ISSN 2047-3338

Maximizing a Lifetime of Wireless Sensor Network by Scheduling

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Abstract— **The increase in the demand for Wireless Sensor Networks (WSNs) has intensified studies which aim to obtain energy-efficient solutions, since the energy storage limitation is critical in those systems. Traditional methods for sensor scheduling use either sensing coverage or network connectivity, but rarely both Schedule sensor nodes work alternatively by configuring some of them an off-duty status that has lower energy consumption than the normal on-duty one. In a single wireless sensor network, sensors assume two main functionalities: sensing and communication. Minimizing energy consumption in a highly dense wireless sensor network needs to maximize off-duty nodes in both domains. "The communication range is twice the sensing range" is the sufficient condition and the tight lower bound to ensure that complete coverage preservation implies connectivity among active node. In this paper we present the different scheduling methods of increasing the lifetime of wireless sensor network. analyze and classify the research of the network lifetime for wireless sensor network, the important point is to introduce some scheduling the methods of the researchers' uses to maximize network lifetime and our proposed work on increasing the lifetime by scheduling. Depletion of these finite energy batteries can result in a change in network topology or in the end of network life itself. Hence, prolonging the life of wireless sensor networks is important. The network lifetime can depend on many other factors too. In this paper, we analyze and classify the research of the network lifetime for wireless sensor network, the important point is to introduce the method the researchers' uses to maximize network lifetime.**

Index Terms— **Wireless Sensor Networks, Energy Limited, Scheduling, Energy Efficiency and Self-Organization**

I. NTRODUCTION

WIRELESS sensor networks have been proposed for a wide range of monitoring applications such as traffic and seismic monitoring, and fire detection. Such networks consist of a group of nodes, with sensing, signal processing and wireless communication capabilities and limited battery energy. Each sensor collects information by sensing its surrounding region and transfers the information to a sink (also called a data center) via wireless transmission.

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Because of the features of sensors, WSNs have been implemented in harsh environments such as in the deep sea, arctic areas, and hazardous war zones.

Different from other battery-powered apparatuses, recharging a sensor's battery is generally impossible. Although solar and wind energy can be used, such energy supplies are not reliable. Scheduling the sensing activity mean when to activate a sensor node for sensing (active mode) and when to keep it idle (sleep mode). One approach based on the sensor activity scheduling technique is to divide all sensors into disjoint sensor subsets or sensor covers and each sensor cover needs to satisfy the coverage constraints. Only one sensor cover is active to provide the functionality and the remaining sensor covers are in the sleeping mode.

Once the active sensor cover runs out of energy and consequently cannot maintain coverage constraints, another sensor cover will be selected to enter the active mode and provide the functionality continuously. In this paper we introduce some methods of scheduling to maximizing the lifetime of wireless sensor network and also review on point coverage area coverage problems of STHGA [1] i.e., the schedule transition hybrid genetic algorithm and comparative study of "most constrained–minimally constraining covering (MCMCC)", "maximum covers using mixed integer programming (MC-MIP)" and the genetic algorithm for maximum disjoint set covers (GAMDSC) with STHGA.

The rest of the paper is organized as follows. In next section we present techniques to reduce energy consumption methods. In section III, we present comparative study discussion of various scheduling algorithm to increase the lifetime of WSN. Finally, we conclude in section V.

II. TECHNIQUES TO REDUCE ENERGY CONSUMPTION

One of the most important features of a WSN is its energy efficiency, as in most of the cases sensors dispose of small batteries that are impossible or impractical to change or recharge. In such conditions it is of paramount importance to develop dedicated communication solutions that handle sensor data gathering in an energy-sparing manner, prolonging thus the lifetime of the network. With the current technology, of energy saving. Maximizing the lifetime of a sensor network by scheduling operations of sensors is an effective way to construct energy efficient wireless sensor networks.

A. Energy –Efficient By Scheduling Scheme

An important method for prolonging the network lifetime for the area coverage problem is to determine a protocol for selecting the set of active sensor nodes through central control. The network activity can be organized in rounds, and the set of active sensor nodes are decided at the beginning of each round. Active node selection is determined based on the problem requirements (e.g. area monitoring, connectivity, power efficiency).different methods has been proposed in literature [16], [17], [18], [19], [20], [21]. S. Tilak et al., [13] proposes a scheduling scheme which periodically chooses a subset of nodes to perform the network tasks and sends the remaining nodes to energy-saving state.

The objective considered in this work is to minimize the number of active nodes in each time period, complying with the requirements established for the network. It should be noticed that all the works referenced above handle with the problem in a static environment: given the set of nodes which could be active, the algorithm looks for the best node arrangement for such a situation. This approach can lead to sub-optimal solutions only, since the dynamic nature of the problem is ignored. In [2], authors propose a node scheduling scheme, which can reduce system overall energy consumption, therefore increasing system lifetime, by turning off some redundant nodes. It's coverage-based off duty eligibility rule and back off-based node-scheduling scheme guarantees that the original sensing coverage is maintained after turning off redundant nodes. In [17], authors presented an approach ESA, and by turning off some redundant nodes extend the networks' lifetime. In the end, the significant improvement in terms of networks lifetime is observed through extensive simulation experiments. Algorithm EECCP [18] considers the network coverage and sensor connectivity simultaneously. Compared with other referred algorithms, the extensive simulation results demonstrate that algorithm can achieve the connected, full/partial coverage requirement. And CCC proposed in paper [18] Utilizes a node of its' optimum coverage and connectivity to transmit to another node and calculate the quantity of the nodes of an optimum cluster. And the simulation results show that CCC improves network lifetime and reduces whole average of energy consumption. In [20] and [21] the authors proposed energy efficient centralized mechanisms to cover the target region completely by dividing the sensor nodes into disjoint sets, such that every set can individually perform the coverage tasks. These sets are then activated successively, and while the current sensor set is active, all other nodes are in the sleep mode. The goal of this approach is to determine a maximum number of disjoint sets, as this has a direct impact on conserving sensor energy resources as well as on prolonging the network lifetime.

To extend the lifetime is to divide the deployed sensors into disjoint subsets of sensors or sensor covers, such that each sensor cover can cover all targets and work by turns. Finding the maximum number of sensor covers can be solved via transformation to the Disjoint Set Covers (DSC) problem or, equivalently, the SET K-COVER problem. Both are proved to be NP-complete. [2], [3].

The schedule transition hybrid genetic algorithm (STHGA) [1] introduces by Xiao-Min Hu, Jun Zhang and *Yan* Yu, It can be applied to both point- coverage and area-coverage disjoint set covers problems. The distinct feature of STHGA is that it adopts a forward encoding scheme for the representation of chromosomes in the population and uses some effective genetic and sensor schedule transition operations finding the optimal complete coverage scheme in WSNs is not easy, because the number of sensors in a target area is so huge that the computation is time-consuming. Cardie and Du [4] proposed a "maximum covers using mixed integer programming (MC-MIP)" algorithm to find the maximum number of disjoint complete cover sets for covering a set of target points. They transformed the problem into a maximum flow problem and then formulated it as a mixed integer programming. By using a branch and bound method, MC-MIP acts as an implicit exhaustive search which guarantees finding the optimal solution. However, as the numbers of sensors and targets become larger, the running time of MC-MIP increases exponentially.

Lai et al., [7] introduced a GA for point-coverage problems.

They termed it the genetic algorithm for maximum disjoint set covers (GAMDSC) and encoded each gene in the chromosome as an integer index of the set that the sensor joined. Using traditional genetic operations and a scatter operator, their algorithm was reported to be able to get near optimal solutions. It can be observed that their algorithm lacks the consideration for redundant sensors in cover sets and the guidance for joining sensors to form complete coverage. Their algorithm is only suitable when the numbers of targets and sensors are small. Slijepcevic and Potkonjak [6] proposed a greedy deterministic approach called the "most constrained–minimally constraining covering (MCMCC)" heuristic to completely cover the target area. MCMCC cannot guarantee finding the optimum, but it works much faster than MC-MIP for problems in a large scale.

In MCMCC, a function is defined favoring the sensor which covers the most constrained field, whereas the other fields covered by the sensor are minimally constraining. Whether a field is constrained or not depends on the number of sensors that can cover the field. Each complete cover set in MCMCC is constructed by selecting sensors according to the heuristic objective function. In the randomized scheduling methods in, sensors are randomly assigned to multiple working subsets of sensors. For each subset of sensors, the algorithm used an extra-on rule for guaranteeing network connectivity and then updated the working schedule accordingly.

Lin and Chen [6] later improved the approach of by detecting and eliminating coverage holes in the subsets. Abrams et al. designed three approximation algorithms for a variation of the SET k-cover problem. However, none of the three algorithms guarantees complete coverage. In addition to heuristic methods, genetic algorithms (GAs) have also been applied. GAs is population based search algorithms, which simulate biological evolution processes and have successfully solved a wide range of NPhard optimization problems. Compared with MC-MIP and MCMCC, using a GA for finding the maximum number of disjoint complete cover sets is expected to search the domain more effectively and reduce the computation time.

Moreover, the problems addressed by MC-MIP and GAMDSC are point-coverage problems, whereas MCMCC can be applied to both point-coverage and area-coverage problems. Area coverage involves a much larger number of coverage targets than point-coverage, because each field in the target area must be completely covered. An enhanced GA is proposed, aiming at solving disjoint set covers problems for maximizing the WSN lifetime. Shu Lei, S.Y. Lee, Yang Jie presents [29] “ETRI: A Dynamic Packet Scheduling Algorithm for Wireless Sensor Networks the Two Ties Buffer model and ETRI packet” scheduling algorithm. Reward and Interest are added as the new constraints to the conventional timing and energy constraints for packet scheduling algorithms.

It can be observed that their algorithm lacks the consideration for redundant sensors in cover sets and the guidance for joining sensors to form complete coverage. Their algorithm is only suitable when the numbers of targets and sensors are small. Moreover, the problems addressed by MC-MIP and GAMDSC are point-coverage problems, whereas MCMCC can be applied to both point-coverage and area-coverage problems. Area coverage involves a much larger number of coverage targets than point-coverage, because each field in the target area must be completely covered. An enhanced GA is proposed, aiming at solving disjoint set covers problems for maximizing the WSN lifetime. The schedule transition hybrid genetic algorithm (STHGA) [1] can be applied to both point coverage and area-coverage disjoint set covers problems. The distinct feature of STHGA is that it adopts a forward encoding scheme for the representation of chromosomes in the population and uses some effective genetic and sensor schedule transition operations.

Our aim of research is Close inspection for limitation like point-coverage and area-coverage problems of existing scheduling methods such as MC-MIP, MCMCC, GAMDSC,

STHGA etc and exploring new means of scheduling for overcoming the limitations such as point-coverage, area coverage problems and subset optimization problems (each subset is to form complete coverage to the target area). Improvement of existing scheduling activity with regard to energy saving in WSN. Enhancing functional operation of scheduling activity. Use of hybrid genetic algorithm for maximizing lifetime of WSN. Developing hybrid approach of combining a genetic algorithm with schedule transition operations, termed STHGA, to address this problem (finding the largest number of disjoint sets of sensors).

III. COMPARAT IVE STUDY AND DISCUSSIONS

The STHGA is tested with different sensor deployments for point-coverage [1]. The performance of STHGA will be compared with the state-of-the-art algorithms [1], i.e., MCMCC [3] and GAMDSC [35]. For STHGA and GAMDSC, each case is tested 100 times independently. The sensors are deployed in a 50×50 rectangle area and the coordinates of sensors’ locations are randomly generated as float-point values in [0, 50]. Analysis and discussions on the operations of the proposed STHGA are also presented. If not specially stated, all experiments for STHGA use the same parameters settings as the population size m = 3, the interval for performing mutation Gm = 100, the mutation rate μ = .5 and the parameters K1 = K2 = 5. These parameter values are set empirically and their influences to the performance of STHGA will be analyzed. Parameter settings of MCMCC and GAMDSC can be referred in [3] and [35]. All cases are run by a computer with a Pentium IV 2.8 GHz CPU.

A. Experiments on Point-Coverage and Area-Coverage Problems

From the table, MCMCC obtains results that are equal to $\tilde{T}$ in four out of the seven cases. Seven point-coverage cases with different numbers *N* of sensors are tested. The number of targets is fixed as 10 and the sensing range *R* is 22 for all the sensors. Using the same stopping criterion as GAMDSC in [35], the maximum number of fitness function evaluations for both GAMDSC and STHGA is 20 100. If the number of disjoint complete cover sets reaches $\tilde{T}$_, the algorithm also stops. GAMDSC is proposed for solving point-coverage problems, whereas MCMCC and STHGA can be used for b both point-coverage and area coverage problems Table I tabulate the results computed by STHGA, GAMDSC, and MCMCC [1].

The $\tilde{T}$ in the table represents the upper limit of the maximum number of disjoint complete cover sets. Because MCMCC is a deterministic algorithm, it is run only once and the result and the time used for computation are recorded. In contrast, the proposed STHGA achieves results that are equal to $\tilde{T}$ in all of the seven cases. The time used by STHGA is much shorter than MCMCC in most of the cases except for Cases 5 and 6. However, MCMCC cannot achieve the optima of the two cases but STHGA can by using a slightly longer time. In comparison with GAMDSC, the advantage of STHGA is obvious. STHGA can find the optima in all of the 100 independent runs, so that only the mean results are tabulated.

However, GAMDSC cannot always obtain the optima within the predefined maximum number of function evaluations except for Case 3, which is the case with the smallest $\tilde{T}$ value. The best and mean results of GAMDSC are presented in the table, plus the average number of function evaluations (avgE) and the average time in microsecond (ms) used for obtaining the best result in each run, and the successful percentage (ok%). STHGA outperforms GAMDSC both in the solution quality and the optimization speed. Using the point-coverage Case 1 as an example, we analyze how STHGA performs better than GAMDSC. Fig. 2 shows the average optimization curves of STHGA and GAMDSC when solving Case 1 within the maximum function evaluation number. It can be seen that STHGA finds high-quality results much faster than GAMDSC. Note that GAMDSC does not use the proposed forward encoding scheme to chromosomes so that the initialization of STHGA and GAMDSC is different. In STHGA, all sensors are initially in the same complete cover set and redundant sensors are then scheduled to form a new cover set. So the initial number of complete cover sets is small.

TABLE I
Test Results for Point-Coverage Cases with Different Numbers *N* of Sensors

Cases			STHGA				GAMDSC					MCMCC	
NO	***N***	***˜T***	***MEAN***	***avgE***	***OK%***	***TIME***	***BEST***	***MEAN***	***avgE***	***OK%***	***TIME (ms)***	***RESULT***	***TIME (ms)***
1	90	30	**30**	596	100%	17	**30**	28.63	19822	8	965	29	31
2	100	23	**23**	241	100%	5	**23**	22.83	11939	84	569	**23**	31
3	110	21	**21**	156	100%	4	**21**	**21**	6141	100	303	**21**	31
4	120	35	**35**	422	100%	15	**35**	35.5	19899	5	1249	35	62
5	130	41	**41**	1856	100%	84	**41**	40.99	10279	99	741	40	78
6	140	44	**44**	3568	100%	172	43	40.72	20100	0	1550	43	93
7	150	42	**42**	532	100%	25	**42**	40.82	19132	24	1517	**42**	109

The number of targets is 10 and the sensing range *R* is 22 for all the sensors. The best results among the three algorithms for each case are bold.

TABEL II
Test Results for Area-Coverage Cases with Different Numbers *N* of Sensors and Sensing Ranges *R*

Cases					STHGA				GAMDSC					MCMCC	
NO.	***N***	***R***	***nF***	***˜T***	***MEAN***	***avgE***	***OK%***	***TIME (ms)***	***BEST***	***MEAN***	***avgE***	***OK%***	***TIME(ms)***	***RESULT***	***RESULT TIME(ms)***
1	100	20	385	7	**7**	93	100	33	**7**	**7**	874	100	126	**7**	1438
2	300	15	673	16	**16**	509	100	400	15	13.19	20100	0	9713	**16**	33922
3	300	20	400	32	**32**	713	100	468	29	26.06	20100	0	10080	**32**	44047
4	400	10	1556	9	**9**	598	100	797	8	6.24	20100	0	13764	**9**	54844
5	400	15	676	23	**23**	800	100	767	20	16.9	20100	0	13268	**23**	81766
6	500	8	2400	7	**7**	878	100	1588	6	4.04	20100	0	17413	**7**	76296
7	500	10	1586	15	**15**	9223	100	11386	8	5.81	20100	0	18527	**15**	124922
8	1000	5	6076	5	**5**	890	100	4534	3	0.89	20100	0	38105	**5**	263469
9	1000	8	2498	17	**17**	1925	100	5901	6	3.19	20100	0	37830	**17**	683890

The best results among the three algorithms for each case are bold.

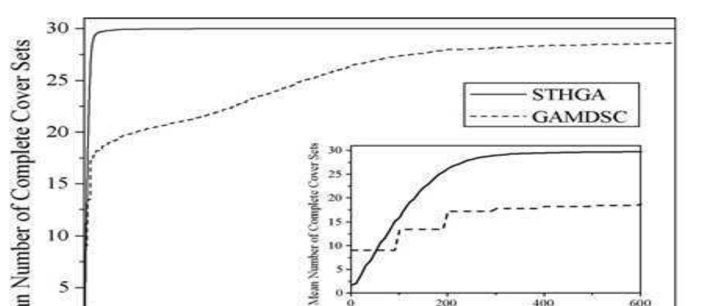

Fig. 2. Average optimization curves of STHGA and GAMDSC when solving the point-coverage Case 1 (N = 90 and the maximum number of disjoint cover sets is 30). The inner figure shows more details within the first 600 evaluations, much larger than the number of targets

In GAMDSC, each sensor is initially assigned to a random cover set. From the inner figure in Fig. 2, the initial number of complete cover sets found by GAMDSC is 9, which is bigger than that of STHGA. However, STHGA soon catches up and then surpasses GAMDSC because the incomplete set is continuously completed through the operations in STHGA. The results demonstrate that STHGA is very efficient. Subset optimization problem occur in STHGA.

V. CONCLUSIONS

Energy efficiency is of paramount importance in wireless sensor networks, as sensors have usually limited energy supply that should be spared so as to maximize the lifetime of the network. In this paper we discuss the various methods of scheduling for maximization the lifetime of wireless network. The problems with STHGA [1] is subset optimization problems, in which the maximum number of subsets that can meet. Objective requirements are needed to be identified. Our focus of work is increasing the lifetime of WSN by scheduling our proposed algorithm needs a new implementation method of GAs for the problems. It is proposed to address issues under the four main heads:

1) Extraction of merits and demerits of existing scheduling activities

2) Proposing alternate strategy or multipronged methods for scheduling and simulating them. Computation of lifetime under proposed mechanism of hybrid genetic algorithm (Finding the largest number of disjoint sets of sensors)

3) Evaluation of fitness functions as an integration of multiple performance parameters for different coverage schemes and optimization of coverage strategy and scheme

4) Developing optimal scheduling algorithm for sensor to enhance the lifetime of WSN. We presented several Scheduling schemes and result analysis on point coverage and area coverage [1] and also find out the problems with STHGA

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