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Big Bang-Big Crunch Algorithm for Dynamic Deployment of Wireless Sensor Network

R.S. Uppal*, Shakti Kumar**
* Department of Computer Science and Engineering, BBSBEC Fatehgarh Sahib
** Baddi University of Emerging Sciences & Technology Baddi

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ABSTRACT

This paper proposes soft computing technique Big Bang-Big Crunch (BB-BC) to address the main issue of deployment of wireless sensor networks. Deployment is the main factor that significantly affects the performance of the wireless sensor network. This approach maximizes the coverage area of the given set of sensors. We implemented our approach in MATLAB and compared it with ABC approach and found that the proposed approach is much better than the said approach.

Corresponding Author:

R S Uppal,
Department of Computer Science and Engineering,
Baba Banda Singh Bahadur Engineering College,
Fatehgarh Sahib, Punjab India 140407.
Email: rsuppal@gmail.com

1. INTRODUCTION

Emergence of Wireless Sensor Networks in the recent era has revolutionize the monitoring and surveillance activities in the field of communication. The study of Wireless Sensor Networks requires vast breadth of knowledge from variety of disciplines [1]. Wireless Sensor Network is understood as a collection of nodes organized into a cooperative network [10 from 2]. These inexpensive, low power communication nodes can be deployed throughout a physical space, providing dense sensing close to physical phenomena, processing and communicating the information, and coordinating actions with other nodes [3]. Wireless Sensor Network consists of thousands sensor nodes, deployed either randomly or according to some pre-defined statistical distribution, over geographic region of interest [5]. Wireless Sensor Networks find diversified application ranging from monitoring biological system to monitoring forest fires through air dropped sensors. Depending upon the area of interest, the placement of the sensors may be located at pre-determined location while other placement could be optimally determined using computational intelligence [4]. Sensing and communication are two primary functions of Wireless Sensor Networks. The effectiveness of sensing and communication is determined by coverage and connectivity of the network. Coverage and connectivity issues largely depend upon the efficient deployment of the nodes in the interest region. Conversely, deployment decisions require optimal calculations of the network's coverage ratio, while maintaining the desired connectivity [4], [7]. One important criterion for being able to deploy an efficient sensor network is to find optimal node placement strategies. Deploying nodes in large sensing fields requires efficient topology control [6]. Due to the diversity of applications, requirements and design goals no single distinctive approach is available to the design and deployment of sensors networks [8]. The major issue in the deployment is to find the optimal placement of nodes, so that a minimum number of them are needed [9].

Optimal placement of nodes means finding the optimal location of sensors in the region of interest of deployment. This is a solution of Mathematical Problem having an objective function to be maximized or minimized within constraints. In the ROI, coverage ratios of different placements are computed and selection of optimal placements could be done by various optimization techniques [4].

Locations of Wireless Sensor Nodes computed in optimal solution of the technique would solve deployment issue of WSN. The deployment position of node is considered by its location coordinate (X, Y). To find out the position of these location coordinates while maintain connectivity and sensing in the target region is the key issue of deployment. The optimal location coordinates of wireless sensor nodes are to be computed using various algorithms for the optimal deployment of wireless sensor network. The region of interest is a two-dimensional grid and the initial deployment of nodes for algorithm is chosen randomly considering random location coordinates.

There are various algorithms which could be used to compute locations of nodes and coverage. The most recent algorithm is Artificial Bee Colony (ABC) algorithm which provides benefit of numerical optimization and clustering. The coverage problem is also optimized using Particle Swan Optimization (PSO) to give the best coverage by computing the location of sensor nodes placement [10].

In this study, we have proposed a new approach of Big Bang Big Crunch algorithm for dynamic deployment of sensors. We have also compared this algorithm to ABC algorithm which shows better deployment.

2. BIG BANG-BIG CRUNCH ALGORITHM

This is nature inspired optimization technique based on theory of Big Bang theory of universe. In Big Bang phase sensor placement is selected randomly and then in Big Crunch phase minimizes fitness function thereby giving optimal deployment and coverage.

Begin

/* Big Bang Phase */

Generate a random set of NC candidates (population);

/* End of Big Bang Phase */

While not TC /* TC is a termination criterion */

Compute the fitness value of all the candidate solutions;

Sort the population from best to worst based on fitness (cost) value;

/* Big Crunch Phase */

For guiding the new search compute the center of mass using following Equation;

$$x_c = \frac{\sum_{i=1}^{NC} \frac{1}{f^i} x_i}{\sum_{i=1}^{NC} \frac{1}{f^i}} \quad (1)$$

Where x_c = position of the center of mass; x_i = position of candidate i; f^i= fitness function value of candidate i;

Best fit individual can be chosen as the center of mass instead of using Eq.1;

/* End of Big Crunch Phase */

Calculate new candidates around the center of mass by adding or subtracting a normal random number hose value decreases as the iterations elapse using Equation ;

$$x^{new} = x^c + l(rand)/k \quad (2)$$

Where x_c stands for center of mass, l is the upper limit of the parameter, rand is a normal random number and k is the k^{th} iteration of the algorithm.

Then new point x^{new} is upper and lower bounded.

End while

End

3. SENSOR DETECTION MODEL

Sensor detection models can be categorized in two ways in WSNs to find out the effective coverage area. One of the models is based on binary detection which is based on assumption that there is no uncertainty and the other model is based on probabilistic detection model [12] which provides more realistic results as compare to first one because it uses probabilistic terms for deciding the effective coverage of the area [6].

The binary detection model is adopted here [11].

Coverage ratio of the WSN is calculated using the Equation 1:

$$CR = \frac{\cup c_i}{A}, i \in S, \tag{1}$$

Where, C_i denotes the coverage area of a sensor i, S denotes the set of the nodes, and A is the total area of interest.

In this model, for a two-dimensional physical space, each sensor node range is considered as circle and is placed at the centre say (x, y) where x and y are coordinates of centre. In area A, n set of mobile nodes such as S = {S_1, S_2, …………, S_n} is to be deployed at n different location having coordinates (x_i, y_i), so as to ensure optimal coverage. The radius r of the circle is the sensing range of sensor. Thus, the sensing area is πr^2, while its communication range is equal and greater than twice the sensing range. So, in a given two-dimensional physical space of area A, the n numbers of sensors are randomly deployed. The coordinates of centre of circles are denoted as (x_i, y_i), where i = 1, 2, 3, …………., n

The area of overlapping between sensing of two sensors i and j is represented by A_{ij} and is calculated by

$$A_{ij} = 2r^2\cos^{-1}\left(\frac{d_{ij}}{2r}\right) - \left(\frac{d_{ij}}{2}\right)\left(\sqrt{4r^2 - d_{ij}^2}\right) \tag{2}$$

Where,

d_{ij} is the distance between the sensor i and sensor j and is calculated by

$$d_{ij} = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2} \tag{3}$$

$$\text{Total Overlapping of Deployment} = \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} A_{ij} \tag{4}$$

The area of overlapping of every sensor with the other (n-1) sensor is represented in the form of square matrix of order n called the Area Matrix.

4. SIMULATION RESULTS AND ANALYSIS

We implemented the proposed deployment of BBBC algorithm using MATLAB. In an area of 100 X 100 square meter, 80 mobile sensors were deployed. Detection radius of each sensor was 7 meter and population size was 20.

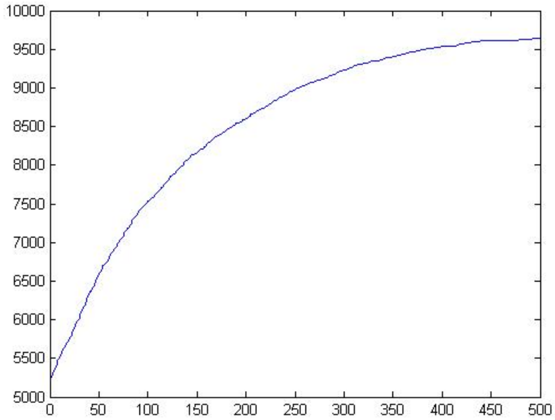

Figure 1. Coverage Area of the deployment vs 500 iterations

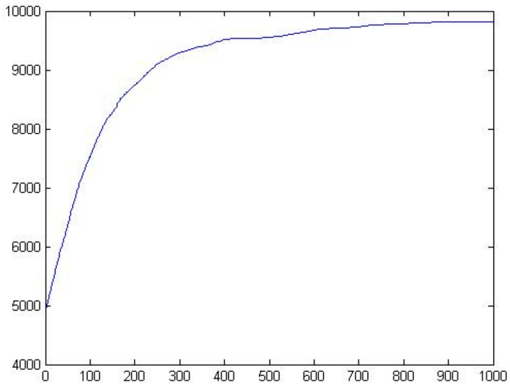

Figure 2. Coverage Area of the deployment vs 1000 iterations

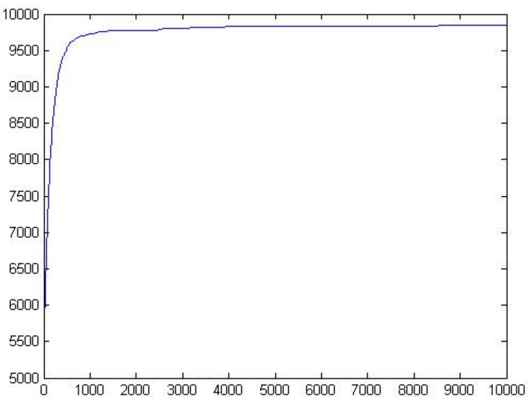

Figure 3. Coverage Area of the deployment vs 10000 iterations

BBBC algorithm was run with 500, 1000 and 10,000 iterations. We compared the performance of our proposed deployment approach with ABC approach in Table 1.

Table 1. Comparison of ABC and BB-BC Approach

Approach	No of Sensors	No. of Iterations		
		500	1000	10000
ABC [27]	100	96.66%	98.33%	99.34%
BB-BC	80	96.98%	98.60%	99.52%

5. CONCLUSION

In this paper, we have proposed BB-BC Approach for the deployment of mobile wireless sensors. The approach was implemented in MATLAB with an initial population of size 20, detection radius 7 and with three different sizes of iterations, viz. 500, 1000 and 10000. It was observed that in all the three iteration procedures, the proposed approach with 80 sensors performed better than the ABC approach with 100 sensors. The coverage area was improved upon by using the BB-BC approach even with lesser number of sensors. Thus, it is concluded that BB-BC is a better deployment technique for mobile sensors than the ABC approach.

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