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RESEARCH ARTICLE

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DEPLOYMENT OF WIRELESS SENSOR NODES FOR MAXIMIZING THE COVERAGE AREA USING AN ALGORITHM INSPIRED FROM PSO

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ABSTRACT

Wireless Sensor Network consists of network distributed spatially, where autonomous sensors monitor physical or environmental conditions. Usage of Wireless Sensor Networks is widespread in many disciplines due to its tiny structure, inexpensive, portability properties; provide a wide range of surveillance and monitoring applications. WSNs are deployed randomly and are supposed to self-organize to create a multi hop network. WSNs face many challenges, like to cope up with dynamic environmental conditions by adjusting their positions, requiring configuration and reconfiguration accordingly. Hence we can say WSNs suffer from two of the main problems i.e., Area Coverage and Energy Efficiency. In my work I have mainly put focus on the Area Coverage Problem. We have tried to overcome the coverage problem by making use of Evolutionary algorithms. Evolutionary Algorithms are inspired from natural evaluation that helps to find optimum strategy for solving a problem. My Thesis work focuses on covering the maximum of area by using Particle Swarm Optimization algorithm. PSO is a population based optimization technique, inspired by social behaviour of organisms, such as bird flocking. The algorithm is implemented by using matlab 13.1 version. MATLAB is a high performance language for technical computing.

Keywords— Wireless sensor networks, sensor nodes, Particle Swarm Optimization, deployment, coverage, distance

I. Introduction

Wireless Sensor Network is the composition of large number of sensor nodes which communicate in an untethered way in short distances. Due to the development of low power, cheaper and multifunctional sensor nodes of smaller size, these factors have lead WSNs gaining popularity everywhere [1]. Some of the application domains of WSNs include military and public security, health care, and real time services. Military and public security applications like chemical biological radiological and nuclear (CBRN) attack detection, battlefield surveillance. Health care applications are like wireless sensor nodes, placed on patients and acquire critical-data for remote monitoring by health care providers. For the Real time surveillance applications some of the areas covered are traffic monitoring, environmental monitoring, irrigation, underwater WSNs ,disaster relief operations [2]. The basic function of WSNs is to monitor areas or targets for a long period. Since sensors are often deployed in inaccessible or remote environments and often spread in an arbitrary manner, a critical issue in the WSN applications is the coverage problem. In most sensor networks, two related viewpoints of coverage exist: worst and best case coverage. In the first-one, attempts are made to quantify the quality of service by finding areas of lower observability from sensor nodes. In best-case coverage, finding areas of high observability from sensors and identifying the best support and guidance regions [4]. In this paper the main concern is to formulate the coverage problem by minimizing the overlapping among the coverage area of sensors and maximizing the coverage of each sensor node. The formulation technique used here is an evolutionary optimization technique called Particle Swarm Optimization (PSO). PSO is a metahuristic technique that initiates the swarm intelligence of the organisms like flock of birds or school of fish. It has been successfully used in the global optimization problems, and the scope is much wider.

II. PARTICLE SWARM OPTIMIZATION: A BRIEF INTRODUCTION

PSO was introduced in 1995, by Kennedy and Eberhart as a solution of complex non-linear optimization problems. It is a pseudo optimization method, inspired by social behaviour of flock of birds. It consists of candidate solutions '*s*', called '*Particles'*, which explore an *n*-dimensional space in search of global solution(*n* is the number of optimal parameters to be determined). Each particle has the features-

- Position x^t_i, $1\le x \le s$
- Velocity v^t_i: is the velocity vector of particle that drives the optimization process and reflects both the own experience knowledge and the social experience knowledge from the all particles;

The fitness function $f(x^t_i)$, is used to evaluate the particle $f(x1,x2.....,xn)$, where $f : R^n \rightarrow R$.

The particle closer to the global optimum solution has higher fitness function value than the farther one. The goal is to maximize the fitness function .The velocity of particle is calculated by

$$V_{ij}^{t+1} = \omega \cdot V_{ij}^{t} + c1 \cdot r1^{t} \cdot (p_{best}{}^{t}{}_{,ij} - X_{ij}^{t}) + c2 \cdot r2^{t} \cdot (g_{best,} - X_{ij})$$

The particle position is updated using the equation:

$$X_{ij}^{t+1} = X_{ij}^{t} + X_{ij}^{t}\ V_{ij}^{t+1}$$

Where

- V_{ij}^t= is the velocity of the particle in dimension *j* at time *t*
- X_{ij}^t= is the position vector of particle in dimension *j* at time *t*
- $p_{best,ij}^t$ = is the personal best position of particle *i* in dimension *j* at time *t* found from initialization through time *t*
- $g_{best,}$ = is the global best position of particle in dimension *j* found from initialization through time *t*
- *c*1 and *c* 2= are the positive acceleration constants which are used to keep balance between the contribution of cognitive and social component
- *r*1 and *r*2 = are random numbers from uniform distribution at time *t*
- *ω*= is the variable used to control the exploration and exploitation capabilities of the swarm

  where ω is calculated using the formula:

  $\omega^{t+1} = \omega_{max} - ((\omega_{max} - \omega_{min}) / t_{max}) * t$, $\omega_{max} > \omega_{min}$

  $\omega_{max}$is the maximum assumed value ofω

  $\omega_{min}$is the minimum assumed value of ω

  t_{max} is the maximum iteration number

  t is the current iteration number.

Stopping Criterion of the algorithm: When the condition is satisfied or the maximum iteration number is reached [5].

III. ALGORITHM

Central idea of algorithm is to minimize or remove intersection among the deployed sensor nodes by using a technique which removes intersection and maximizes the coverage area of dynamically configurable nodes. Here, the evolutionary algorithm, Particle Swarm Optimization (PSO) algorithm is used. The technique used is the combination of PSO with a new distance expression as fitness function.

A 2D area of 80*80 square meters and 20 sensor nodes are simulated in Matlab. The algorithm randomly chooses the coordinate position which lies within that area to place the nodes. The overlapping or intersection among the nodes is calculated, if found then removed using the PSO algorithm and the final coordinate positions are displayed.

Following assumptions are made regarding the nodes deployment:

1. The nodes are of homogeneous nature i.e., all nodes have the same radii.
2. The nodes can be either mobile nodes or stationary nodes.
3. The nodes deployment can be random or stationary.
4. We have n number of nodes given.

Methodology:

1. Initially an array of distinct values as $[x_1, x_2, \ldots x_i \ldots . x_n, y_1, y_2, \ldots . y_i \ldots \ldots y_n]$ lying under a specified range is passed.
2. The algorithm randomly picks a set of twenty nodes having coordinate positions as $[x_i, y_i]$ of the array.
3. Sensors are deployed by taking (*x, y*) as centre and *r* as radius.
4. Of the chosen nodes, all possible combinations of the nodes are made and the intersection of each node combination is calculated.
5. Intersection Index is calculated using the objective function.

if 'I' is the Intersection Index, then

I=(D-d)

Case 1 : If I = 0 (means D = d) and there is no intersection.

Case 2 :I= -ve (means D < d) , there is no intersection.

Case 3 :I= +ve (means D > d), and intersection exists.

Bigger is the value 'd' , lesser is 'I'.

6. The algorithm picks the combination by choosing the best solution i.e., nodes possessing minimum intersection, verifies the condition and do processing if required by applying PSO.
7. If the node set satisfies the condition, the coordinate positions are saved as final otherwise other combination is picked.

To remove intersection among the node set, the equations defined in Particle Swarm Optimization algorithm are used, given below

- The velocity of particle is calculated by $V_{ij}^{t+1} = V_{ij}^{t} + c1 \cdot r1^{t} \cdot (p_{best,ij}^{t} - X_{ij}^{t}) + c2 \cdot r2^{t} \cdot (g_{best,ij} - X_{ij})$
- The particle position is updated using the equation:
  $$X_{ij}^{t+1} = X_{ij}^{t} + V_{ij}^{t+1}$$

- While comparing two points or nodes (x1, y1), (x2, y2); x1, x2 are kept fixed and new value of y1, y2 is calculated until maximum iteration limit is reached, if so then we vary x coordinates.
- The new value is considered by calculating the particle velocity V_i^{t+1} and adding this new velocity to the previous value of y2.

The various parameters applied for calculating the new velocity are assumed as given below:

- The initial velocity v_i^0 is set to 'zero'.
- R1,r2 are random values lying within the range (0,1), such that r2= 1- r1 respectively.
- $P_{best}$is the best node position of the node itself retained till yet where the minimum intersection is noticed and is saved in the memory.
- Y_2 coordinate of 2nd node value which shows the minimum intersection with the considered point of 1st node is taken as G_{best}.

Objective Function:

Let there are two nodes lying close to each other. To calculate the distance among centre to centre of two nodes, If 'd' is that distance ,then it is calculated using the Euclidean Distance formula:

$$d = \sqrt{(x2 - x1)^2 + (y2 - y1)^2}$$

For the intersection to be 'zero', this calculated 'd'>=D whereas

D=(r1 + r2)

r1=radius of sensor node s1.

r2=radius of sensor node s2.

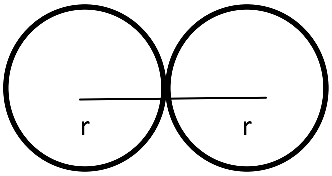
As sensors are of homogeneous nature, hence

r1=r2=r

So Equation becomes

D=(r + r)

=> *D=2*r*



Hence the objective function is defined as:

d>=D

Here D is the standard value used for the measurement of intersection.

Table 1 shows the values attained by parameters used in applying PSO Equation.

Table 1 : Elaborating the parameters used in PSO:

parameters	**Definition**	**Values**
v_i^0	Initial velocity	0
r1	Random value 1	Random value between (0,1)
r2	Random value 2	r2=1-r1
P_{best}	Best value of y2 amongst its previous iterations	
G_{best}	Y_2 coordinate value which shows the minimum intersection with the considered points	
Y_2	Currently considered coordinate	
c1	Cognitive component	Random value between 1&3
c2	Social component	Random value between 1&3, such that c1=c2

IV. EXPERIMENT AND RESULTS

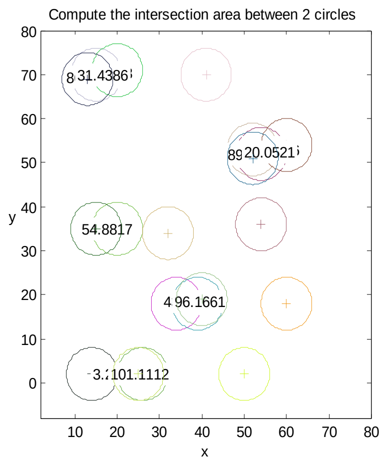
Under the simulation conditions, various cases regarding the sensing radius 'r' are discussed such that 'r' is changed to determine how it affects the coverage area. The number of nodes selected is 20.

The performance of the algorithm is ivestigated by coducting various simulation Experiments. The tests are conductedby taking sensing range worth radius *r=6, r=7, r=8.* C1 and C2 are kept 2.0, inertia weight is kept between 0.2 to 0.8, r1ad r2 are generated randomly by the system.

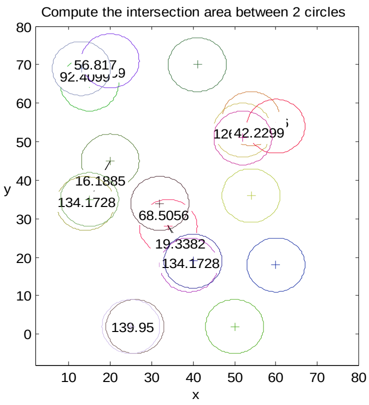
The initial positions before running the algorithm are shown.

Results obtained after running the algorithm are as below-

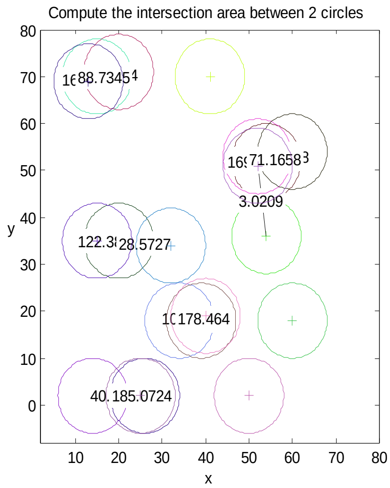
In case (i) intersection is removed successfully, i.e., all nodes possess zero intersection, but much of the area is left uncovered. The left area can be covered either by increasing the node's radius or by deploying increased number nodes. In case (ii) the intersection is reduced to zero. The coverage rate is increased but some portion is still left uncovered which leads to coverage holes. In case (iii) after increasing the node radius to 8cm the coverage area is significantly improved and sufficient results are obtained. The nodes are able to cover the area in the effective way, preventing to the formation of bigger coverage holes.



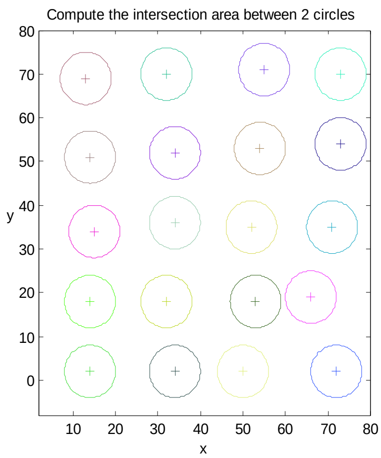
Case i: radius= 6 cm



Case ii: radius=7 cm



Case iii: radius= 8 cm



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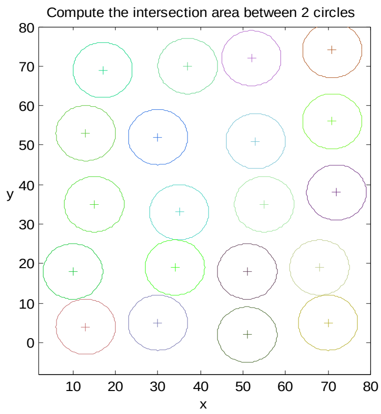
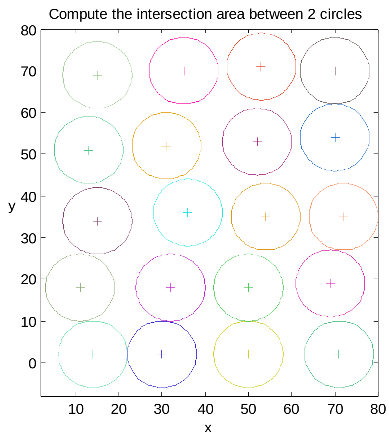


Case ii: radius= 7 cm



Case iii: radius= 8 cm

The following tables and graphs show the effect of iterations on performance of the nodes while covering the area.

Observation 1:

Radius of the nodes=6cm

Number of nodes=20

Area of Interest=80*80 cm2

Below is the table and graph showing the effect of iteration numbers on the coverage rate:

Table 2: Results shown for node radius of 6 cm

No. Of Iterations	0	50	75	100	150	200	250
Coverage Rate	0	.45	.56	.65	.70	.80	.85

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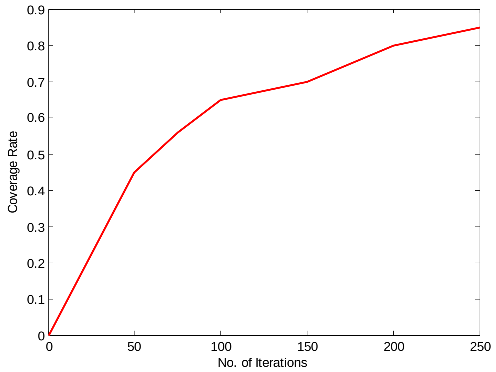

Figure: 5.7 Coverage rate for node radius=6cm

Observation 2:

Radius of nodes= 7 cm

Number of nodes= 20

Area of Interest=80*80 cm2

The table and graph given below tells the value of coverage rate on the various phases by changing iteration numbers:

Table 3: Results shown for nodes of radius 7 cm.

No. of Iterations	0	50	75	100	150	200	250
Coverage Rate	0	.45	.43	.60	.78	.82	.92

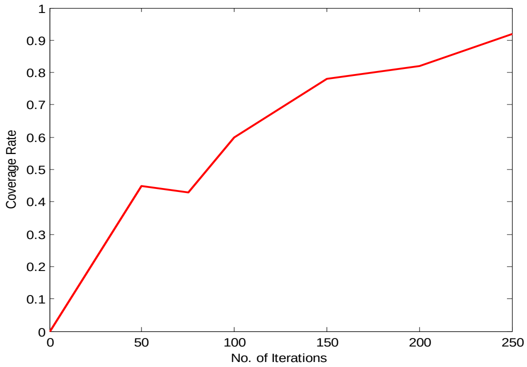

Figure: 5.8 Coverage rate for node radius=7cm

Observation 3:

Radius of nodes= 8 cm

Number of nodes= 20

Area of Interest=80*80 cm2

The table and graph showing the effect of iterations on the coverage rate calculated from node position are given below:

Table 4: Results shown for nodes of radius 8 cm

Number of iterations	0	50	100	150	200	250
Coverage Rate	0	.75	.73	.88	.85	.97

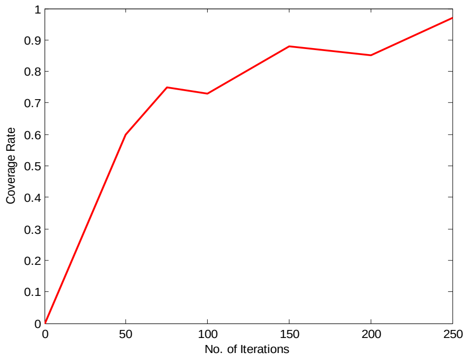

Fig 5.9 Coverage rate for node radius=8cm

In this experiment, number of nodes taken is 20 in 80*80 square metre of area. The Sensing range of node (radius) is taken to be 6cm. The overall coverage rate is calculated using the formula given below:

Cov(%)= (((CovS1)U(CovS2)U (CovS3)U……….U (CovSn))/Total Coverage area)* 100 *(5.1)*

Comparison Chart of area covered by nodes with different radii.

The chart shows the comparison of Observation 1, Observation 2 and Observation 3.

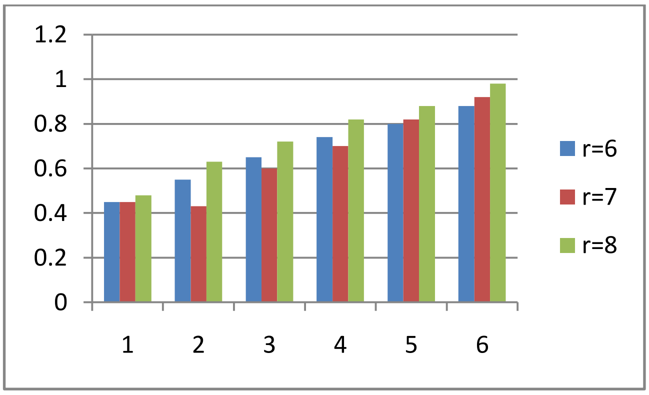

Figure 5.10: Comparison chart of different observations

The column chart clearly shows that the set of nodes with largest sensing radius shows the best area coverage with increased number of iterations.

V. Conclusion

Today coverage has become an important aspect for achieving QoS in applications of WSNs. In this paper we have applied PSO algorithm to remove intersection. The technique has produced good results within the reasonable computational time. The factor that has influenced the complexity of algorithm is the number of sensor nodes. Final results have shown that the intersection amongst nodes has been removed and coverage of area has been increased.

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