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GENETIC ALGORITHM APPROACH FOR TARGET COVERAGE IN WIRELESS SENSOR NETWORK

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ABSTRACT

Wireless Sensor Networks (WSNs) technology is operated in various domains like home security, healthcare management, military applications, and so on. However, target coverage (TC) is one of the major exercises of WSN. Lots of energy-efficient TC issues have been proposed over the period. But, the underline principal of many of the proposed algorithms is Maximum Cover Set (MCS). Cover Sets (CS) are developed in MCS for sensor networks to observe the every target. It is challenging to achieve maximal CS and therefore, it is an NP-complete problem. Besides, the each node cooperates in constructing the CS and as results consumes significant amount of energy. Thus, we propose genetic algorithm based approach to optimistically manage the energy consumption for enhancing the WSN lifetime. The proposed method utilizes the few sensors to manage all the targets and simultaneously, enhances the sleep state of the node to extend the WSN lifetime. The proposed method assists in improving the performance of WSN by consuming less energy power.

KEYWORDS: *Genetic Algorithm; Lifetime; Sensor; Wireless Sensor Network*

INTRODUCTION

Wireless sensor networks (WSNs) have been broadly operated for home security, healthcare management, military applications, and so on Amutha et al. (2020); Sangwan and Singh (2015); Cardei and Wu (2006). Nodes used in WSN have a predefined radius for communication. They are arranges in a clusters to form a sensor covers and it is utilized for target monitoring in a particular region for a certain amount of time. In traditional coverage approach, generally the information about the environment is available and thus, optimum coverage solution is attained by covering every target through single sensor Amutha et al. (2020); Sangwan and Singh (2015). But, in real- world scenario such an approaches are not appropriate as any node can become unavailable due to run out of energy. Hence, it is recommended to have multiple nodes for continuously covering the targets Moh'd Alia (2017); Elhoseny et al. (2017a). But, it requires a appropriate nodes management as significant amount of energy gets consumed over the time Yuan et al. (2017); Elhoseny et al. (2017b). Therefore, node status needs to be maintained properly with time constraint for continuous coverage and optimal utilization of energy resource. Thus, it is a NP-complete problem and can be addressed using evolutionary algorithms Yang et al. (2014); Ahmed et al. (2014).

A node energy consumption is featured by data collection, processing and transmission. Also, various parameters like distance, throughput, and so on effects the overall residual energy of a node. Thus, various methods has been proposed in the literature to overcome the issues for enhancing the life of WSN. The cluster based approaches like Low energy adaptive clustering hierarchy (LEACH) Heinzelman et al. (2000), energy efficient unequal clustering (EEUC) Li et al.

(2005), and leader election with load balancing energy (LELE) Shirmohammadi et al. (2009) are proposed to share the load to achieve the fault-tolerance system. Due to dynamic nature of WSN, various clusters or Cover Sets (CS) are possible and thus, it becomes challenging to identify the best optimal solution. To mitigate the issue, the evolutionary algorithms has been operated on WSN. The genetic alforithm (GA) has been used for enhancing the WSN lifetime Elhoseny et al. (2014); Yuan et al. (2017); Elhoseny et al. (2017b). Besides, a hybrid approach based on simulated annealing (SA) and particle swarm optimization (PSO) algorithms has been introduced to provide the energy efficient solution for WSN Wang et al. (2007).

Based on above discussion, we can conclude that the CS is static in nature and hence, fails to provide the adequate solution to dynamic WSN. Thus, in this work, we have proposed the following features to mitigate the traditional issues:

- GA-based approach is proposed to continuously monitors the targets and utilized the GA optimistically for identifying the suitable CS.
- GA-based approach develops the best CS by considering all the influencing parameters responsible for reducing the WSN longevity.
- The proposed approach with respect to the requirement selects the CS for enhancing the WSN lifetime.

The remaining paper is structured as follows: Section 2 discusses the literature survey. Section 3 presents the proposed model for the target coverage problem. Section 4 summarizes our experimental results and discussions. Section 5 presents the conclusions and future work.

RELATED WORK

Initially, LEACH was introduced with the concept of clustering for managing adequate the energy utilization among the sensors Heinzelman et al. (2000). A particular sensor in a cluster has been randomly declared as a representative. As an result, the energy loss was significant and hence, the approach fails to provide the optimal solution. Afterwards, the LEACH approach was extended by Nayak and Devulapalli (2015) in fuzzy domain through the development of fuzzy clusters. The restriction on communication between the sensors has been proposed in Lindsey and Raghavendra (2002) to exploit the distance property for efficient management of energy. Further, the distance property was explored by proposing EEUC for identifying the cluster representative Li et al. (2005). However, it has been observed that approach generates the various sizes clusters based on the distance from base station. Next, the coverage issue was handled by considering the location property in the field for constructing the logical regions Nadeem et al. (2013). Then, the clusters are developed along with representatives and communications was decided based on distance. Diallo et al. have introduced the degree of connectivity parameter to determine the suitable representative of cluster and hence, the sensor with decent connectivity with other sensors has been considered.

Furthermore, the management of target coverage (TC) has been performed by constructing the appropriate types of CS Diop et al. (2014). Thus, a coverage-centric node selection issue has been presented in Zou and Chakrabarty (2005) and to mitigate the problem active node linked governing set was developed for performing the activities. A concept of scheduling for active and sleep node in WSN has been introduced under low duty cycle Wu et al. (2006). Besides, the nodes available in CS must be scheduled appropriately for increasing the lifetime of WSN. Polynomial-time approximation method was adopted for measuring the WSN lifetime through the data gathering and TC process Lu et al. (2014). The analysis of energy efficient pattern in WSN has been performed based on transmission and consumption of energy without influencing the rate of sensing coverage Dao et al. (2011). Also, the analysis of WSN node energy has been performed through targets for network longevity by designing the maximal set covers. It preserves the energy by allowing the significant nodes to remain in sleep mode Cardei et al. (2005). The heuristic approach has been introduced to improve WSN liftime by determining the energy conservation disjoint set to identify the suitable TC Ali Jamali et al. (2010); Cardei and Du (2005); Zorbas et al. (2007). The many nodes were employed for improving the WSN lifetime and hence, scheduling algorithm was proposed in Li and Gao (2008) for dealing with coverage problem.

Based on above discussion, searching for an optimal solution is an challenge. Thus, artificial bee colony based approach was designed for sensor deployment to enhance WSN lifetime Kittur and Jadhav (2017). The organization of sensors has been performed through GA to address the K -coverage problem Elhoseny et al. (2017b). The identification of minimum active sensors for maximum area monitoring has been achieved through GA for efficient K-Coverage Ebrahimian et al. (2010). The GA approach has been introduced for efficient deployment of sensors to maximize the coverage area Mnasri et al. (2015). However, static behaviour of CS unable to achieve the appropriate structure for dynamic WSN. Therefore, in this paper GA is considered to continuously observe the targets for identifying the optimal CS to enhance the WSN longevity.

PROPOSED METHOD

Fig. 1 represents the proposed model for identifying the optimum CS. In the initial stage, sensors are encoded using binary chromosome. In the second stage, the GA is operated to determine the optimum CS. The candidates in the CS are considered after each iteration based on target position and nodes range. In the final stage, the chromosomes are verified with respect to the all targets. Based on best available CS and expected energy consumption C, the next best group is chosen for upcoming iteration to enhancing the WSN lifetime.

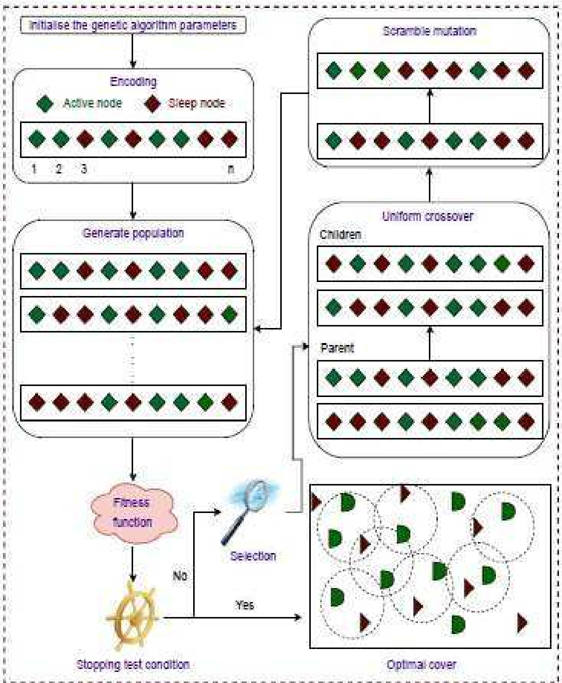

Figure 1: Proposed Method.

Let, target set T = {T_1, T_2, ..., T_T } is observed by WSN nodes W = {W_1, W_2, , W_w}. The area L × M is considered for the installation of T and W. Also, T must be within the radius "R" of W, i.e. W>T. The criteria is essential to observe the T continuously for modify the states of specific W to sleep when criteria is not satisfied and furnishing the system with dynamic characteristics. The system assist in maintain the E of W and finally, provide to enhance the lifetime of WSN. Hence, a set of active W are necessary to identify the suitable CS. Hence, R, E, and C are considered for the selection of nodes. C is assume to be active cover in the upcoming iteration. Thus, the total expected consumed energy for a particular CS is given as

$$C_{total} = \sum_{i=1}^{N} C_i$$

where N is the total number of nodes in a particular CS. The total energy spend by the node is given as

$$E_{total} = E_{RX} + E_{SX} + E_{TX}$$

where E_{RX}, E_{SX}, and E_{TX} is expressed as E utilized for receiving P- bit data

$$E_{RX} = P \times G_R$$

E utilized for hearing P-bits data

$$E_{SX} = P \times G_S$$

$$E_{TX} = L \times G_{elec} + L \times G_{mp} \times d^{\mu}$$

Where G_{elec} signifies energy dissipated per bit per meter^2. G_{mp} are transmitter amplifier model parameters, and path loss factor and Euclidean distance between nodes are expressed by μ and d, respectively. Residual energy of nodes is calculated using following Equation $E_{residual}$ □ E □ E_{total}

In each iteration, the $E_{residual}$ will be updated.

In the proposed work, each node is expressed as gene in a chromosome. The value hold by it is 0 (Status: sleep node) or 1 (Status: active node). The proposed GA, generates the new population through the crossover and mutation operation. The uniform crossover approach is considered in the proposed method due to its capability to preserve the solution sequence without affecting the diversity of chromosomes.

Also, scramble mutation approach is adopted in the proposed method to bring the diversity in the genetic population. Fitness function forthe evaluation of population is given as

$$f = \sum_{a} \frac{E_{residual}(a_i)}{E(a_0)} + \frac{E_{total}}{C} + \frac{1}{d}$$

Where, particular node a have the E at iteration i. d is the distance between the node and base. The f consists of normalized $E_{residual}$. Also, the ratio of C assist in minimizing the C and inverse d helps in preferring the node with minimum distance.

PERFORMANCE EVALUATIONS

This section presents and discusses the results of the proposed optimized method. Also, the experimental setup with evaluation metrics is presented. The the state of the art method are utilized for the comparison of the proposed method.

Evaluation Setup

The proposed optimization work has been verified using simulation environment (CPU: i5 3.5 GHz, RAM: 4 GB). The results of proposed work is compared with Zhao and Gurusamy (2008); Katti (2019). The various parameters employed in the work is presented in the Table 1 and python programming language is used with various libraries for the implementation of proposed algorithm. A 200 × 200 m2 2D area is assumed for the experimental purpose with homogeneous WSN. The T are installed randomly in L × M area with equal sensing range R for each W. Besides, the analysis of proposed work is performed by varying the multiple parameters. The node state switching happens and thus, E required for it is negligible. Fig. 2 demonstrate the WSN topology with 30 T (red colour) and 100 W (green colour). A disjoint connected coverage algorithm (NCCA), no disjoint connected coverage algorithm (DCCA), and communication weighted greedy cover (CWGC) are employed for the comparison with proposed optimized approach.

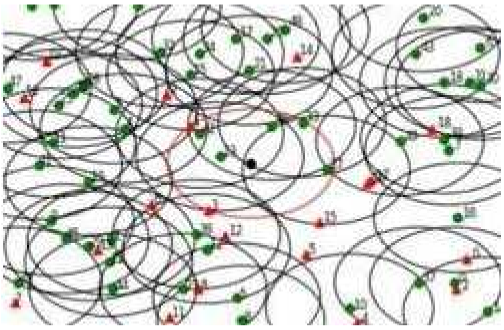

Figure 2: WSN Topology.

RESULT ANALYSIS

This section presents and discusses the results with different parameter study.

Analysis of WSN Lifetime through Number of Nodes

The result has supported to determine the association between W and network lifetime. Firstly, 150 W are considered and it is incrementally grown by 25 up to 350. Also, 20 T are deployed in the L × M area. Fig. 3 displays the effect of W on WSN lifetime. A trend of rise in a WSN lifetime with the increase in the W has been notified. A trend is observed as significant W's are accessible for the activity, and major W's are in sleep state. As an effect, significant E of WSN is maintained with a rise in the W's. The proposed optimized method performs better than the comparative models. Hence, the enhancement is the outcome of GA on network lifetime. The lifetime has improved nearly by 22.0% to 30.0% and almost stands consistent with an rise in W's.

Table 1: Simulation Parameters

Parameters	values
Network Size	200 m × 200 m
No. of Nodes (W)	Not fixed
No. of Targets (T)	Not fixed
Range of Sensors	100 m
G_{elec} (Energy consumed by electronics circuit in transmission and reception)	50 nJ/bit
G_{mp} (Transmit amplifier)	100 pJ/(bit/m2)
G_S (Sensing energy)	20 nJ/ bit
G_R (Receiver energy)	50 nJ/ bit
E_{TX} (Transmit energy)	50 nJ/ bit
E_i (Initial energy of nodes)	20 Joule
P	500 Bits
Data rate	1 Kbps
Path loss factor μ	2
3*Evaluation metrics	WSN lifetime
	Coverage time
	Average energy consumption

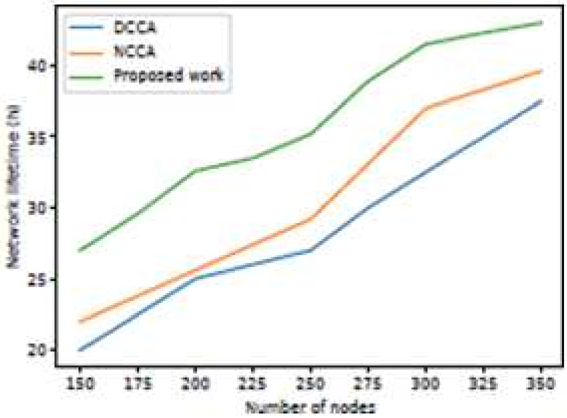

Figure 3: Analysis of WSN Lifetime through Number of Nodes.

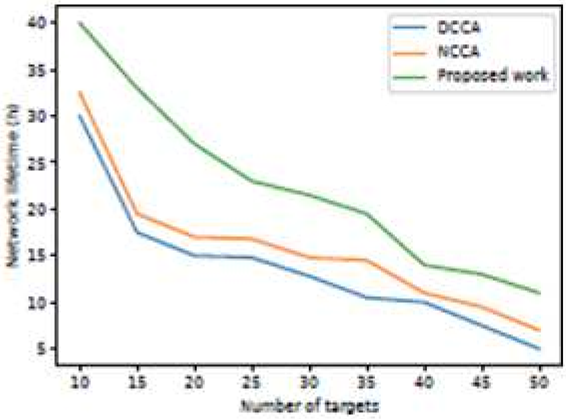

Figure 4: Analysis of WSN Lifetime through Number of Targets.

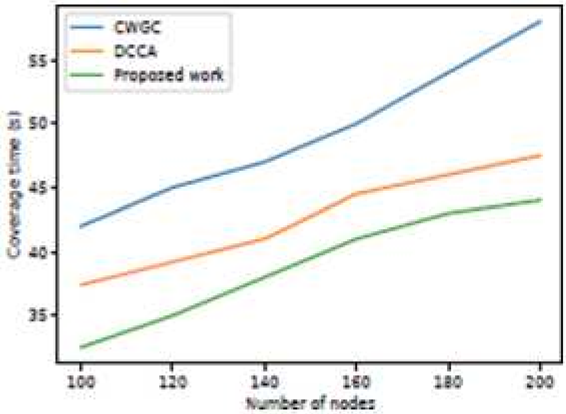

Figure 5: Analysis of Coverage Time through Number of Nodes.

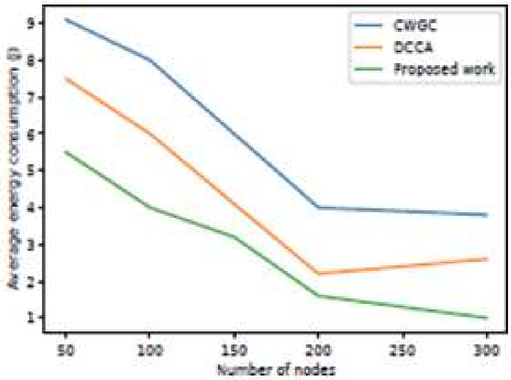

Figure 6: Analysis of Average Energy Consumption through Number of Nodes.

Analysis of WSN Lifetime through Number of Targets

The result has supported to determine the association between T and network lifetime. Firstly, 10 T are considered, and it is incrementally grown by 5 up to 50. Also, 300 W's are deployed in the L × M area. Fig. 4 displays the effect of T's on WSN lifetime. A trend of reduce in a WSN lifetime with the increase in the T has been notified. A trend is observed as significant T's are accessible for the activity, and therefore, majority W's are in active state. Hence, significant WSN E is required with an rise in the T's. The proposed optimized method performs better than the comparative models. Hence, the enhancement is the outcome of GA on network lifetime. The lifetime has improved nearly by 30.0% to 32.0% and almost stands consistent with an rise in T's.

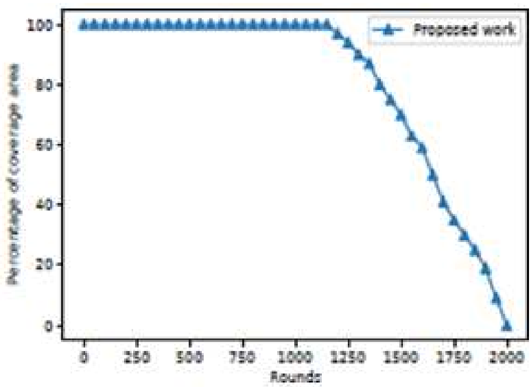

Figure 7: Analysis of WSN Coverage Area through Rounds of G.

Analysis of Coverage Time through Number of Nodes

The result has supported to determine the association between W and coverage time. Firstly, 100 W's are considered, and it is incrementally grown by 20 up to 200. Also, 30 T's are deployed in the L × M area. Fig. 5 displays the effect of W's on coverage time. A trend of rise in coverage time with a enhancement in the W has been noticed. A trend is observed as significant time is needed for determining suitable W. Therefore, notable time is consumed with rise in W's. The proposed optimized method performs better than the comparative models by utilizing less coverage time. The enhancement is the outcome of GA on network lifetime. The time has decreased nearly by 30.0% to 40.0% and almost stands consistent with an rise in W's.

Analysis of Average Energy Consumption through Number of Nodes

The result has supported to determine the association between W and E consumption. Firstly, 50 W's are considered, and it is incrementally grown by 50 up to 300. Also, 20 T's are deployed in the L × M area. Fig. 6 displays the effect of W's on E consumption. A trend of rise in E consumption with a enhancement in the W has been noticed. A trend is observed as significant W's are are accessible for the activity, and therefore, majority W's are in active state for the and receiving, transmission, and sensing. Therefore, notable E is required with rise in W's for target monitoring and communication. Some E is saved as all w's are not participated in designing the sets. As W's rise in the WSN, significant W's cover T's because W's are densely installed. Majority of W's active means significant consumption of E by W's for processing. W's utilized E in communication and sensing of T's.

Analysis of WSN Coverage Area through Rounds of GA

The result has supported to determine the association between GA rounds and coverage area. Fig. 6 displays the effect of GA rounds on coverage area. A trend of rise in round with decrease in coverage area is observed. But, the trend is after execution of 50.0% of rounds. A trend is noticed because GA utilizes the resources effectively and hence, after 50.0% consumption of round the decrease in the coverage area is observed.

CONCLUSION

In this work, an GA-based algorithm is introduced to handle the energy issue of the WSNs. Also, the GA-based approach presents a decent solution for the TC problem. The proposed work handles and propose the nodes for effectively utilizing the energy through evolutionary algorithm concept. It acquires through varying the node's state and dynamically changing position of targets. The proposed optimized approach is verified by multiple parameters and it illustrates the algorithm's effectiveness. The GA algorithm chooses suitable nodes to cover all targets and, hence, improves WSN lifetime by consuming less energy. Thus, it provides the solution to energy as well as coverage problem. The proposed method displays decent results in comparison to alternative approaches.

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