Harmony Search Algorithm for Solving *m* Connected Coverage Problem in WSN

Sudesh Sharma, Sarvesh Kumar, Chandra Prakash Verma, Hemat Gaur

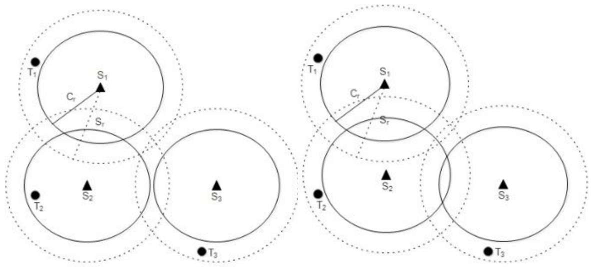
***Abstract:** Addressing the coverage problem is not a complete set of tasks for solving data aggregation in Wireless Sensor Networks. Since the collected information of each sensor node to reach the base station the deployment of sensors plays a critical role in WSN. This paper addresses m connected coverage problem which covers all the given targets and provide a complete connectivity between the sensors for effective data aggregation of data to the base station. A widespread Harmony Search Algorithm which is a metaheuristic algorithm for solving optimization problems is imposed in this sensor deployment concept. The results of the proposed algorithm have been compared with other existing techniques and the results shows that proposed algorithm outperforms existing algorithms.*

Keywords: Wireless Sensor Network, Harmony Search, m connected coverage

I. INTRODUCTION

In the past few decades, three exists an immense advancementin the field of Wireless Sensor Network (WSN) especially in terms of coverage and connectivity. In general, a WSN can be either structure or unstructured [1]. An unstructured WSN can be defined as a set of sensor nodes that are distributed randomly on the field. Due to this random distribution monitoring the network maintenance such as connection management and sensor node failure detection is a hectic process. Rather in a structured WSN, the sensor nodes are distributed in an organized manner where all the nodes form a connected network. Coverage is the process that ensures the guarantee of covering the entire region within the given sensor nodes [1]. Connectivity deals with the establishment of connections between the deployed sensor nodes [2].Furthermore, coverage problem can be deal with two factors, area coverage or target coverage [3]. Area coverage deals with monitoring the given entire environment whereas target coverage deals with specific region in the given area.

The requirement of coverage in highly depend on the requirement of coverage. Some application needs continuous monitoring of the region whereas some other application requires only scheduled monitoring [4]. This restriction is due to the limitation of power source in WSN. On concerning the problem of coverage in WSN along with the connectivity is another critical aspect of WSN where each sensor node should be located within the communication range of another sensor node [5]. The deployment of sensors in the field can be of two types, deterministic and random. In deterministic process the deployment of sensor gives the best result of place to deploy the sensors and this will be deployed when the information of target region is already given as a priori and the optimal placement finding of sensor nodes is a time-consuming process. When random process is handled for deployment of sensor nodes then the coverage of entire region can have the possibility of being biased or either some of the regions are filled with dense number of sensors and the others are covered with less number of sensors. An example of nonconnected and connected coverage of sensor nodes are given in Figure 1.



(a)Non-Connected Graph (b) Connected Graph
Figure 1. Connected and Non-Connected Graph of WSN

In Figure 1(a), the sensor nodes S_1 and $S_2$are connected to each other for efficient transformation of information but the sensor node S_3 is neither connected to S_1 or S_2. Though all the targets$T = \{T_1, T_2, T_3\}$ are covered by the set of sensor nodes $S = \{S_1, S_2, S_3\}$, since the sensor node $S_3$is not connected to any of the sensor nodes, this graph can be stated as nonconnected graph. In Figure 1(b), the sensor nodes *S* are connected to at least any one of the other sensor node and also covers the entire target region *T*, this graph can be termed as connected graph. In this paper we address the issue of providing the connected network with minimal number of sensor nodes.

Rest of the paper has been organized as follows: Section 2 refers to the literature study related to the research work handled in this target based WSN stream, Section 3 provides the detailed information of the problem that is handled in this paper, Section 4 deals with Modified Harmony Search for solving the M connected coverage problem, Section 5 holds the experimental results and discussion and finally section 6 concludes the paper.

II. RELATED WORK

Cheng et al., [6], proposed model for connected target k-coverage problem in heterogeneous wireless sensor networks. They used two algorithms namely centralized

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connected target k-coverage algorithm and distributed connected target k-coverage algorithm to provide energy efficient and coverage of heterogeneous network. Their proposed model minimized connected target k-coverage with least k-active sensor nodes. Their proposed model reduced the number of active sensor nodes and each node can connect to sink node to forward data.

Coverage problem in wireless senor network deals with deploying sensor nodes with maximum coverage area by scheduling and analyzing sensor nodes. Connectivity in wireless sensor network provides communication among sensor nodes through directly or indirectly to forward data to sink node. Wang et al., [7] proposed coverage issue in heterogeneous network based on coverage and reach ability. Lazos et al., [8] proposed stochastic coverage for heterogeneous network and they formulated minimum coverage problem as intersection problem. Due et al., [9] solved an issue for scalability and performance issues for heterogeneous network using differential coverage algorithm.

Zorbas et al., [10] proposed an efficient algorithm to maintain discrete active sensor nodes to cover all the available targets and provide connectivity among the network. They proposed an algorithm to schedule sensor nodes to increase the lifetime of network connectivity. The author proposed optimized connected coverage heuristic algorithm to maintain connectivity of the network with maximum network lifetime. Scheduling in sensor network coverage includes area coverage and target coverage. This author solved target coverage issues in wireless sensor network with optimized connected coverage algorithm.

Cardei et al., [11] proposed linear programming and greedy based technique to solve coverage problem in sensor network. In their proposed work, the sensor nodes cover more than one coverage set and thus it increases the number of coverage set in the network.

Greedy based target coverage algorithm was proposed [12] to maximize the number of sensor coverage sets by maintaining and managing poorly target nodes. Based on cost function the authors proposed heuristic methodology to manage poorly connected targets and improve the lifetime of network.

III. PROBLEM DEFINITION

Let us consider that there are m sensor nodes $\{s_1, s_2, \dots, s_m\}$ in the region G where n targets are available $T = \{t_1, t_2, \dots, t_n\}$. Each sensor node in the region G, has a communication range C_r for communication with other sensor nodes in the field and sensing range S_r for sensing the given target $t_i \setminus I \in T$. If the distance between sensor nodes s_i and s_j is less than S_r then the nodes s_i and $s_j$are connected to each other where $i, j \in m$.The coverage matrix($Cov\ M$) can be defined as

$$CovM_i = \begin{cases} 1\ if\ t_i \le S_r\ (s_j) \in n,\ j \in m \\ 0\ otherwise \end{cases} \quad (1)$$

And the connection matrix can be defined as

$$ConM_i = \begin{cases} 1\ if\ d(s_i, (s_j) \le C_r, i, j \in m \\ 0\ otherwise \end{cases} \quad (2)$$

Harmony Search

Harmony Search (HS) is a popular metaheuristic population based algorithm which is used for solving optimization problems. In this paper, the harmony search algorithm is used for optimizing the efficient placement of sensor nodes to cover all the targets and to maintain the connectivity. Harmony search works under three different forms, (1) it follows the Harmony Memory (HM) which it stored based on best results, (2) a slight pitch adjustment, (3) randomization. It parameters used for pitch adjustment and use of HM is based on r_{pa} and r_{accept} The pitch adjusting Harmony can be defined as

$$x_{new} = x_{old} + B_{range} \times \varepsilon \quad (3)$$

Where $B_{range} \in [-1, 1]$

Mapping HS – m Connected Coverage WSN

Each variable in HS is considered as a potential deployment region of a sensor node $s_i \in \{0,1\}$. The defined algorithm for solving m Connected Coverage using HS is given in Algorithm 1.

HS - *m* Connected Coverage WSN

Input: Number of sensor nodes *m*, Number of Targets *m*, objective function *f*()
Begin
Initialize Population size (*PopSize*), Maximum Iterations (*MaxIT*)
Initialize the Harmony Memory (HM) with random memery values
Initialize $r_{pa} r_{pa}$ and r_{accept}
while($t \le MaxIT$)*do*
for each $i \in Popsize$
for each $j \in |S|$
if($rand < r_{accept}$)*then*
Choose *j* from HM
elseif(*r* and <r_{pa}) *then*
Adjust *j* using Eq. (3)
else
Generate a random variable for *j*
endif
end for
if$\left(f\left(x_i^{new} < f\ (x_i^{old}\right)\right)$ *then*

$$x_i^{t+1} \leftarrow x_i^{new}$$

endif
end while
End

Output: Potential Positions to place the sensor nodes from the available positions

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Algorithm 1: HS - m Connected Coverage WSN

IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

Simulation setup of the proposed algorithm has been done in MATLAB version 8.3 with a system configuration Intel Core i7 Processor, with 3.2 GHz Processor Speed, 4GB RAM and with windows 10 as operating system.

For convenience of simulation region, the system has been kept idle with base utility functionalities. Under two simulation scenarios the proposed algorithm has been tested. There are 2 different scenarios carried out for testing the proposed algorithm. In the 1st grid a total region of 50x50 square meter has been simulated and in 2nd grid 100x100 square meter region has been developed. For 1st grid the base station is placed at 25x50 and for 2nd grid it is in 50x100.

For execution process the parameters are set as follows:

Table 1: Parameter Settings

Parameter Settings	
Population size	100
Maximum iterations	500
r_{pa}	0.1~0.5
r_{accept}	0.7~0.95
B_{range}	[-1, 1]
ε	[-1, 1]

Performance Measures:

A. Computational Time: It is defined as the time taken to complete the given number of iterations

B. No. of sensor nodes deployed: It is defined as the ratio between the number of sensor nodes deployed to the given available positions.

C. F value: F value is the ratio between the number of available positions to plot the sensor nodes and the total number of sensor node deployed.

$$F = \frac{K}{L}$$

where K is the total number of available positions to plot the sensors and L total number of deployed sensors.

The simulation region of 50x50 square meter grid in MATLAB is as follows

Figure 2: 50X50 GRID

o – Sensor Nodes * - Targets

A total of 50 random generated targets and 40 sensor nodes is in this simulation region of 50x50 Grid. The resultant table is given below

Table 2: Simulation Results of Grid 50X50

Algorithms	Comp. Time (s)	No. of Nodes Deployed	F-Value
GA	6.19	29	1.379
PSO	5.02	25	1.6
HS	4.97	17	2.352

Representation of total number of nodes deployed for every 100 iterations in 50x50 grid in the form of chart is given below

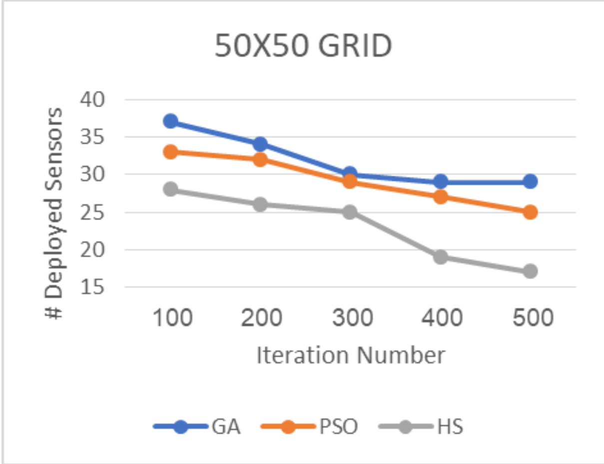

Figure 3: Comparison of optimal results w.r.t. iterations for 50X50 GRID

The simulation region of 100x100 square meter grid in MATLAB is as follows

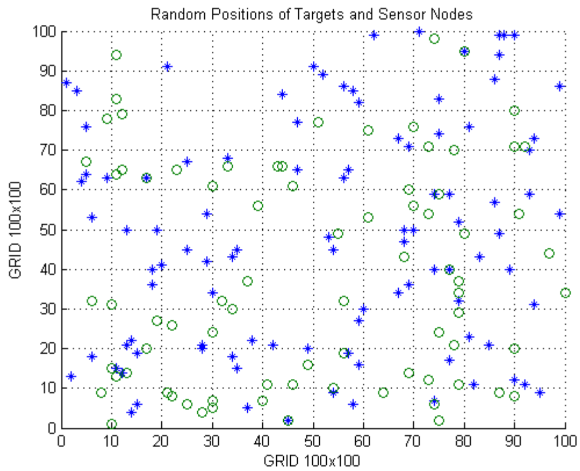

Figure 4: 100X100 GRID

o – Sensor Nodes * - Targets

Below tabulation holds the performance values of GA, PSO and MKEA algorithm.

Table 3: Simulation Results of Grid 100X100

Algorithms	Comp. Time (s)	No. of Nodes Deployed	F-Value
GA	8.16	52	1.538
PSO	7.32	47	1.702
HS	6.24	41	1.951

Table 2 and 3 indicates that our proposed approach outperforms the existing techniques.

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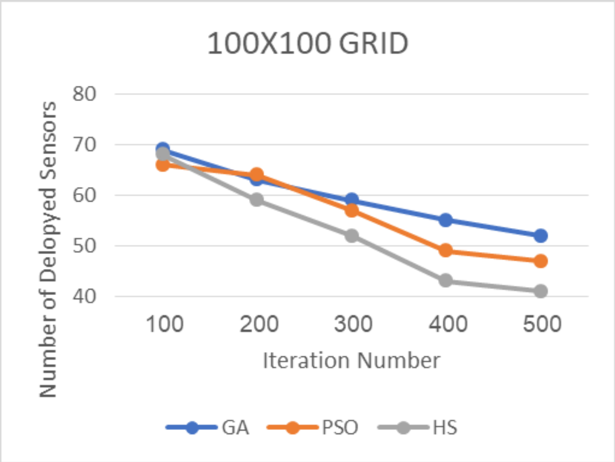

Figure 5: Comparison of optimal results w.r.t. iterations for 50X50 GRID

V. CONCLUSION

In this paper, the Metaheuristic Harmony Search Algorithm is used for solving m connected coverage WSN network. In Introduction section a detailed explanation regarding the problem is given and the given problem is defined in Section 3 mathematically. The result of the proposed method has bee compared with other Evolutionary Algorithms GA and PSO and the results shows that the proposed algorithm outperforms existing algorithms. The future of this research work can be enhanced to solve m connected k coverage problem.

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