Indonesian Journal of Electrical Engineering and Computer Science
Vol. 10, No. 3, June 2018, pp. 1278~1286
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v10.i3.pp1278-1286

Random, PSO and MDBPSO based Sensor Deployment in Wireless Sensor Network

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Article Info

Article history:

Received Nov 21, 2017
Revised Feb 20, 2018
Accepted Mar 11, 2018

Keywords:

DBPSO
MDBPSO
PSO
Wireless Sensor Network

ABSTRACT

Wireless Sensor Network (WSN) is emergingtechnology and has wide range of applications, such as environment monitoring, industrial automation and numerous military applications. Hence, WSN is popular among researchers. WSN has several constraints such as restricted sensing range, communication range and limited battery capacity. These limitations bring issues such as coverage, connectivity, network lifetime and scheduling and data aggregation. There are mainly three strategies for solving coverage problems namely; force, grid and computational geometry based. This paper discusses sensor deployment using Random; Particle Swarm Optimization (PSO) and grid based MDBPSO (Modified Discrete Binary Particle Swarm Optimization) methods. This paper analyzes the performance of Random, PSO based and MDBPSO based sensor deployment methods by varying different grid sizes and the region of interest (ROI). PSO and MDBPSO based sensor deployment methods are analyzed based on number of iterations. From the simulation results; it can be concluded that MDBPSO performs better than other two methods

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1. INTRODUCTION

Advancement in wireless communication have enabled the development of low-cost, multifunctional, small sensor nodes which can sense the environment, perform data processing and communicate with each other un-tethered over short distances [1]. Wireless sensor networks idea is envisioned and defined as self-deployed, error prone, long living inexpensive communication devices that are densely deployed to collect data from physical space. Sensor nodes communicate with each other to detect events depending on the application, to collect and process data, and to transmit the sensed information to the base station by hopping the data from node to node [2]. The sensor nodes are deployed either randomly or according to statistical distribution which is predefined, over a geographic region of interest (ROI). Wireless sensor network consists of various sensor nodes that are used to monitor any target area like forest fire detection by our army person and monitoring any industrial activity by industry manager [3]. A sensor node has resource constraints, like low battery power, limited signal processing, limited computation and communication capabilities and a small memory; that's why it can sense only a small portion of the environment [4]. Hence, energy saving along with coverage optimization is a critical issue in the design of a WSN.

WSN issues which can be formulated as optimization problems are localization, node deployment, data aggregation and energy-aware clustering. Limited communication and sensing range causes the problem of connectivity and coverage. To solve both problems, the sensors are positioned with respect to each other [5]. Coverage problem is regarding making sure that each of the point in the region of interest to be monitored is covered by the sensors. In order to maximize coverage the sensors are to be placed not too close so that the sensing capability of the network is fully utilized. At the same time; they must not be located too far to avoid the formation of coverage holes (area outside sensing range of sensors).

Random deployment method distributes sensor nodes stochastically and independently within the field. It is usually for dangerous or abominable such as battle field, foe military and disaster application or in hospitable areas where network size is large. Dropping sensors from a plane would be an example of random deployment. Random deployment could cause some of the sensors being deployed too close to each other while others are too far apart.

Traditional analytical optimization techniques require more computational efforts, which grow exponentially as the problem size increases. An optimization method which requires moderate memory with computational resources and yet produces good results is expected, especially for implementation on an individual sensor node. Swarm optimization methods are computationally efficient alternatives to analytical methods available. Particle Swarm Optimization (PSO) is a popular multidimensional optimization technique [6]. Strengths of the PSO are ease of implementation, high quality of solutions, computational efficiency and speed of convergence [7].

The PSO based sensor deployment method tries to find the optimal positions of sensor to cover the complete region of interest (ROI). PSO method uses a fitness function as an objective to be minimized. The aim in the sensor deployment is to fully cover the region of interest using minimum number of nodes. This method iteratively evaluates the coverage as its fitness function.

The coverage optimization strategies are implemented during deployment phase and coverage is calculated based on the placement of the sensors on the region of interest (ROI). They are categorized into three groups, namely; force based, grid based or computational geometry based approach [8]. To determine the optimal position of the sensors force based methods use attraction and repulsion forces. While grid based methods use grid points for the same objective. Voronoi diagram and Delaunay triangulation from the computational geometry approach are commonly used in WSN coverage optimization method. MDBPSO is a Grid Based method for deployment of sensor nodes. It is expected that MDBPSO Based approach will achieve maximum coverage for the Wireless Sensor Network (WSN) due to strategic deployment of SNs as compared to the other coverage strategies such as force and computational geometry based approach.

Random deployment; grid based PSO and MDBPSO based deployment has been implemented and tested with variable grid size, number of nodes and sensing range with stationary sensor nodes.

The Network simulator helps the developer to create and simulate new models on an arbitrary network by specifying both the behavior of the network nodes and the communication channels. It provides a virtual environment for an assortment of desirable features such as modeling a network based on a specific criteria and analyzing its performance under different scenarios [9]. Network simulator2 is used for simulation of the methods. Section 2 discusses random deployment. Section 3 elaborates PSO based deployment whereas Section 4 discusses MDBPSO based deployment, Section 5 contains simulation results. Finally the concluding remarks are given in Section 6.

2. RANDOM DEPLOYMENT

Many scenarios adopt random deployment for practical reasons such as deployment cost and time. But it does not guarantee full coverage because it is stochastic in nature, hence often resulting in accumulation of nodes at certain areas in the sensing field but leaving other areas deprived of nodes. In both situations coverage problem will arise, the sensing capabilities of the sensors are wasted in the first condition and the coverage is not maximized, while in the later, blind spots will be formed. There are big coverage holes as the network size grows. Uneven node topology may bring about unbalanced energy consumption and lead to a short system lifetime. Figure 1 shows Random Sensor deployment with sensing radius 0.5 m, grid size 0.5m X 0.5m. ROI: 10 meter X 10 meter, Number of nodes: 100Tables and Figures are presented center, as shown below and cited in the manuscript.

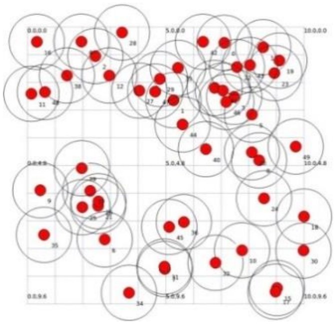

Figure 1. Random sensor deployments, coverage 42%

Table 1. Effect of Grid Size on Coverage Calculation

Sensing Radius = 0.5 meter		
	% Coverage for different grid sizes	
No. of Nodes	5 X 5	10 X 10
60	80.66	77.83
100	93.13	92.24
140	96.81	96.12
180	98.48	98.33
220	100	100

Table 1 shows the effect of grid size on coverage calculation with increasing number of nodes. It can be concluded that as number of nodes goes on increasing % coverage also goes on increasing.

3. PSO BASED DEPLOYMENT

These limitations motivate the establishment of a planning system that optimizes the sensor reorganization process to enhance the coverage rate after initial random deployment. This method tries to find the optimal positions of sensor to cover the complete region of interest (ROI). The particles move in limited region to form uniformly distributed sensor network. PSO method uses a fitness function as an objective to be minimized. The aim in the sensor deployment is to fully cover the region of interest using minimum number of nodes. This method iteratively evaluates the coverage as its fitness function. Sensor placement problem is viewed as discrete problem as the region of interest is divided into finite number of grids. The grid based strategy is used in this method to evaluate the coverage estimate of the network. Following are the steps involved in implementation of PSO based deployment of sensor nodes:

1. Initialize the position and velocity vectors & assign random values to it.
2. Evaluate the fitness of particle p and assign it to personal fitness of particle p. Find the particle p with minimum fitness from P and assign its position vector to global best position vector and its best fitness as global best fitness.
3. For number of iterations & each particle p repeat steps 1 to 3.
4. Calculate new velocity using equation
   $$\boldsymbol{v}(t+1) = (w*\boldsymbol{v}(t)) + (c1*r1*(\boldsymbol{p}(t) - \boldsymbol{x}(t))) + (c2*r2*(\boldsymbol{g}(t) - \boldsymbol{x}(t))) \quad (1)$$
   Equation (1) updates a particle's velocity.
5. If new velocity is greater than maximum velocity then use maximum velocity as new velocity.
6. Apply position update equation $(t+1) = (t) + \boldsymbol{v}(t+1)$ (2)
   & evaluate the fitness of particle p.
7. If the new fitness is less than personal best then update the personal best fitness and position & find the best particle in particle vector P.
8. If the fitness of particle p is less than global best fitness then update the global best position vector and global best fitness. If the global best fitness is zero this indicates that full coverage is achieved therefore stop the iterations.
9. Create n nodes and assign x and y coordinate values from global best position vector & then stop.

Figure 2 shows PSO based deployment with sensing radius 1 m, grid size 1 m X 1 m. ROI: 10 meter X 10 meter.

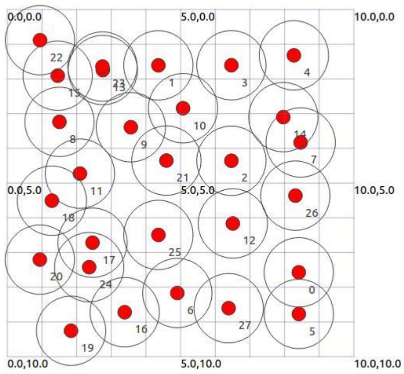

Figure 2. Sensing radius = 1 m and grid size = 1 m X 1 m, ROI: 10 m X 10 m

Table 2. Effect of Sensing Area on Number of Nodes & Iteration

Sensing Radius = 1 m		
Grid Size	1 m X 1 m	
Sensing Area	Nodes	Iterations
4x4	4	13
5x5	4	33
6x6	10	168
7x7	11	276
8X8	19	390
9x9	22	462
10x10	40	757

Table 2 shows the effect of sensing area on number of nodes and iterations required. It can be concluded that as sensing area goes on increasing number of nodes and iterations required also goes on increasing.

4. MDBPSO BASED DEPLOYMENT

Modified Discrete Binary Particle Swarm Optimization (MDBPSO) is implemented for improving the coverage while deploying the sensor network. MDBPSO operates in discrete problem space for the multi-valued problems. To solve the problem of poor convergence modified sigmoid function is used. The same velocity update equation (1) is used for this method. However, the position update equation is different from equation (2) in the following manner.

The velocity is first transformed into a number between (0, M - 1) using the following sigmoid transformation given by

$$S_{id}= (M-1) / (1+ e^{-V_{id}}) \quad (3) \quad [8]$$

The positions of the particles are discrete values between (0, M-1). Note that for a given S_{id} there is a probability of having any number between (0, M-1). The sigmoid transformation proposed in equation (3) in the binary PSO maps the value of velocity from (-∞ to +∞) to (0 to 1) [10]. But this causes the poor convergence of the method; as the negative as well as positive velocities are mapped to same values of sigmoid function so when deciding the new position method has no way to determine in which direction to move. This causes method to trap into certain solution. A new modified sigmoid transformation is proposed in this method to overcome this problem. The modified sigmoid transformation is given as:

$$S'_{id}=2*| S_{id}- 0.5| \quad (4)$$

The modified sigmoid also maps the values of velocities from (-∞ to +∞) to (0 to 1). This function can be used with the sign of velocity for the direction and helps the method to converge within finite number of iterations. The high value of velocity indicates that the particles position is unfit so it causes the position value to be changed and low value of velocity decreases the probability of changes in position. Finally, if the velocity is zero, the position is perfect [10]. The position of particle is calculated using sigmoid value and number of grid points given by:

$$Xid = S'id * M - 1 \qquad (5).$$

The position is updated only if value of sigmoid function is not zero. A zero value of sigmoid function indicates that no change in position is required.

1. Assume the number of nodes is *n*.
2. Initialize the position and velocity vectors.
3. Assign random values to position vector and assign this position to personal best position vector of particle p.
4. Evaluate the fitness of particle p and assign this fitness to personal fitness of particle p.
5. Find the particle p with minimum fitness from P and assign its position vector to global best position vector global best position and its best fitness to global best fitness.
6. Apply velocity update equation to calculate new velocity.
7. If new velocity is greater than maximum velocity then use maximum velocity as new velocity.
8. Calculate sigmoid value & new position. Evaluate the fitness function of particle p.
9. If the new fitness is less than personal best then update the personal best fitness and position & find the best particle in particle vector P.
10. If the fitness of particle p is less than global best fitness then update the global best position vector and global best fitness.
11. If the global best fitness is zero that indicates that full coverage is occupied by sensors therefore stop the iterations.
12. Create n nodes and assign x and y coordinate values from global best position vector & then stop.

Figure 3 shows MDBPSO based deployment with sensing radius 1 m, grid size 1 m X 1 m. ROI: 9 meter X 9 meter.

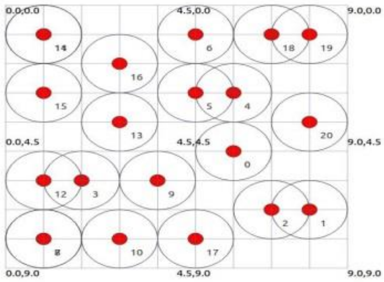

Figure 3. Sensing radius = 1 m and grid size = 1 m X 1 m, ROI: 9 m X 9 m

Table 3. Effect of Sensing Area on Number of Nodes & Iteration

Grid Size / Sensing Area	Sensing Radius = 1 m, 1 m X 1 m: Nodes	Iterations
4x4	3	8
5x5	4	11
6x6	7	23
7x7	10	38
8X8	17	45
9x9	21	149
10x10	37	280

Table 3 shows the effect of sensing area on number of nodes and iterations required. It can be concluded that as sensing area goes on increasing number of nodes and iterations required also goes on increasing.

5. RESULTS& ANALYSIS

Here, the results of Random, PSO and MDBPSO based sensor deployment method are presented. The methods are simulated for the different grid sizes & sensing areas starting from 4 m X 4 m to 10 m X 10 m with sensing radius of 1 m.

It can be observed from the Table 4 and Figure 4 that the MDBPSO requires very less number of iterations as compared to PSO based sensor deployment. This trend is followed even if sensing area goes on increasing from 4X4 to 10X10.

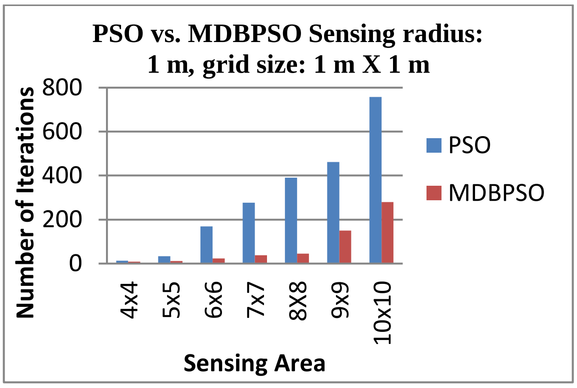

Figure 4. Comparison of PSO & MDBPSO for sensing area vs number of iterations

Table 4. Effect of Sensing Area on Number of Iterations in PSO & MDBPSO

Sensing Radius = 1 m		
Grid Size =>	1 m X 1m	
Sensing Area (mxm)	Number of Iterations in PSO	Number of Iterations in MDBPSO
4x4	13	8
5x5	33	11
6x6	168	23
7x7	276	38
8X8	390	45
9x9	462	149
10x10	757	280

Here in Figure 5 & Table 5, rectangular sensing area is considered and varied from 5X3 to 10X4 and number of nodes required for Random, PSO and MDBPSO systems are calculated.

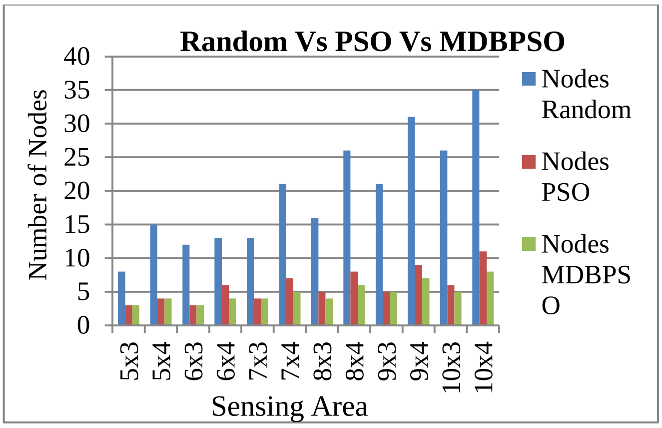

Figure 5. Comparison of random PSO & MDBPSO for sensing area vs number of nodes for rectangular grid are

Table 5. Comparison of Random PSO & MDBPSO for Sensing Area vs Number of Nodes for Rectangular Grid Area

Grid Size => Sensing Area (mxm)	Sensing Radius = 1 meter Nodes : Random	1 m X 1m Nodes : PSO	Nodes : MDBPSO
5x3	8	3	3
5x4	15	4	4
6x3	12	3	3
6x4	13	6	4
7x3	13	4	4
7x4	21	7	5
8x3	16	5	4
8x4	26	8	6
9x3	21	5	5
9x4	31	9	7
10x3	26	6	5
10x4	35	11	8

From Figure 5 & Table 5, it can be concluded that number of nodes required for PSO and MDBPSO are almost equal but are always less than that of Random deployment. Also, in some cases such as 6X4, 7X4, 8X3, 8X4, 9X4, 10X3 and 10X4 number of nodes required in MDBPSO are less than that of PSO. Here, square sensing area is considered and varied from 4X4 to 10X10 and number of nodes required for Random, PSO and MDBPSO systems are calculated.

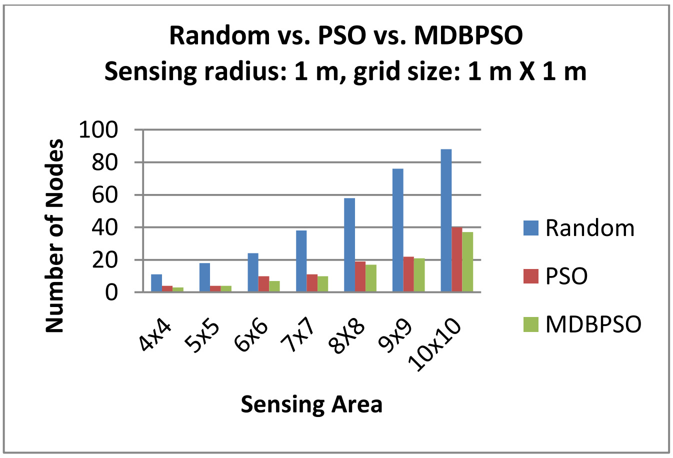

Figure 6. Comparison of random PSO & MDBPSO for sensing area vs number of nodes for square grid area

Table 6. Comparison of Random PSO & MDBPSO for Sensing Area vs Number of Nodes for Square Grid Area

Grid Size => Sensing Area (mxm)	Sensing Radius = 1 meter Nodes Random	1 m X 1m Nodes PSO	Nodes MDBPSO
4x4	11	4	3
5x5	18	4	4
6x6	24	10	7
7x7	38	11	10
8X8	58	19	17
9x9	76	22	21
10x10	88	40	37

From Figure 6 & Table 6 it can be concluded that number of nodes required for PSO and MDBPSO are almost equal but are always less than that of Random deployment. Also, in some cases such as 4X4, 6X6, 7X7, 8X8, 9X9 and 10X10 number of nodes required in MDBPSO are less than that of PSO. Above graphs proves that MDBPSO requires less number of nodes as compared to Random and PSO based sensor deployment for rectangular as well as square grid area.

6. CONCLUSION

WSN has issues such as coverage, connectivity, network lifetime and scheduling & data aggregation. Connectivity and coverage problems are caused by the limited communication and sensing range. Coverage issue can be solved at the time of sensor deployment itself by strategically deploying sensor nodes. It is observed that random deployment does not have any control on distribution of sensor nodes thus requires very high number of nodes to achieve the complete coverage of the ROI. Moreover, overlap is very high due to non-uniform sensor distribution. As the number of nodes is very high the network becomes expensive and complex to maintain. From the results of MDBPSO, it can be said that the number of nodes required for complete coverage is lower than the nodes required for PSO method. Number of nodes required for complete coverage using PSO and MDBPSO are almost equal for small size of ROI however as the size of ROI increases the MDBPSO requires less number of nodes than PSO to achieve complete coverage. The number of iterations required for complete coverage in MDBPSO is also less than that required in PSO. In MDBPSO, the sensor distribution is better and the overlap is very less than that of PSO. Thus, it can be said that MDBPSO perform better than random and PSO based sensor deployment.

REFERENCES

[1] Zhao J., Wen Y., Shang R. and Wang G., "Optimizing Sensor Node Distribution with Genetic Method in Wireless Sensor Network," *Advance in Neural Network*, pp. 242-247, 2004.
[2] Tamizharasi, A., Selvathai, J.J., KaviPriya, A., Maarlin, R., Harinetha, M., "Energy aware heuristic approach for cluster head selection in wireless sensor networks" *Bulletin of Electrical Engineering and Informatics (BEEI)*, 2017; 6(1): 70-75.
[3] Saini, R.K., Ritika, Vijay, S., "Data flow in wireless sensor network protocol stack by using bellman-ford routing algorithm", *Bulletin of Electrical Engineering and Informatics (BEEI)*, 2017; 6 (1): 81-87.
[4] AmitabhaGhosh and Sajal K. Das, Chapter 9, "Coverage and Connectivity Issues in Wireless Sensor Networks," University of Texas at Arlington.
[5] Nor Azlina Ab. Aziz, Kamarulzaman Ab. Aziz, and Wan Zakiah Wan Ismail, "Coverage Strategies for Wireless Sensor Networks," *World Academy of Science, Engineering and Technology*, Vol.: 26, pp. 135-140, 23-02-2009.
[6] J. Kennedy and R. Eberhart, "Particle swarm optimization," in *Proc. IEEE Int. Conf. Neural Network*, vol. 4, pp. 1942– 1948, 27 Nov.–1 Dec., 1995.
[7] Raghavendra V. Kulkarni, Ganesh Kumar, "Particle Swarm Optimization in Wireless-Sensor Networks: A Brief Survey," *IEEE Transactions on Systems, Man & Cybernetics-Part-C*, pp. 1-7, March 2010.
[8] Bhuvnesh Gaur, Pardeep Kumar, "Wireless Sensor Deployment Using Modified Discrete Binary PSO Method", *International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering*, ISSN 2321 – 2004, ISSN 2321 – 5526, Vol. 1, Issue 3, pp. 82-89, June 2013.
[9] Toor, A.S., Jain, A.K., "A survey on wireless network simulators", *Bulletin of Electrical Engineering and Informatics (BEEI)*, Vol. 6, Issue 1, 2017, pp. 62-69.
[10] Neha Jain, Kanchan Sharma, "Modified Discrete Binary PSO based Sensor Placement for Coverage in WSN Networks", *International Journal of Electronics and Computer Science Engineering*, ISSN- 2277-1956, Vol. 1, pp. 1548-1554, 2011.
[11] ShirinKhezri, KarimFaez, AmjadOsmani, "Modified Discrete Binary PSO based Sensor Placement in WSN Networks", *International Conference on Computational Intelligence and Communication Systems*, IEEE DOI 10.1109/CICN.2010.49200 2010

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