have the same sensing region whereas in sleep mode, they cannot sense in order to save energy. In order to say a target as covered by a sensor when it lies within the sensing region of the sensor, we need to find the maximum number of disjoint sensor covers in order to prolong the lifetime of WSN. This problem can be solved through transformation to the DSC problem [13] that can be defined to find the maximum number of disjoint complete cover sets C, and the corresponding cover set C_i is satisfied [14].In the recent works target coverage problem in HWSN be able to represented as Set Cover problem, here each set cover represents the on/off status of sensing units.

III. LITERATURE REVIEW

A. *Network Lifetime Maximization*

Extensive studies of network lifetime maximization by solving Target coverage have been conducted in the past several years

1. Coverage problem and Conventional Methods in Wireless Sensor Networks

In [15] the objective is to find a subset of sensors for partial coverage with a given coverage guarantee, as well as to ensure that the graph of communication induced by the chosen sensors is connected. To achieve this shortest path tree is determined and a cost function is determined based on the total area with the intention of a sensor candidate covers is used. The simulation results show that network lifetime is maximized more than three times when compared to the full coverage approach.

Another connected cover set generation algorithm proposed [16] in turn to extend the lifetime of the network. It assumes each and every one of the nodes in the cover sets is disjointed and it attempts to maximize their network lifetime. At the same time as they find a shortest path tree towards choose the relay nodes with the purpose of manage to keep connectivity in the network. These two function as a model of simplified energy consumption. Here in contrast to a real network environment, the energy that is consumed for communication is predefined for all sensors and independent on the distance between the nodes, making it far from true. There is also an assumption that each sensor consumes the same amount of energy, despite of the number of targets these sensor covers. But in a real-time scenario, the energy consumed by WSNs increases with the distance between the nodes, while the amount of the transmitting data depends on the size of the packets.

Also a similar coverage scenario is proposed in [17] with an objective to maximize the network lifetime for $k\ to\ 1$ wireless sensor-target surveillance networks. Solution consists of three steps. The major objective of this work is to reduce the computation time of the surveillance system via workload matrix followed by linear programming techniques, decomposition of LP is followed by Hall's theory to obtain the network lifetime maximization and lastly finding a target watching timetable for each sensor is relying on the schedule matrices. This similar coverage scenario extended in [18] to accommodate the similar k to 1 wireless sensor-target problem with a more routing requirement. It made an additional assumption that, a sensor can watch only one target at a time. It is remarkable that this assumption significantly reduces the difficulty in solving such kind of target coverage problem however, the assumption may not be suitable for some applications like Sensor Web project or the multiple targets tracking system where heavy load should be distributed with limited number of sensor nodes and a sensor node needs to be responsible of different targets at the same time.

Discovering maximum number of connected covers should concurrently satisfy both sensing coverage and network connectivity is solved by using iterative method which consists of two essential steps [19]. In the first step of the work, a virtual backbone is created to satisfy full coverage connectivity. In the second step, the residue energy of each sensor is updated .The whole procedure is repeated until the completion of all nodes in WSN.

The partial target coverage problem is introduced in [20], where two neighbouring targets may not be covered in the same cover set, because of the consideration that it may provide similar data. Though, this decision is not taken by a scheme that is based on statistical or geographical information from the past data collections, but by a parameter that uses the Euclidean distance between more than two targets. Hence, it propose an algorithm that computes the desired cover sets, comparing its performance in terms of network lifetime appearing as a full coverage algorithm. Broad experimental results are presented for different topologies of sensor and target placement. Using this full coverage approach, monitoring 90% targets may yield twice the network lifetime. It is important these studies do not consider energy consumption through relay and transmission of data.

In [21] a Minimum Movement-assisted k-Coverage problem is solved for HWSN. Here a minimum set of sensors are chosen and reposition to suitable positions in the entire region is enclosed by at least k number of sensors. It is possible to systematically establish a maximum subset of candidate sensors for probable relocations. A heuristic approach is proposed to this sensor relocation problem and evaluates its performance through simulations in sensor networks of various scales yet; the network connectivity is not included in their method of evaluation.

To address the problem of network lifetime maximization for HWSN where different sensor nodes targets are should to be covered through reserved diverse initial energy level. It becomes a very challenging task because it is need to satisfy both target Q-coverage condition and connectivity condition. Target Q-coverage requirement might need to satisfy different QoS such as sampling rate, the number of transducers, sensing data rate, etc.., Later came an approach which is based on column generation [22] in which column corresponding to a feasible solution. Main idea is to find a column with sharpest rise in lifetime and based on which we iteratively search for the maximum network lifetime solution at the same time as satisfying different coverage constraints. In order to solve rate of convergence, this work extended by using random selection algorithm [23]. Simulation results demonstrated that the extended random selection algorithm obtains enhanced sensing ranges with maximum network lifetime while satisfaction of different constraints such as energy utilization, sampling rates, and communication ranges.

Energy aware routing algorithm is given by Abolfazli & Mahdavi [24] that is primarily based on clustering techniques is appropriate for the multi-hop large scale networks. The main idea of this work is to use network leveling techniques to increase the efficiency of clustering algorithm. Comparative clustering can be achieved with the known algorithms such as EELBCRP and BMR. Apart from comparison with the existing algorithms, the simulation results of proposed algorithm also show the enhancement of the network lifetime significantly.

Wang [25] introduce a new K-coverage algorithm by considering energy constraints in HWSNs. Mainly, the network activity in these HWSNs networks is ordered in rounds. Each round is performed via the initial step and then performs information sensing step. In order to satisfy K-coverage constraints, cost function is determined to each to test whether the particular sensing node is covered or not. In the experimental setup, the wireless sensors and all targets are randomly deployed in the sensing field. Six different types of experimental settings with different number of wireless sensor are assessed. However discovering maximum number of connected covers is difficult as each connected cover mightn't concurrently assure both sensing coverage and network connectivity.

2. Coverage problem and Optimization Methods in Heterogeneous Wireless Sensor Networks

In recent, there is a trend to use the evolutionary approach to address this coverage issue. For example, to find the largest number of sensor's disjoint sets with every set being competent to completely cover the target area, a genetic algorithm has been proposed [26]. To the same problem, in [27], a memetic algorithm has been developed.

A Hybrid approach genetic algorithm based a Schedule Transition Operations with Genetic Algorithm, termed STHGA is proposed in recent work [26]. The major aim of STHGA is to solve target coverage problem based on forward encoding scheme. The uniqueness of the forward encoding scheme is that the chromosomal maximum gene value is increased steadily with the quality of solution obtained that is related to the number of disjoint complete cover sets. Apart from sensors sensing ranges and the number of sensors, the influence of sensors idleness correlated with the performance of STHGA has also been analyzed. Experimental results demonstrate that the proposed STHGA algorithm is outperforms when compare to conventional approaches for both Quality of Service (QoS) and optimization speed.

The Memetic Algorithm [27] utilizes both Darwinian evolutionary scheme and Lamarckian local enhancement in order to search for optimal solution where the considerations for local exploitation and global exploration are given. Furthermore, the proposed Memetic Algorithm mightn't consider any assumption concerning the maximum number of covers as their upper bound. Experimental results demonstrate that the Memetic Algorithm significantly outperforms when compare to heuristic-evolutionary algorithms in terms of Quality of Service (QoS) thus extending WSN lifetime.

Kuhn-Munkres Parallel Genetic Algorithm [28] is introduced to overcome the set cover problem to prolong network lifetime of WSNs in a large-scale environment. The algorithm that is proposed here schedules the sensors into a number of complete cover sets that are disjoint. Then sensors are triggered for in batch of conservation of energy. It utilizes well-known strategy called divide-and-conquer for reduction of dimensionality and adopts the polynomial Kuhn-Munkres algorithm to splice the feasible solutions obtained in each sub area to improve the efficiency of search substantially. Note that the studies mentioned above do not consider the real energy consumption for QoS parameters.

The Connected Set Covers (CSC) problem with the intention of discovering a maximum number of set covers such with the intention of each sensor node desires to be activated and connected to the Base Station. So the computation complexity of CSC problem is considered to be NP-hard complete problem which is solved by using three optimization methods such as Integer Programming (IP)-based solution [29], greedy approach and a distributed & localized heuristic. Experimental results obtained through simulation validate IP approaches are presented. Furthermore, they also assume that a sensor can only monitor the maximum of one target at a time that simplifies the difficulty in dealing with the problem.

In [30], the authors transformed the Target Coverage (TC) problem into a Maximal Set Cover (MSC) problem in which sensors are arranged into set covers. Maximizing the network lifetime is achieved by maximizing the number of set covers. Each and every set cover is activated where the sensors in an activated set cover are liable for sensing all the targets at a specific time, while the remaining sensors are in the sleep state. So the computation complexity of MSC problem is considered to be NP-hard complete problem which is solved by using two heuristics methods such as linear programming and greedy techniques in centralized manner. Similar to [30], the TC problem is addressed in [31] for fixed sensing range. Here the goals are to schedule sensors acting alternatively between the active and the sleep states and regulate their sensing ranges so that all targets are covered by these active sensors and the lifetime of network is maximized. The earlier MSC problem is converted as Adjustable Range Set Covers (AR-SC) and solved by using ILP constraints. Rounding-Relaxation techniques are used to solve this AR-SC problem. A greedy heuristic is proposed to get both centralized and distributed or localized solutions for the given set covers. However, connectivity of network is not considered in [30-31].

In order to find best optimal sensor node in the cover set, heuristic algorithm uses a cost function with the intention of monitoring the capabilities of a sensor and at the same time as maintaining battery life of the sensor. Through simulations, one can infer that the proposed algorithm [32] overtakes similar heuristic algorithms were identified in the literature, producing collections of set covers of optimal (or at least near-optimal) size. The proposed heuristic algorithm is designed for a diverse range of node deployment environments by these cover sets with less execution time.

In order to maximize network lifetime, power saving problem is formulated as Set Covering Problem (SCP). By using Modified Ant Colony Optimization (MACO)[33] minimum set covering is solved for a minimum set of nodes where node selection method is based on the energy of each node in a set providing energy-efficient sensor network.

Li et al [34] introduce scheduling methods for solving k-Coverage problem in whole network lifetime. The complexity of this problem is NP-hard, two heuristic algorithms have proposed that is applicable under different scenarios. A faster Communication Weighted Greedy Cover (CWGC) algorithm is proposed for solving k-Coverage problem in distributed manner. Simulation results demonstrated that the CWGC algorithm performs better when compare to other greedy methods in terms of the 45% network lifetime and the efficiency of the system. But it is hard to implement for practical application and it's not centralized manner.

Pyunetal [35] introduce new scheduling schemes for solving Multiple Target Coverage (MTC) via the consideration of together targets coverage through the sensor and the redundancy of overlapped targets. He introduced two sensor scheduling schemes: optimization scheme and the heuristic scheme are verified power saving results through simulation. Zhao *et al* [36] proposed a greedy algorithm that addressed both sensing coverage and network connectivity. However, the algorithm is capable of handling only the coverage of discrete points. Thus it is difficult to extend the algorithm to HWSNs that encompass different types of devices. Some of the heuristic and other methods have been used to extend HWSN are described below:

Poly type Target Coverage (PTC) problem for HWSNs extended with clustered configurations is discussed in [37]. The problem is originated from IP to maximize the network lifetime of HWSNs. To overcome this problem they introduced an Energy-efficient Target Coverage Algorithm (ETCA) with the purpose of energy efficiency consumption of sensor nodes. Here, each sensor node initially calculates its sensing capability with neighbour nodes and sends a message with its current status information to a cluster-head. After successful reception message, the cluster-head decides which sensing units have to turned on to cover the targets in the most optimized way depending upon the information received from all its member nodes. Experimentation through simulation shows that the performance of ETCA is close to the IP-solution which is an energy efficient optimal coverage scheme. Simulation results demonstrated that the ETCA maximize network lifetime is upto 16% high when compare to Energy First (EF) algorithm.

Lee& Lee [38] proposed a new Discrete Particle Swarm Optimization (DPSO) method for HWSN by considering two types of nodes such as powerful node and ordinary node to prolong network lifetime. Powerful nodes are Cluster Heads (CHs) that is capable of communicating directly to the data sink of network, whereas ordinary nodes are used to sense the desired information and sends the processed data to powerful nodes. HWSNs have its own merits as its heterogeneity improves there is also an improvement in network's lifetime and coverage. DPSO, handles the optimization problem taking care of how many nodes (both powerful and ordinary nodes combined) to minimize the network cost meanwhile guaranteeing a desired coverage during a given period.

In order to maximize network lifetime PSO with dynamic clonal selection is proposed by [39]. This PSO algorithm manages together the clonal quantity and variation range of particle. This particle range corresponds to the locations of every mobile sensor nodes via network coverage rate and similarity among the other nodes is also determined to avoid local optimum problem. Through the simulation results it can be observed that the performance of network coverage is improved more effectively when compared with other algorithms. Khedr [40] propose a new distributed algorithm to find the minimum connected cover of the inquired region by discovering the redundant sensors in HSWNs each with arbitrary sensing range and being unaware of its location or relative direction of its neighbour. Performance metrics are analyzed, it shows that distributed algorithm enhance the network lifetime when match up to existing algorithms.

IV. MOTIVATION FROM REVIEW

In literature several methods have been proposed for discovering one connected cover from a WSN. Such connected cover obtained through those methods may be most selected under certain criteria, such as minimum size or minimum energy consumption [23], [24]. Though, generating a series of optimal connected covers by repeating the above methods should not maximize network lifetime. Since discovering maximum number of connected covers not concurrently assure both sensing coverage and network connectivity. As we already discussed it is difficult to extend the generic algorithm of heuristics to HWSNs as it encompass different types of devices. So, in order to maximize the total network lifetime, we propose an energy-efficient heuristic solution for the given target coverage problem.

It is inferred from the literature study that this ACO-based approach can maximize the lifetime of heterogeneous WSNs. The major objective of this approach is to discovering the maximum number of connected covers must satisfy together sensing coverage and network connectivity. A graph called construction graph is designed. Each vertex of graph denotes the assignment of a device in a subset. The ants discover a best path on the network graph model to maximize the number of connected covers depending on their pheromone and heuristic information to enhance the searching speed. The proposed ACO-based approach is applied to a different HWSNs and this research work is extended from the work [41].

V. CONCLUSION AND FUTURE WORK

Wireless Sensor Networks (WSNs) and their quality of services are strongly dependent on the network performance. The primary norm for evaluating a WSN is the network lifetime which is defined as the time period that the network satisfies the requirements of application. For maximizing the network lifetime, this survey work considers the problem of finding the maximum number of coverage in both WSN and HWSNs. In literature, quite a few methods have been proposed to solve energy efficiency problem in WSNs. On the other hand in the HWSNs there are different sensors with different functionality, so the creation of WSN becomes very difficult. Monitored information is sent to single sink via CH by all the sensors in the network leads to overlapping and collision in networks thereby creating difficulty in finding the maximum number of connected cover and sensing range. The computational time is very important in case of such algorithms but they are difficult to extend the algorithm to heterogeneous

WSNs that comprise different types of devices. Ant Colony Optimization (ACO) is a famous meta-heuristic inspired by means of the foraging behaviour of real ants. This proposed ACO-based approach (ACO-MNCC) has been used in the recent work for converting the search space of the network lifetime maximization problem in HWSNs into a graph model. The HWSNs lifetime maximization can be achieved by finding the maximum number of connected covers. In future work we extend this schema to fully k-cover a field, satisfying Quality of Service (QoS) and other meta-heuristic algorithm have been also replaced to measure the performance efficiency in HSWN.

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