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Sensor Node Deployment and Scheduling for Enhancing Network Lifetime in WSN

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Abstract: Wireless Sensor Network is collection of tiny nodes in huge number called as sensor nodes. Each sensor node is equipped with non-rechargeable battery with limited power. Sensor nodes are deployed to gather useful information from the field to be monitored. Information collection in WSN should be in an efficient manner. When nodes are randomly deployed, all the nodes may not be used efficiently which will reduce the network lifetime. Proper deployment and well planned scheduling is required to improve network lifetime. In this paper, Heuristic and Ant colony scheduling techniques are used for activation of cover sets after proper deployment using artificial bee colony algorithm. This analysis will help to improve the performance parameters of wireless sensor network.

Key word: **-** Wireless Sensor Network, Network lifetime, Coverage, Deployment, Scheduling, Upper bound

I. INTRODUCTION

Wireless Sensor Networks (WSNs) is as a self-configured and infrastructure less wireless networks use to monitor and track physical or environmental conditions. For monitoring and tracking huge numbers of tiny sensor nodes are placed in area to be monitored. Wireless sensor networks are covered the applications like target tracking, environmental monitoring, surveillance, and data collection for factors such as humidity, temperature, light, and pressure or the weight, velocity, and movement direction of an object in the area of the interest [1]. Once WSN is deployed, each target in an area should be continuously monitored. It is referred as Target coverage problem in WSN[3]. However, while these networks are widely used in many applications, the main issue focused here is network lifetime. Network lifetime is the time duration from the activation of WSN to the instant when required coverage is not provided. Improvement in WSN lifetime is highly depends on the sensors' positions, known as the deployment of the network. In the dynamic deployment, sensors are initially located in the area with random positions. If the sensors are mobile, they can change their positions by using their knowledge of other positions. With these movements, they try to increase the coverage rate. On the other hand, if the sensors are stationary, they do not have the ability to change their positions [4].

Coverage may be Area coverage problem,Such coverage requires monitoring/gathering information about an entire region. So entire area of interest should covered by all the sensor nodes that are deployed [5].

Target coverage, this coverage concerns about monitoring a set of specific locations in the region. To cover particular target, different deployment algorithms are used for positioning sensor nodes at specific location. Target coverage problems evolved in 3 stages; Simple coverage, *k*-coverage and *Q*-coverage.

Simple coverage: In simple coverage, Each target should be monitored by at least one sensor node. Such coverage may not fulfill coverage requirement if one of the sensor node become fails. For compensating node failures or in case of monitoring with greater accuracy, simple coverage was not sufficient. This paved the way for K-coverage.

K-coverage: In K-coverage, each target has to be monitored by at least K sensor nodes, where K is a predefined integer constant. K-coverage provides more network lifetime compared with simple coverage. But K-coverage problem seems unfit for applications where targets need not essentially be monitored by the same number of sensor nodes.

Q-coverage: When coverage requirement varies depending on application, it is suitable to use Q-coverage. where $T = \{T1, T2, . . . , Tn\}$ number of target nodesshould be monitored by $Q = \{q1, q2, . . . , qn\}$ number of sensor nodes such that target Tj is monitored by at least qj number of sensor nodes, where n is the number of targets and $1 \leq j \leq n$. Sensor coverage is important while evaluating the effectiveness of a wireless sensor network. A lower coverage level (simple coverage) is enough for environmental or habitat monitoring or applications like home security. Higher degree of coverage (K-coverage) will be required for some applications like target tracking to track the targets accurately [6].

Our approach in this paper is, after proper deployment of sensor nodes in WSN, implement scheduling techniques. We obtain analysis of two scheduling algorithms one is Heuristic scheduling and other is ant colony algorithm. Where we have shown that both scheduling algorithms provides calculated maximum upper bound.

II. Scheduling

Every sensor node in WSN needs to operate for long periods of time working on a tiny not rechargeable battery. Therefore, it is important to optimize the energy of all sensor operations, which include sensing, computation, and communication. This requires designing of scheduling techniques that are energy-efficient in the sense of requiring low processing and low transmission power. WSN consist of large number of sensor nodes and therefore to enhance the network lifetime divides the sensor nodes into a number of sets, such that each set completely covers all the targets. This sensor sets are activated successively, such that at any time instant only one set is active. The sensors from the active set are in active state (e.g. transmit, receive or idle) and all other sensors are in the sleep state, If ,while meeting the coverage requirements, sensor nodes alternate between the active and sleep mode, this will result in increasing the network and application lifetime compared with the case when all sensors areactive continuously[7].

III. Upper Bound

The upper bound is the maximum achievable network lifetime for a particular configuration.

Assume m number of sensor nodes as S1, S2, . . . , Sm which are randomly deployed to cover the region with dimension as X by Y. These m number of sensor nodes monitors the n targets as T1, T2, . . . , Tn.

Each sensor node has an initial energy Eo and a sensing radius Sr . A sensor node Si, $1 \leq i \leq m$, is said to cover a target Tj, $1 \leq j \leq n$, if the distance between Si and Tj is less than Sr . The coverage matrix is defined as,

$$\text{Mij} = \begin{cases} 1 & \text{if Si monitors Tj} \\ 0 & \text{otherwise} \end{cases} \qquad (1)$$

where $i = 1, 2, \ldots, m$
$j = 1, 2, \ldots, n.$

Now consider initial battery power as bi and energy consumption rate of each node as ei and thus bi' = bi / ei represents the lifetime of battery in terms of time. By using above data, the upper bound is calculated as,

$$U = \text{minj}\left(\frac{\sum_i \text{Mij} * \text{bi}'}{\text{qj}} \right) \qquad (2)$$

For k-coverage,

$q\,j = k, j = 1, 2, \ldots, n.$

IV. Artificial Bee Colony Based Deployment

One of the dynamic deployment method based on intelligent behavior of Honey Bee Swarm. Using the concept of Honey bee Swarm in WSN, placements of sensors are done to the place where large numbers of targets are present so that each target is covered by large number of sensors.

In this algorithm, initially all the targets are covered such that each sensor node at least covers one target and network lifetime is calculated using equation (2). This network lifetime is used as the fitness function for evaluating the solutions. Each sensor node is associated with a cluster, where a cluster corresponds to the set of targets monitored by the sensor node. Let Di = (Xi ,Yi)be the initial position of i^{th} cluster. F (Di)refers to the nectar amount at food source located at Di. After watching the waggle dance of employed bees, an onlooker goes to the region Di where large numbers of targets are present with probability Pi defined as,

$$\text{Pi} = \frac{F(Di)}{\sum_{l=1}^{m} F(Di)} \qquad (3)$$

Where m is the total number of food sources. The onlooker finds a neighborhood food source in the vicinity of Di as,

$$\text{Di}\,(t+1) = \text{Di}\,(t) + \delta ij \times f \qquad (4)$$

Where δij is the neighborhood patch size for j^{th} dimension of i^{th} food source, and f is a random uniform variate $\in [-1, 1]$.

It should be noted that the solutions are not allowed to move beyond the edge of the search region. The new solutions are evaluated using the fitness function (2). If any new solution is better than the existing one, the old solution is replaced with new solution. Scout bees search for a random feasible solution. The solution with the least sensing range is finally selected as best solution. Flowchart for ABC deployment is shown in fig.1.

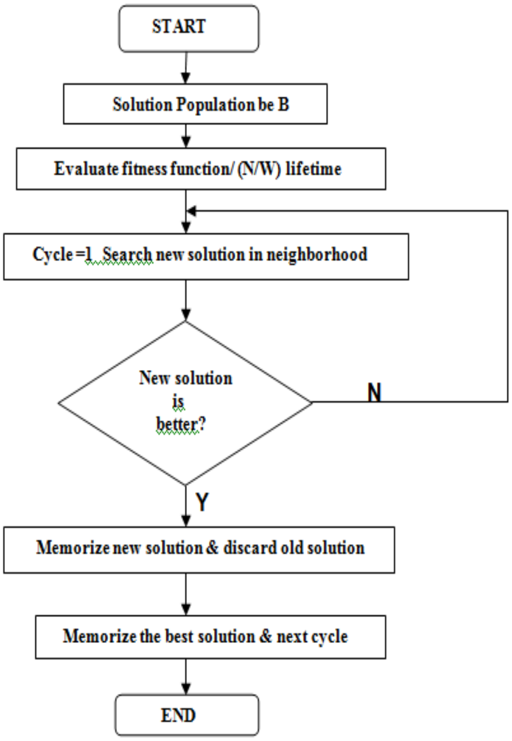

Fig. 1 ABC Algorithm Flowchart

V. Sensor Node Scheduling

Using sensor deployment, optimal deployment locations are known. Now sensor nodes have to be scheduled such that each sensor node need not be awake all the time. The numbers of sensor nodes deployed in the area are greater than the optimum number required to monitor the targets. Proposed heuristic and Ant colony algorithm are used to find cover sets and switching from one cover to another in a scheduled manner such that only minimum numbers of sensor nodes remain active at any time to improve network lifetime.

1. A Heuristic for Sensor Scheduling: It is one of the methods utilized for scheduling of sensor cover sets. In this work, weight based heuristic approach is used for cover set formation which includes following four steps.
First, Weight assignment which is performed to decide the priority of sensor nodes. Priority is assigned on energy of sensor node, more energy sensor nodes are assigned to highest priority.
Secondly, cover formation that uses a priority based method. In the order of priority, if any new sensor node contributes to k/Q coverage requirement, it will be added to the cover set.
Next cover optimization where by optimizing the generated cover sets, the proposed scheme attempts to minimize the energy usage. For that, during scheduling first highest priority sensor nodes are activated and finally lowest sensor node which makes WSN more effective.
Finally Cover activation and Energy reduction, in that sensor nodes in the optimized cover are activated. The total energy that each node consumes should not fall beyond the minimum usable energy, *Emin*
Algorithm for heuristic scheduling technique is understood by flowchart given in fig 2.

2. Ant Colony Algorithm: Another method of sensor scheduling which is implemented in this work is Ant Colony Scheduling algorithm. One of the Bio-inspired mechanisms which provides low energy, data collection structure in wireless sensor network. It can avoid network congestion and fast consumption of energy of individual node. Also it prolong the life cycle of the whole network.
In this algorithm initially initialize parameters as number of ants m, the weights of α and β and evaporation rate ρ. Then ants were placed on those subsets where at least one of the sensor is base station connected..
Each ant selects the next subset and selection is based on the current energy of each set of sensors.
When all the ants will complete one cycle, the pheromone of the subsets adjusted. The iteration

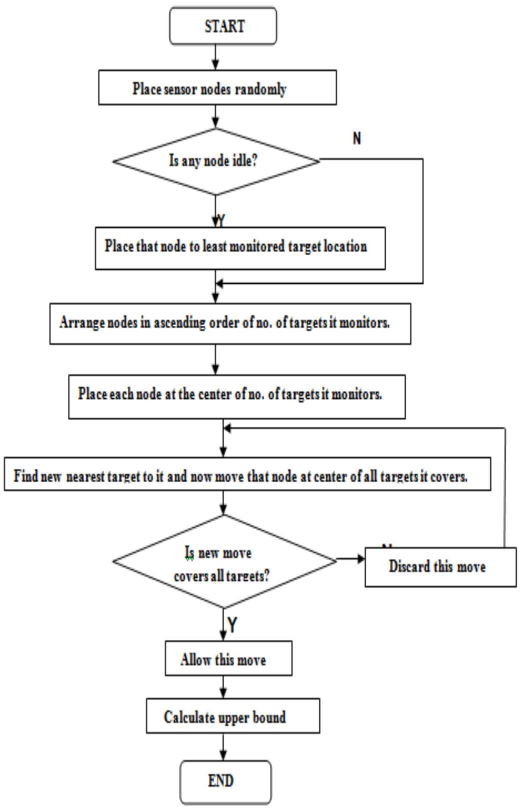

Fig.2 Heuristic Scheduling Algorithm Flowchart

will be stopped when the solution set meet the condition of monitoring all the targets. Flowchart for this technique is given in fig 3.

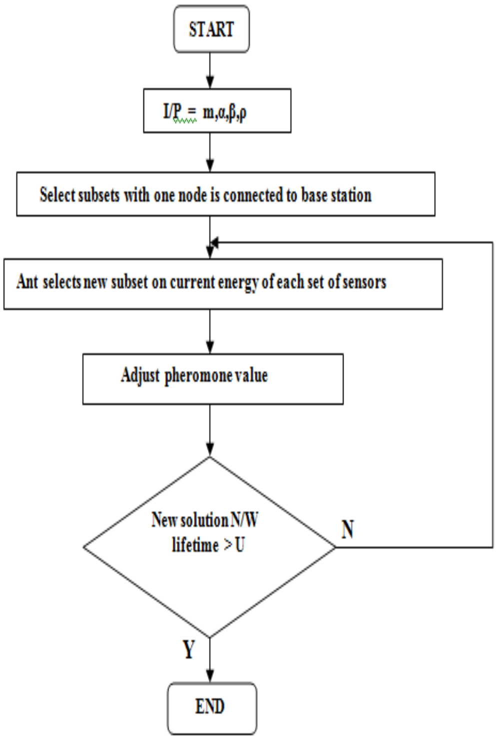

Fig.3 Ant Colony Scheduling Algorithm

VI. Simulation Results

Before analyzing both scheduling techniques, sensor nodes have to be deployed effectively. For that during simulation, first sensor nodes are placed using Artificial Bee Colony algorithm. Sensor nodes are movable and homogeneous while target nodes are fixed. WSN parameters for this simulation are given below

Region area= 500m x 500m and 400m X 400m
Number of Target Nodes = 25
Number of Sensor Nodes = 50, 100, 150
Sensing Range of Sensor Node = 75m
Energy of sensor nodes = 1000 Unit

A. ABC Deployment

Random Deployment is the suitable and feasible way of placing sensor nodes in area which is to be monitored and specially region area which is not easily accessible. But random placement may not provide target coverage requirement and also not effective one.

Use of deterministic ABC deployment, keeps large number of sensor nodes in sleep mode during scheduling which is used to save energy in sensor node. So compare to random deployment ABC shows enhanced network lifetime shown in fig 4.

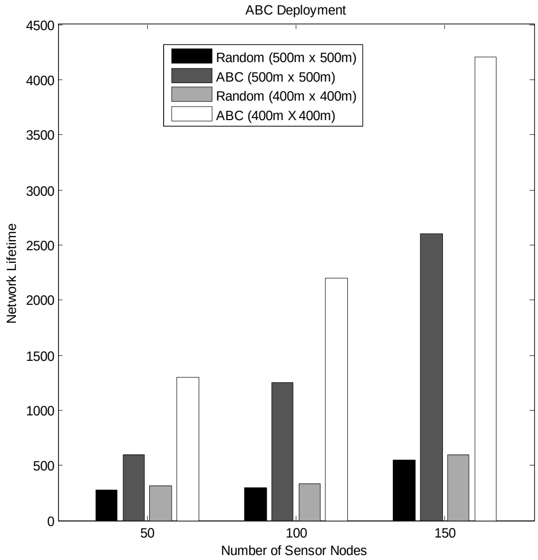

Fig. 4 ABC Deployment Results

Table 1 and Table 2 shows network lifetime for random and ABC deployment algorithms for target nodes equal to 25 and 50 respectively.

Table 1 : Network Lifetime for Nt = 25

Region Area	Ns = 50		Ns = 100		Ns = 150	
	R	ABC	R	ABC	R	ABC
300 x 300m^2	352	1086	380	2800	550	5200
400 x 400m^2	325	945	350	2360	540	2645
500 x 500m^2	279	1150	330	1270	510	1630
600 x 600m^2	250	820	319	980	494	1432

Table 2 : Network Lifetime for Nt = 50

Region Area	Ns = 50		Ns = 100		Ns = 150	
	R	ABC	R	ABC	R	ABC
300 x 300m^2	327	702	330	2500	604	5500
400 x 400m^2	304	571	318	1259	649	2521
500 x 500m^2	240	898	295	1468	491	1600
600 x 600m^2	0	632	261	913	470	1420

Table 1 and 2 shows that when sensor node density is increases in same area then network lifetime increase. Because number of 1's in coverge matrix increases and increses results of upper bound. For number of sensor nodes equal to 150, number of target nodes equal to 25 and in 300 x 300 m^2 region area, ABC provides near about ten times network lifetime compare to random.

Also table 2 shows that for region area of 600 x 600 m^2, random deployment fails to provide proper coverage when 50 sensors are used to cover 50 targets.

B. Scheduling Techniques

For scheduling of sensor nodes, simulation is carried for Heuristic and Ant colony algorithms. Results for Heuristic scheduling is shown in fig 5.

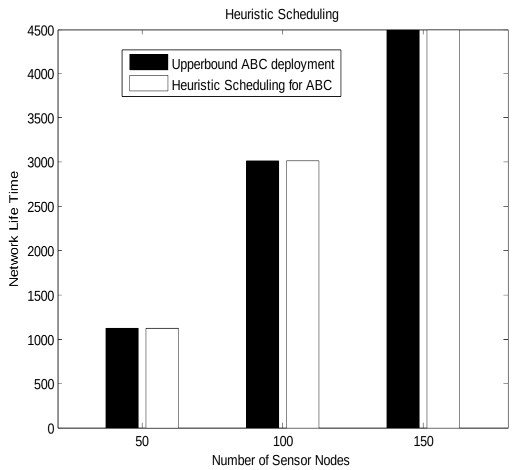

Fig 5 Heuristic Scheduling Results

Fig. 5 shows calculated network lifetime upper bound in ABC and network lifetime after Heuristic scheduling are the same. For scheduling of cover sets, this technique selects sensor nodes which are having more energy and satisfies coverage requirement.

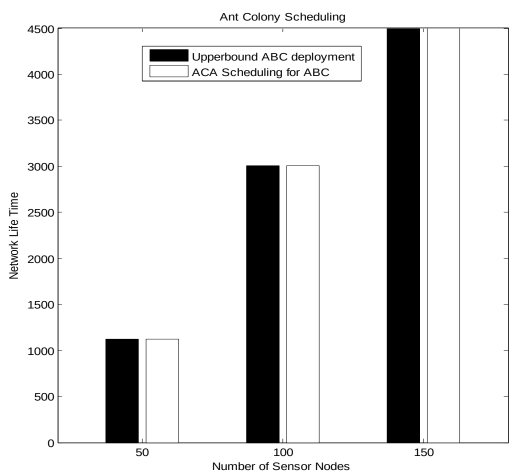

Fig 6 Ant Colony Scheduling

Same as heuristic scheduling, ACA scheduling is also capable of providing maximum calculated network lifetime as shown in fig 6. Performance of both scheduling technique is same because both techniques are based on selection of sensor node by remaining energy of sensor node.

C. Effect of coverage

This Simulation consists of change in coverage (for different values of K) on network life time after scheduling. Fig. 7, 8 and 9 shows the results for 300m x 300m region area with change in value of K.

Number of sensor nodes = 50, 100 and 150

Sensing range = 50m, Number of target nodes = 25

Fig 7 and 9 shows the effect of variation of K on network lifetime for number of sensor nodes equal to 50 and 150.

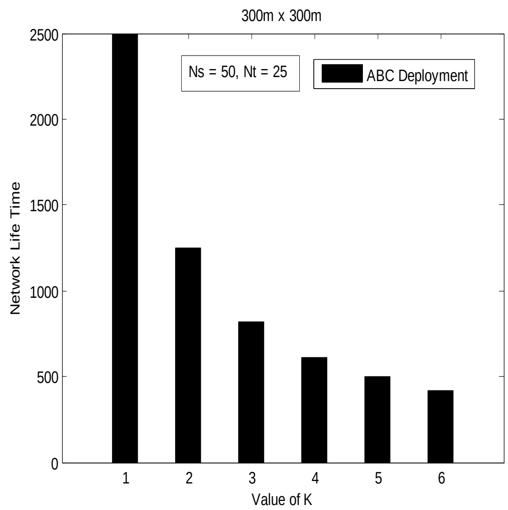

Fig 7 Effect K- coverage for Ns=50

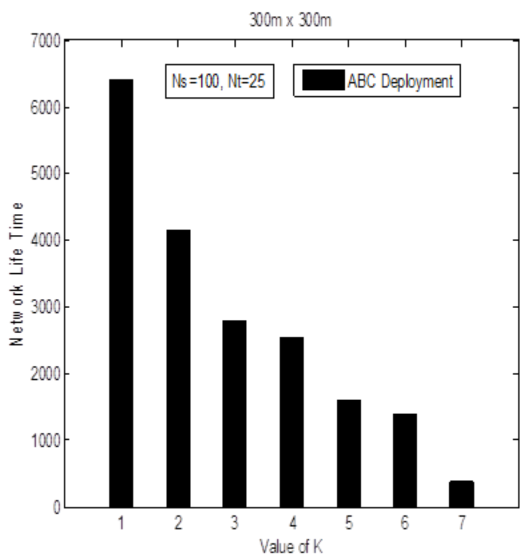

Fig 8 Effect K- coverage for Ns=100

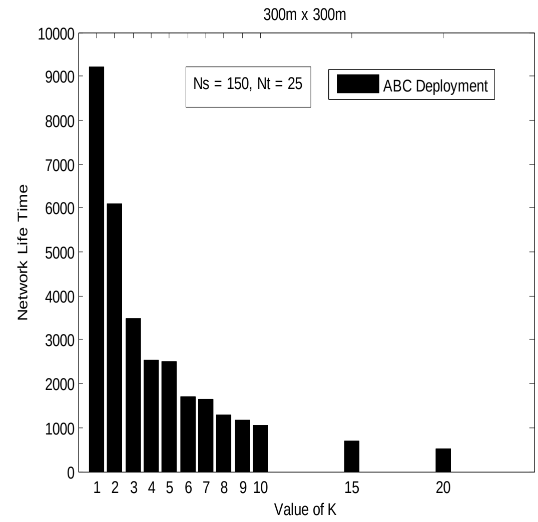

Fig 9 Effect K-coverage for Ns=150

From the graph, it is clear that compare to 50 sensor nodes, for 150 number of sensor nodes network survives even for K is more than 10 which is not attained in other two cases.

For the situation when number of sensor nodes equal to 100, to attain the maximum network lifetime as value K increase, number of sensor nodes deployed in the region of interest has to be increased. The requirement of increase in sensor nodes for K = 5 are 180, for K = 6 are 200 and for K = 7 are 230. It is shown in fig. 10 and numbers of sensor nodes are given table 3.

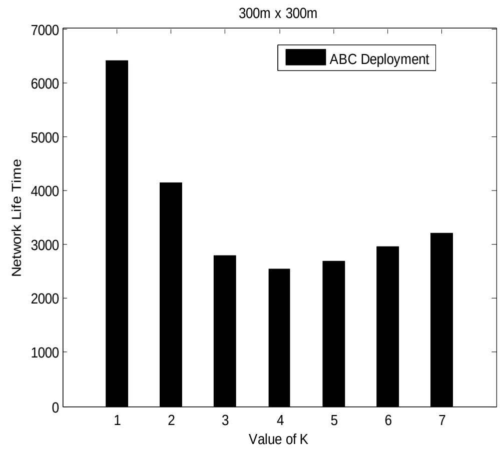

Fig 10 Effect of increased sensor nodes

Table 3 : Number of increased sensor nodes

Value of K	Number of sensor nodes
3	100
4	100
5	180
6	200
7	230

After proper deployment of sensor nodes, the next phase is scheduling of sensor node cover set for efficient performance of WSN, Where the task is alternately turning ON and OFF cover sets which are formed to give required coverge.

Simulation results of Heuristic and Ant colony scheduling shows that both techniques are capable to attain the maximum calculated upper bound of network lifetime in case of simple and K-coverage. As in both techniques, activation of sensor node is based on residual energy of sensor node. Also for less number of sensor node, WSN fails to satisfy coverage requirement for higher values of K and increased value of K, drops network lifetime. This can be improved by deploying more number of sensor nodes.

VII. Conclusion

Target coverage with improving network lifetime is achieved with optimum repositioning and less consumption energy of sensor nodes. For efficient deployment, in this paper ABC deployment is implemented. Result clears that ABC deployment is more efficient and provides optimal network lifetime compare to random deployment. While for scheduling, Heuristic and Ant colony techniques are useful to provide calculated results. Our future work will base on same work considering heterogeneous mobile sensor node.

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