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BFO OPTIMIZED DEPLOYMENT IN SELF-ORGANIZING WSN WITH MOVABLE NODES

Pooja Nagchoudhury
Department of Computer Science
JIET, Jodhpur, Rajasthan, India

Saurabh Maheshwari
Department of Computer Science
GWEC, Ajmer, Rajasthan, India

Kavita Choudhury
Department of Computer Science
JIET, Jodhpur, Rajasthan, India

Abstract— **The optimal deployment of nodes is essential for WSN so as to cover the entire area with optimal number of sensor nodes. The proposed algorithm can be used to identify the number of nodes required to cover the area with the location of nodes in network. Behavior of Biological inspire Bacteria Foraging Algorithm is used to identify the location of nodes. The nodes represents as a bacteria searching for optimal location in the network. The paper presents an optimal algorithm for sensor node deployment in WSN. The entire area is cover with regular hexagon and the nodes in the network are move to the vertices of hexagon. This leads to form clusters of hexagonal shapes. The node at the center of hexagon is the CH and nodes at the vertex are member of cluster. Node at vertex is CH of another hexagon. This leads to connect the cluster with each other to cover the entire area. The simulation results of the proposed algorithm are also shown in the paper.**

Keywords— **WSN, sensor node deployment, clustering, bacteria foraging, bio-inspired, nature inspired, hexagon**

I. INTRODUCTION

Wireless sensor network cconsists of large number of sensor nodes. Every sensor nodes have sensing unit, energy unit, processing unit, storage unit and transmitting / receiving unit [1, 2, 5, 18]. Self-organize nature, Rapid deployment and fault tolerance makes the WSN to use in many areas like in climatic analysis, commercial applications, military surveillances, tracking application, agricultural application etc. [18]. Various issues which have to keep in concern while constructing WSN are: reliability, flexibility, cost, easy of deployment etc. [8]. The WSN is organized in many ways but Multi hop cluster model is appropriate model for WSN among all models [6].

Large size of WSN requires self organization. All entities of self organized network configure them into a structured network. Thus requires minimum centralized control. The self organized nature of network make network flexible, robust and scalable. The self organized WSN supports distributed protocol. This allow nodes and nodes if cluster for localize sensing and processing [16].

Bacterial Foraging Algorithm is a bio inspire algorithm used for optimal localization, formation of cluster etc. Bacterial Foraging Algorithm (BFA) copies the searching behavior of Escherichia coli bacteria (E. Coli) which is found in the small intestine of human body. E. Coli bacterial finds the nutrient rich location. An E. Coli bacteria has two types of movements: tumbling and swimming. In swimming movement, the bacteria move in a straight line in a given direction, whereas in tumbling the bacteria randomly change the direction of association [1, 2, 14].

The nodes are deployed in random manner but accurate deployment is essential for the performance of WSN. The nodes are deployed using the unmanned aerial vehicle were the manual deployment is not possible [1, 3]. The deployment is easy when the area is accessible by human, the positions of node are registered at the time of deployment and for small network, and otherwise the deployment is complex process [17].

The nodes in the network are grouped together to form clusters. Every cluster has a cluster head. Nodes sends data to it cluster head, the cluster head perform operations on received data and transmits further to the base station or to the other cluster heads depends on their connectivity whether they are directly cconnected with the base station or not [13]. Ssynchronization of nodes, Cluster size, connectivity etc. is various issues that affect the clustering [19]. Clustering plays an important role while organizeng a WSN. Clustering affects the performance of network [10].

The rest of the paper is organized as follows. Literature survey is explained in section II. Proposed algorithm is explained in section III. Experimental results are presented in section IV. Concluding remarks are given in section V.

II. LITERATURE SURVEY

Surveys on various clustering methods with their performance are given in [2, 6, 14]. Hamid and Masood in [12] focus on increasing the life of network by presenting a clustering method which is the extension of LEACH. The method transmits using gateway nodes. Gurjot singh et. al. in [14] explains the deployment of sensor nodes using the concept of clustering. The positions of nodes are identified by Bacterial Foraging Algorithm inside the cluster. This improves the life of WSN. Authors in [9] uses voronoi diagram to explain the concept of nodes clustering and presented a comparative study on it. To construct clusters Voronoi diagram of network is build.

In paper [1] author proposed an optimal method of sensor node deployment in wireless sensor network and explains why the deployment is essential in WSN. The algorithm works in two phases: one to identify the location of nodes and next to cover the entire area.

Raghavendra V. Kulkarni et. al. in [18, 20] presented that the Bacterial Foraging Algorithm (BFA) finds location of sensor nodes more accurately but having deployment delay as compare to Particle Swarm Optimization (PSO). In [19] various techniques of localization are explained. The clusters are formed in distributed manner motivated with the behavior of biological model. Challenges like size of cluster, rotation of cluster head, synchronization etc. are encountered while constructing the clusters which are discussed in [19].

Ankit Sharma et al. in [8] projected a proposal of clustering which is combination of BFA, HEED and LEACH protocols. This increases the life of WSN network. Qiao Li et al. in [15] presented an algorithm enhancement of LEACH namely Low Energy Intelligent Clustering Protocol (LEICP). It works more efficiently than LEACH. In every round auxiliary cluster head selects the cluster head by BFA and cluster head then decides the next to whom the message was send using dijkstra algorithm. So that the optimal path is used to send message.

Authors in [17] proposed a range free localization algorithm that more efficiently localizes nodes which are situated at the center of field or network, because algorithm takes three anchor nodes for localization.

In [3] author presented an algorithm for node deployment, were the nodes are deployed at the center of hexagon. But the vertexes of the hexagon are not used for deployment of sensor nodes.

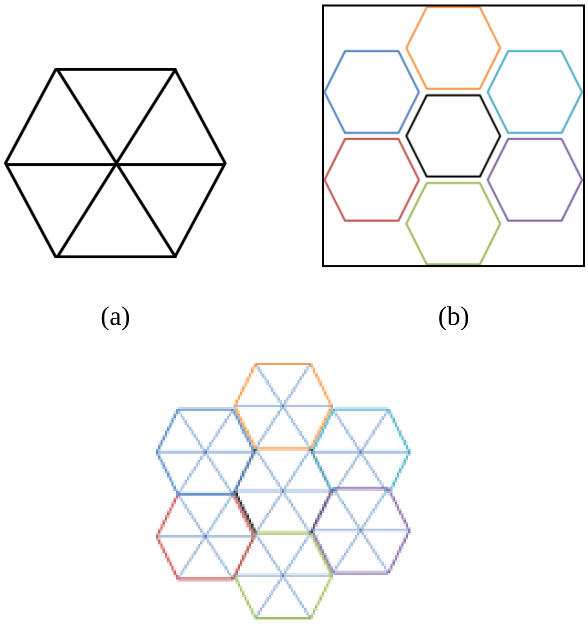
III. Proposed Algorithm

The proposed method is more suitable for movable sensor nodes in the field to reach an optimum location after initial deployment through aircraft in remote areas. The aim of the proposed method is to cover the whole geographical area with optimal number of nodes. The nodes must reach to their optimal position. In this section the proposed method for deployment using bacteria foraging has been discussed.

A. Hexagonal Network Architecture –

The network consists of a large number of movable nodes operational with wireless directional antenna, memory for storing routing, global positioning systems (GPS) for coordinates, and wireless proximity table. It may be possible that some area is having multiple sensor nodes and in some there may not be any of the nodes fallen. Proper deployment is essential to cover the whole area with equal number of nodes. Nodes are movable, they can move to their optimal locations. The nodes will be thrown to the random locations generally through the airplanes. Nodes are moved to their desire locations on the basis of proposed algorithm.

The goal of the proposed method is to move the nodes on vertices of a regular hexagon and the cluster head is placed on the center. The radius r of the circle circumscribing this hexagon gives the distance between the nodes. The distance from the center to all the vertices is also r. When two hexagons are in contact with each other no space is left in between them (figure 1(b)). As space is left in between two circles and squares when they are contact with each other. To cover whole area without leaving even a smaller space, hexagonal structure for clusters is favourable. The cluster head will be at the center of hexagon and nodes which are taking part in cluster will be at the vertices of hexagon. The nodes on the vertices of any hexagon are centers of other hexagons. This way all the clusters are interconnected and disseminate the sensed information with minimum power consumption.



(a) (b) (c)

Fig. 1. (a) Hexagonal Structure of cluster (b) Multiple hexagons covering area (c) Vertices of Adjoining hexagons become centers for neighboring clusters.

B. Bacteria Foraging Algorithm –

Bacterial Foraging Algorithm (BFA) copies the searching behavior of Escherichia coli bacteria (E. Coli) which is found in the small intestine of human body. E. Coli bacterial finds the nutrient rich location. An E. Coli bacteria has two types of movements: tumbling and swimming. In swimming movement, the bacteria move in a straight line in a given direction, whereas in tumbling the bacteria randomly change the direction of association. Three steps of BFA are: a) Elimination step, b) Reproduction step and c) Chemotaxis step. Iinitially bacteria start with any arbitrary position and calculate the objective function. It continuously moves in a same direction until it found the bad objective function. This whole step is Chemotaxis step. After Chemotaxis steps, the bacteria's reproduces to form a healthy bacteria by combining two or more bacteria and the next step is the elimination-dispersal, in which the bacteria splits into bacteria's and the non-healthy one is eliminated. These steps are repeated continuously until the objective function is reached. The table 1 shows how the BFA is mapped with optimal node deployment.

Table 1 Mapping of BFA with optimal node deployment

BFA Algorithm	Node Deployment
Bacteria	Movable Nodes
Swimming movement	Moving to the vertices of same cluster
Tumbling movement	Moving outside the range of current cluster.
Elimination process	ID of one of the nodes reaching at same vertex is eliminated from the network to decrease extra communication packet
Reproduction process	Nodes reaching on the same vertex reproduce a new node with double battery power but single communication link
Chemotaxis	Process of tumbling and swimming
Dispersal step	Extra nodes move to empty locations in uncovered area
Objective function	To reach to any of the vertices of the hexagons
Convergence efficiency	The total number of steps each node moved is also recorded to measure convergence efficiency

C. Optimal node deployment using bacteria foraging algorithm

The proposed method is for self-deployment and no central intervention is needed. The node themselves runs the algorithm and finds the optimal location. The aim is to cover entire geographical area with minimum number of nodes and least power consumption for data transition and minimum number of hops between two nodes. The regular hexagonal geometry explained in last section is optimal in the entire context. All nodes are equiv distance with each other and equipped with directional antenna. A node transmits data only in 6 directions at particular angles. The guarantee that a node will be in the direction path and range is increased since all the vertexes are occupied with nodes. The transmitting node is situated at center. It transmits to its neighbors only. This is a cluster. Locations where the person can visit in every corner may place the nodes explicitly on the identified positions of regular hexagon vertices. Large remote areas like forests where forest fire detection is to be done and the number of fire sensors are also very large, the nodes are deployed using airplanes at random locations. They have to be placed such that they cover whole space.

Steps of the proposed algorithm are:

1. Random deployment of the nodes by air.
2. Node assigned as super parent begins foraging algorithm.
3. Foraging algorithm(p)
   a. Node p senses its geographic location from GPS.
   b. Each node calculates geographic location of its feasible hexagonal vertices by boundary hexagon algorithm as {v1, v2, v3, v4, v5, v6}.
   c. The new vertex locations are compared with earlier vertex location list, those vertices which already exists or are very near to each other are merged to produce same node.
   d. The updated list is broadcasted in the network after insertion of new vertices.
   e. The node broadcast knowledge_beacon to get the list of nodes that are in its range r.
   f. These nodes also store their cluster head which is node p.
   g. The **objective function** of the bacteria foraging algorithm for these range nodes is to reach to any of the vertices of the hexagons.
   h. If number of range nodes <= 6 then all of these are placed on the vertices through performing **swimming** step of **Chemotaxis**.
   i. Else if the numbers of range nodes > 6 then any six nodes decided by p moves to the vertices and remaining nodes are left at their current locations, these will be moved later during **tumbling**.
   j. The message will be a directed signal in all six directions separated 60 degrees with each other from the center.
   k. The vertices of the node p are moved into a queue since they have moved to their final location now they will be new center nodes and will make a cluster around them.
   l. When all the nodes are in the queue, it means all the nodes have reached to some vertex then the **Chemotaxis converges** and objective function is achieved.
   m. If two nodes reach on the same vertex then they **reproduce** a new node with double battery power but single communication link as per BFO.
   n. ID of one of the nodes is **eliminated** from the network to decrease extra communication packets.
   o. The total number of steps each node moved is also recorded to measure **convergence efficiency**.
   p. Convergence of the algorithm will remove the redundancy of the nodes due to random deployment with their optimal placement positions at hexagonal vertices.
   q. Multiple nodes at same location can be used as extra battery power or to be located in the regions which are left without any node.
   r. Extra nodes reaching at same vertex will move to empty vertices locations in the uncovered area which are new locations during **dispersal** step of BFA.

IV. Experiment and Result

The simulation of the proposed node deployment scenario has been done in MATLAB. Various size of area is considered under simulation.

A. Deployment Plots

The nodes are randomly deployed in an area represented as blue * in the figure 2 (a). The node creates regular virtual

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hexagon around them. Initially hexagons are overlapped (figure 2(b)) with each other. This shows that the deployment is not appropriate. After the run of the proposed algorithm the intermediate and final results are shown in figure 2 (c), 2 (d) and 2 (e), 2 (f).

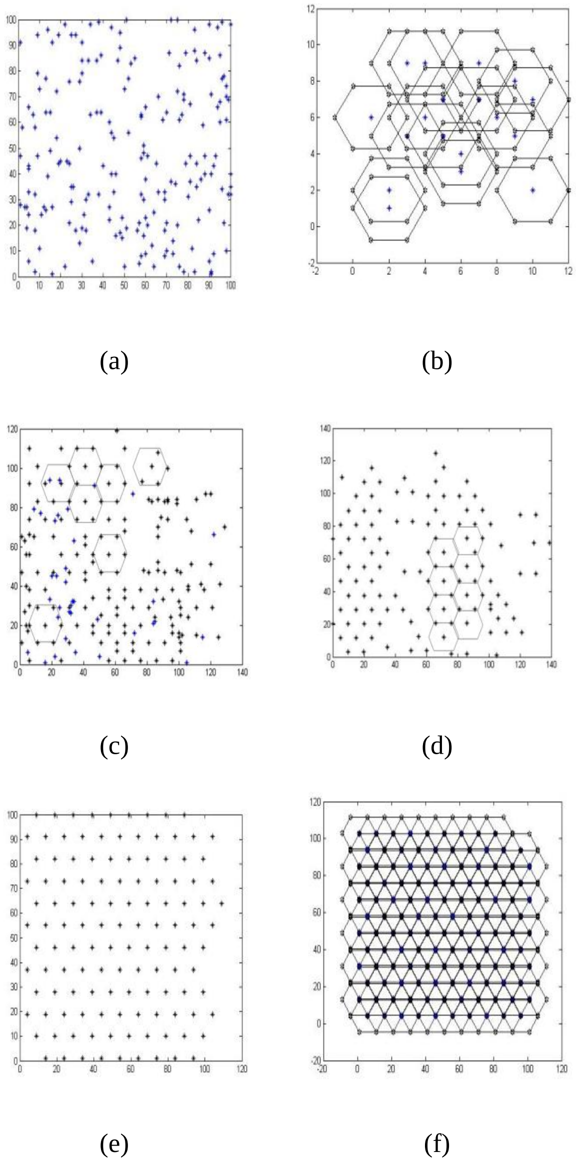

Fig. 2. (a) Random Nodes deployment (b) Overlapping Hexagonal Architecture (c) Intermediate hexagonal structure of clusters (d) Final Hexagonal equidistant nodes (e) Node Deployment on Identified Vertex Locations in a Field (f) Hexagonal Cluster Structure in Complete Field

Various number of nodes n in simulation is used. In final architecture the number of final nodes are less. This is due to elimination of repetitive nodes. Areas where no nodes exist it means no node could reach there, the overlapping nodes are move on empty area to cover the complete area.

Another analysis of the proposed method can be done on the basis of optimal number of nodes is a geographical area. In figure 2(e) it can be seen that all the nodes are arranged at vertices of some node. Complete field is now covered with hexagons only. The optimal number of nodes N needed to cover the entire area is given by the nodes that are plotted in the figure 2(e). The figure 2(f) shows that the optimal locations identified by algorithm are such that no hexagons are now overlap with each other and entire area is now cover with hexagons.

B. Optimal Locations List (OLL)

This parameter tells the minimum number of nodes needed to cover the complete field sensing is known as optimal location list. This estimates the optimal number of nodes needed for the field. One node per vertex is placed at least. The length of this list is one of the outputs of the proposed work.

C. Deployment Delay (DD)

This is the time taken by the network to self-organize. The optimal locations are calculated and then the nodes start to move from their current location to the nearest optimal location. The time taken by the nodes to reach to the optimal location is termed as deployment delay. DD should be minimum as possible to avoid unnecessary time delay in node deployment for real-time WSN applications.

D. Average Distance Moved Per Node

This is the parameter that tells the amount of distance a node has to move to reach to an optimal location. Since the movement also needs the power so it has to be minimized. The average distance moved by a node for various n and r=10m is less than 10m which is very good.

$$DM = \frac{\sum_{i=1}^{n} node(i)\_distmoved}{n}$$

E. Average Reproduction level

If number of nodes initially deployed is more than the optimal number of nodes needed then it is normal to have multiple nodes residing on same location. More the number of nodes at the same location more reproduction will take place.

$$avg\_rep = \frac{\sum_{i=1}^{n} rep(i)}{n}$$

Another measurable parameter is the maximum amount of reproduction at any location. This will measure the nodes with highest battery power. This high power node can be used for other higher level computation tasks such as decision making, data collection at local site or multiple movements. This parameter can be calculated using the following equation:

$$\max\_rep = \max\left(rep(i)\right) \;\forall\; i = 1 \; to \; n$$

F. Results and Parametric Analysis

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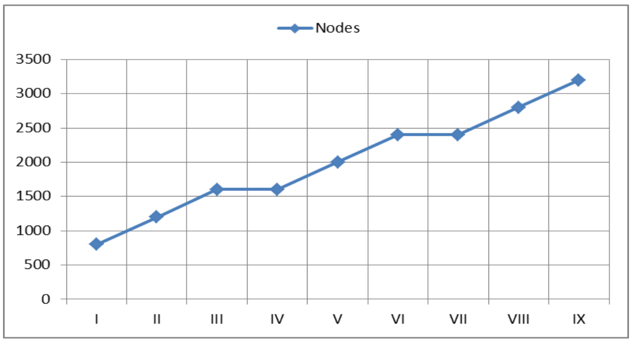
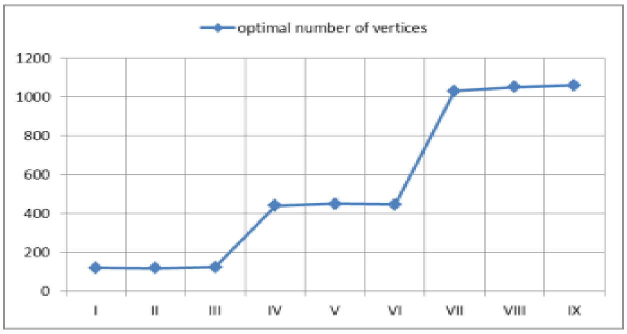
The simulation is run several times and some of the trials are selected randomly which have been summarized in table 2.

Table 2 Summarized Results of Various Analytical Parameters for Various Trials

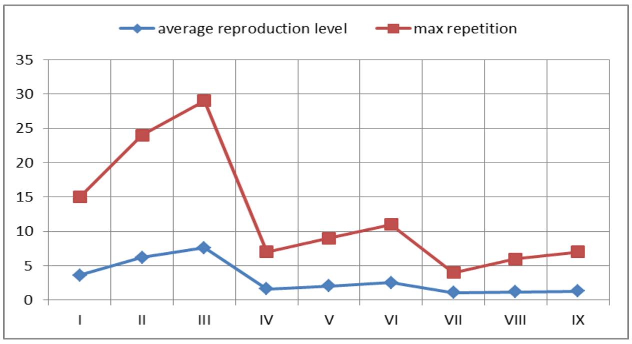
Parameters	Trials								
	I	II	III	IV	V	VI	VII	VIII	IX
Range (units)	10	10	10	10	10	10	10	10	10
Area (unit length and breadth)	100	100	100	200	200	200	300	300	300
Nodes	800	1200	1600	1600	2000	2400	2400	2800	3200
average reproduction level	3.6	6.2	7.6	1.6	2.04	2.56	1.1	1.2	1.3
max repetition	15	24	29	7	9	11	4	6	7
optimal number of vertices	120	119	125	440	450	445	1010	1040	1060
average distance moved per node (units)	3.57	3.63	3.66	3.61	3.59	3.64	3.66	3.59	3.63
Deployment Delay (sec)	4.09	6.58	9.1	12.03	16.75	21.67	33.9	40.2	46.6



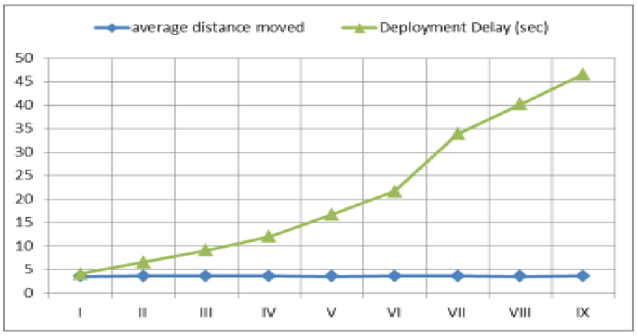
(a)



(c)



(b)



(d)

Fig. 3. (a) Increase in Number of Nodes Needed as the Deployment Area Size Increases (b) For Constant Area the Reproduction Level and Repetition Increases But as the Area Increased the Overall Reproduction Decreases (c) Constant Number of Optimal Deployment Locations Which Increases as the Area Increases Between Trails Pairs III & IV and VI & VII (d) The Constant Nature of Average Distance Moved Showing Energy Efficient Nature of Proposed Algorithm and Increasing Deployment Delay w.r.t Increase in Number of Nodes and Area Size.

The range is kept constant so that the algorithm can be established on same hardware since the range depends on the transmission hardware module. As the deployment area increases, the number of nodes required to cover the area also increases shown in fig 3 (a). For the constant range and size of area the amount of average reproduction and maximum reproduction increases with respect to the excess number of initial nodes shown in fig 3 (b). This is due to the fact that as the number of nodes increases in a fixed area than the reproduction of nodes also increases. But as the size of area increases the reproduction decreases. For constant area and range the number of optimal vertices needed is constant but these increase as the size of area is increased as shown in fig 3 (c). The average distance moved in all the trials is constant as shown in fig 3 (d). This is the most important deduction for the stability of the proposed algorithm. Any variation in the parameters does not affect the average distance moved by the nodes which is around3.6 units. This is very less in comparison to very large area size. Thus the proposed algorithm is highly energy efficient. In previous methods [3] this distance moved is more than 100 units. The deployment delay is increasing as the field area and number of nodes is increasing which cannot be avoided but still this delay is comparatively less than [20] where the delay is more than 150 sec. So the performance of the algorithm is unquestioned now.

V. CONCLUSION

The method for optimal sensor node deployment has been formalized in this paper. The method can be proved in many ways for the optimality since the hexagonal architecture of cluster followed here is optimal in context of power utilization and minimum number of nodes to cover complete area. The movement of the nodes which is much power consuming is minimized as the average distance moved per node is very less and constant irrespective of other network parameters. In previous methods [3] this distance moved is more than 100 units. The deployment delay is increasing as the field area and number of nodes is increasing which cannot be avoided but still this delay is comparatively less than [20] where the delay is more than 150 sec. So the performance of the algorithm is unquestioned now. The results have been compared with state of the art methods and analyzed for varying simulation parameters. The algorithm is energy efficient as the distance moved to reach to optimal location is very less and constant irrespective of the variation in the parameters. The proposed method is also beneficial for offline calculation of node coordinates to place the nodes manually in the field, which increases the proposed algorithm scope. The proposed method needs to be formalized in other manners to compare all the parameters with existing deployment methods.

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