A REVIEW ON LIFETIME EXTENSION OF WIRELESS SENSOR NETWORKS BY SOLVING SET K-COVER PROBLEM

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Abstract - In last two decades, wireless sensor networks (WSNs) are extensively being implemented in various state-of-the-art technologies such as device-to-device, machine-to-machine, smart grids and Internet-of-Things. Due to the limited battery-powered sensors, it is imperative to utilize their energy efficiently in order to continue the network operation for the maximum achievable duration. Thus, network lifetime (NL) extension approaches have drawn the attention of many researchers due to their significant role in maximizing the un-interrupted performance of energy-limited WSNs. This paper reviews the set of NL extension approaches in WSNs in terms of configurations, applications, and optimality.

Keywords - Wireless sensor network, Disjoint subsets, Coverage, Lifetime

I. INTRODUCTION

Wireless sensor networks (WSNs) are broadly being utilized in various areas of daily life like vigilance by military, automation in factories, supervision of traffic, climate observation, heath monitoring of aero vehicles and in biomedical applications. Lifespan of a WSN (the period in which the region of interest is sensed given some coverage restriction) is a major parameter for the measurement of its efficiency. Consumption of power needs to be limited for the achievement of long functional period of WSN due to reason that the battery of these nodes are very hard to change or recharge [1-6].

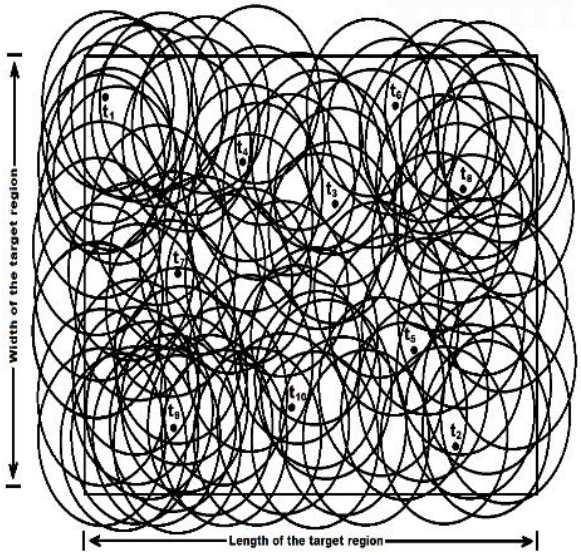


Figure 1: An example of WSN to sense the multiple objects for the surveillance application.

Based on the capability of sensing nodes movement, there are divided in to three categories, wireless mobile sensor, wireless static sensors and wireless hybrid sensor. A wireless static sensor network of these nodes which remain stationary and are not able to alter their position after their deployment in certain target location, these types of wireless static sensor network are discussed in [3]. Wireless mobile sensor network, nodes are prone to movements and are not on the same location, they are able to shift their location as following certain algorithm to attain optimal coverage.

A hybrid wireless sensor network is the combination of static sensing devices and mobile sensing devices. Wireless mobile sensor modifies their location to take over the place of wireless static sensor nodes which exhausted their battery span while achieving the coverage [7].

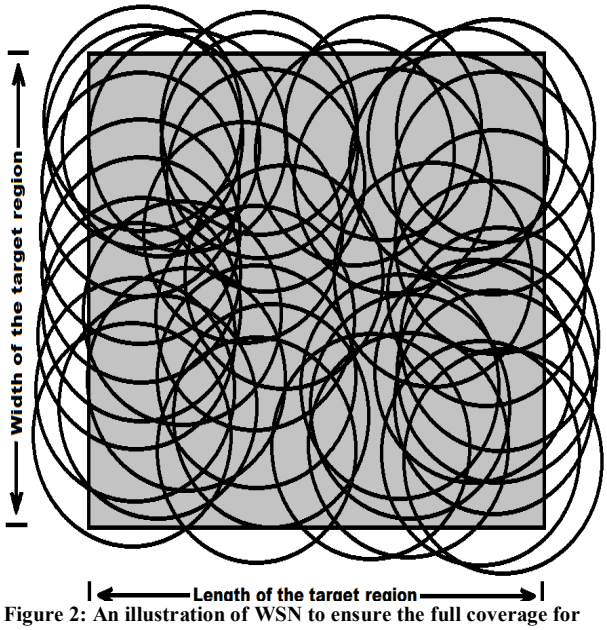


Figure 2: An illustration of WSN to ensure the full coverage for the region of interest.

Coverage guarantees that every spot of the destined area should be perfectly sensor by sensing nodes. Location and range of these wireless nodes are utilized as inputs to algorithms used for finding coverage [8].

The applications of coverage are commonly divides as coverage of target, area as well as barrier [3], [4], [9].

The main goal of the target coverage is sensing multiple spots in some given region, whereas the area

coverage application focuses the complete region by sensing on each spot in that area, likewise barrier coverage emphasize on monitoring a certain area given by dual parallel curves.An illustration for the target coverage, area coverage and barrier coverage are illustrated in figure 1, 2 and 3, respectively.

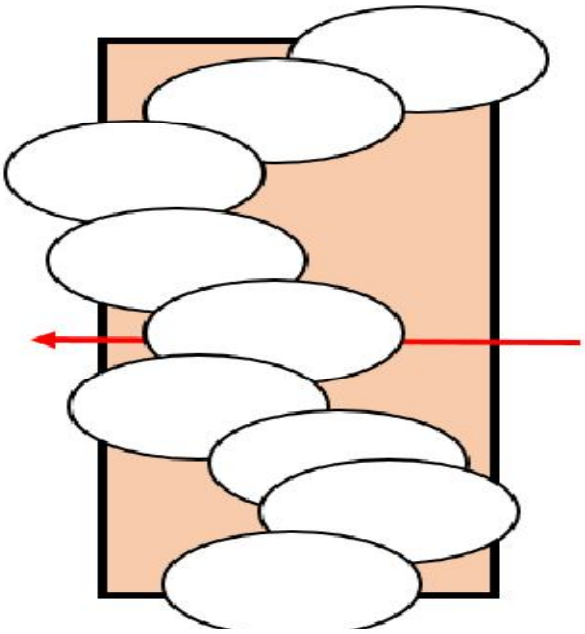


Figure 3: An example of barrier coverage.

The arrangement of sensing nodes in certain desired area is commonly accomplished in two ways, first random way and other deterministic way [10]. In random way, sensing nodes are haphazardly employed for vigilance application in far flung and no-go areas like battle field etc. In these scenarios, for long run time of sensing nodes, scheduling is very effective and efficient technique to disperse the employed sensing nodes into a large number of disjoint subsets of sensing devices (DiSenDs) in a way that every DiSenD should meet the coverage constraint. Deterministic way have an early knowledge about target area and each sensing node is placed node by node at each pre identified location, the drawback of this deterministic way is, it is much time taking, because of huge quantity of sensing nodes which cannot be easily placed in remote and out of reach areas. In these scenarios, a wide quantity of sensing nodes is deployed incoherently from some drone or air vehicle to meet the coverage constraint of desired area. Different arrangements of sensor placement is referred in references [11-15].

For the improvement of communication time period of wireless sensing nodes, scheduling is a promising technique which can manage the sensing operations [16],[17]. A sensing node has two modes of operation, first is active mode and other is sleep mode (which is also code power saving mode). Active state considers a sensing node to execute all of its tasks, which include sensing the input, processing the data and communicating data. These tasks consume a huge quantity of power. Unlike the sleep mode sensing nodes utilize lower portion of power.

Sensing nodes are able to change their mode from sleep to active mode or from active to sleep if desired.

If a DiSenD accomplishes the coverage limitation, left over DiSenDs will have to change their mode to sleep, for saving the power [18-20]. Focusing these types of scenarios and maximizing the working period of WSN under coverage limitation have been investigated in [5], [21-25].

II. SET K-COVER PROBLEM

In this problem, searching the optimal number of DiSenDs in wireless sensor network is called as “SET K-Cover” or “Disjoint Set Covers” problem. It is proved that these problems are non-deterministic polynomial (NP) complete problems [22], [23]. Variety of heuristics examined the lifetime maximization of WSNs by resolving the Disjoint Set Covers problem.

Authors in [26] considered a deviation in Disjoint Set Covers problem. Authors compromised the sensing coverage limitation because each group of sensors is able to cover only limited number of objects and the objective was to increase the number of sensor groups which sensor the area of interest. They suggested three approaches i.e., randomized, distributed greedy and centralized greedy algorithm (RDGCG) for deviated disjoint SET K-Cover problem. However, none was able to ensure full coverage.

Berman et al in [27] assumed the information of initialenergy and its utilization rate for every sensing device. The restriction on mutually exclusive groups of sensors is trade-off. Therefore, every sensor can contribute in dissimilar groups till it contains some power. They devise the sensor network life span problem (SNLP) for discovering an observing schedule with the greatest network duration. They proposed an approximated algorithm for the coverage of q-portion (e.g. 95%) of the target region of interest.

Authors in [23] referred a target coverage situation for surveillance in power effective wireless sensing nodes. A combined integer programming focused heuristic known as “maximum covers using mixed integer programming (McMiP)” to disperse the groups of placed sensing nodes in optimum number of DiSenDs and justifying the coverage limitation for a group of familiar target spots.McMiP utilizes technique known as brute-force to searchlarge number of DiSenDs,but,McMiP is impractical for real life application. Since its computation complexity goes exponentially large with quantity of placed sensing nodes.

Authors in [22] suggested a greedy deterministic method, known as “the most constrained minimum constrained covering (MCMCC)” heuristic

Approach	Sensor Subsets	Configuration	Application	Description	Optimality
RDGCG [26]	Non-disjoint	Static	Area coverage	Randomized, Distributed Greedy & centralized greedy approaches	Near-optimal
SNLP [27]	Non-disjoint	Static	Area coverage	GA based scheme for coverage of q-portion.	Near-optimal
McMiP [23]	Disjoint	Static	Target coverage	Brute-force search scheme	Near-optimal
MCMCC [22]	Disjoint	Static	Target & Area coverage	Greedy deterministic approach	Sub-optimal
GAMDSC[30]	Disjoint	Static	Target coverage	Scattering & conventional GA operations	Near-optimal
DEDSC[31]	Disjoint	Static	Target coverage	Recombination & conventional DE operations	Near-optimal
MA [32]	Disjoint	Static	Target coverage	Integer coded GA with recycling operation	Sub-optimal

Table1: Literature Review for Disjoint Set K-Cover Problem

to extend the working period of wireless sensing devices. The complexity for computation for MCMCC heuristic is order of polynomial time, as it finds the near to optimal quantity of DiSenD in few scenarios (for example, approximately 80% of optimal solution).

Some authors have also studied the SET K-Cover problem utilizing meta-heuristics such as Genetic Algorithm (GA)[28], [29]. GAs are population based iterative algorithms which have solved variety of complex problems.Authors in [30] discussed a genetic algorithm for large disjoint set covers termed as GAMDSC for searching theoptimal number of DiSenDs for target-coverage problem of wireless sensing nodes. However, GAMDSC gives near-optimal solution. GAMDSCcomprises of traditional genetic algorithm as well as scattering operationswhich guaranteesthe existence of one critical sensing node in each DiSenD. The time complexity for GAMDSC lies in between MCMCC and McMiP.

The differential evolution (DE) based approach, termed as DEDSC, is proposed to search the maximum number of DiSenD for target-coverage application of WSNs [31]. DEDSC consists of conventional operators of DE such as mutation, crossover and selection along with the recombination operation which guarantees the assignment of a unique schedule number to each sensor covering a target point (termed as critical target point) most sparsely. Recombination operation was considered to be an important operation to confirm the existence of one sensor which covers a critical target point. However, the authors of [31] did not perform this key operation in each generation. Moreover unlike STHGA, DEDSC did not perform any transition operation of sensors to convert an incomplete DiSenD to complete one.

Liao et al. [32] proposed an integer coded GA and local search approach, termed as memetic algorithm (MA) to resolve the Set K-Cover problem by considering the target coverage application of WSN. The MA approach performs the mutation and crossover operation using integers. To evaluate the quality of chromosomes, they introduced a novel fitness function which utilizes both the set of DiSenDs and the role of every sensing device with the each DiSenD. Along with integer-coded GA, MA utilizes a local search approach, termed as recycling operator, to boost its performance. Authors validates the performance of MA by comparing with the three variants of conventionalinteger-coded GA, GAMDSC [30] and order-based MA (oMA) with respect to the set of DiSenDs achieved, success rate and computing time. A summary of all NL extension techniques is also presented in Table 1.

CONCLUSION

Set K-cover problem involves around the categorizing the deployed sensing devices into maximum number of DiSenDs. NL can be prolonged by scheduling these DiSenDs one by one while satisfying the coverage constraint of multiple objects or an area, completely. Hence, NL extension approaches are required to solve the Set K-Cover problem. This paperreviews the different NL extension techniques in WSNs in terms of their configuration, applications, and the optimality.

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