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Optimization of Wireless Sensor Network Coverage based on Evolutionary Algorithm

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Abstract— Wireless Sensor Network (WSN) has recently drawn lots of attention due to its application in the medical, environment, military and industry. For maximum coverage, sensor node has to support mobility so as to improve this coverage. The spatially distributed sensor nodes collect information from the environment through their movement. Mobility of sensor node is dependent of connectivity and optimization of the coverage in a target area. Finding near optimal solutions for sensor node deployment is still an issue in Wireless Sensor networks (WSN). Optimum deployment of the sensor nodes is essential for better utilization of the sensor network. In this paper, an optimization mechanism is proposed and evaluated. The objectif of this technique is to provide fault tolerance in WNSN in order prolonge its lifetime, to reduce its complexity and to increase the quality of service (QoS) for WSNs applications. The solution is based on Particle Swarm Optimization (PSO) algorithm and was compared, via simulation, with randome deployment. Simulation results show that, the proposed algorithm outperforms randome deployment in terms of coverage.

Index Terms — Deployment; Coverage Optimization; Lifetime, Particle Swarm Optimization, Mobility, Sensor.

1 INTRODUCTION

Wireless Sensor network comprises of a sensor and vehicles that are deployed to carry out cooperative monitoring over target area. Most of the sensors are mobile, and network topology change dynamically with the environment condition thus the network will simply be a failure. The spatially distributed sensor node claim useful data about the target environment by motion via the environment.

The main problem in the wireless sensor network is coverage; however, the coverage problem depends on a coverage model in the wireless sensor network. Coverage model can guarantee the quality of service, fault tolerance and lifetime of sensing area and due to the large variety of application. Sensor node has different quality in different geographical location. Wireless sensor node uses unit disk model to cover the area, in unit disk. The usage of each sensor is identified with unit radius r in the area and each node has connectivity to other sensor nodes in corresponding radius. One aspect to improve sensor coverage is movement of the sensor nodes. This research question is classified as a NP-Hard (non-deterministic polynomial-time in computational complexity theory) problem and it covers an efficient algorithm problem.

2 RELATED WORK

Chakrabarty [2] introduced the *k*-coverage problem of a number of *n* point placed as a linear programming problem. The optimization problem is to find a best solution in grid points in which each grid is covered by at minimum *k* node and it decreases the cost of sensor for perfect coverage. They proposed a divide-and-conquer access for solving the problem.

Huang [3] formulated *k-coverage* problem of a set of *n* sensor node in subregion of sensing area, and the check if the sub-region is *k-coverage* or not. However complexity of computation was expensive in geometry because many $O(n^2)$ sub-region divided by circle were existed. He assumed that the two type of sensor radius were equal. The optimization problem is to find a solution of sensor to sensing region so that sub-region covered minimum number of *k* sensor and the cost of the computation is minimize. Thus, he proposed a "Euclidean distance" approximation approach for sensor placement.

Corte [4] studied the deployment of wireless sensor networks and proposed a coverage control for mobile sensor node and optimizing notation of quality of service(QoS), that is provided by sensor network in dynamic environment. The current approach to the notion of sensor coverage involves finding optimal sensor placement for each sensor node deployed in WSN.

Haymar [5] studied the deployment of wireless sensor network and proposed mobility control of sensor based on Particle Swarm Optimization and coverage that can provide of reliability of *k-coverage*, sufficient sensing target area and fault tolerant capability. The current approach to the move-

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ment of the coverage problem involves finding sufficient/insufficient deployment in WSNs in which the number of sensor node is minimized and target area are covered by k sensor for the purpose of energy conservation and reliable quality of service. Since the algorithm that finds the low number of sensor node for k coverage is NP-hard [2], researchers have focused on finding the optimal solution in polynomial time. There are two types of the approximation algorithm for *k-coverage.* They are centralized algorithm [7] and distributed algorithm [8,9]. For centralized method, a set of sensor node as well as their position, must be allocated. A distributed algorithm does not rely upon global information. In this algorithm sensor, node does not need to identify the sensor node location.

Wang [10] proposed a centralized algorithm for the coverage problem and he suggested the following coverage pattern $R_c < \sqrt{3}R_s$. The sensor node can be a complete coverage by separating it from the distance of R_c. After the computing of target position, Wang [10] introduced the change sensor node movement on maximum-weight maximum-matching to ration that mobile node movement to the best position.

Butler and Rus [11] introduced a complete surveillance in mobile node. The solution is an expedition enough mobile node to the event position, while providing for accomplished surveillance field. In order to approach the event distribution by mobile sensor node Buttler and Rus (2008) presented two distribution schemes for moving toward the event, such as the group of mobile node trends, toward of the sensed event. These algorithms use minimum communication and computation with the size mostly of $\sqrt{n(logn)}$. They also presented another algorithm that was able to maintain an approximate complete coverage while still unit on the event location. In addition, in this algorithm, the coverage varies in the amount of communication and computation required with the size of $\sqrt{n(logn)+nc}$.

Bai [12] introduced limited mobility model for the *k-coverage* in wireless sensor network. He presented the density of emptiness for *k-coverage* of network, and the quantity of mobile node the majority to move in order to heal the coverage hole and vacancy. Bai [12] attempted the deployment of optimization algorithm in distributed manner to improve *k-coverage* of the mobile node used particle swarm optimization under limited mobility.

Both mobility of sensor node and coverage have great effect on the WNSN quality of service, however, there are few works which combine these to the techniques to reach the near optimal solution for WNSN deployment problem.

3 Problem formulation

For additional knowledge, the first problem description of the Sensor deployment dates back to Chvatal [13], who introduced the art gallery problem. In a no suit geometry plan; a minimum number of spectators is needed to secure the walkway. This problem is categorized as a NP-hard problem [2]. In order to figure out an NP hard problem, some approaches can be used (for example Integer Linear Programming and Voronoi algorithm). However, in this paper, the focus is on the problems and solutions which are based on PSO.

Particle swarm optimizations seek to improve the performance by sampling the area of the parameter space that has high probability in order to find best solution. PSO is motivated from the simulation of the social behavior of natural species. The algorithms are called Particle Swarm Optimization because the manipulation of possible solutions resembles the mechanics of natural behavior. As an optimization technique, PSO algorithms simultaneously examine and manipulate a set of possible solutions and with this global search after each iteration, it will be closer to the optimal solution.

In this approach, the proposed algorithm will be designed and implemented. To create PSO, firstly, the fitness function needs to be improved. Fitness function is computed based on the coverage of the position of sensor. The proper designing of the fitness function can help the algorithm in two ways. It is essential to initially find the best optimal solution coverage problem and then to decrease the complexity of the algorithm which can help the algorithm to run faster and more efficiently. However reaching for the best fitness function design is not possible in the first step and the attacking approach here is to simplify the problem with two or three constraints to solve the problem. After successful results, more constraints are added to it. The fitness function is one of the most important objects in PSO. It can guarantee good coverage and speed of the algorithm.

PSO is a stochastic search technique that was successfully applied in many problems, especially NP-hard and it proved to be exceptional in many other heuristics. It often contacts optimal or near optimal suspension [3]. However, many works have been done to figure out the Sensor Network deployment problem with PSO where each of them defines the problem and its facets in a different manner. The examples of investigations that implemented the artificial algorithms, besides PSO, for Sensor Network Deployment can be found in Davoodi [13] for Genetic Algorithm (GA) and [14] for a fuzzy optimization algorithm.

3.1 Pso Algorithm

Particle swarm optimization (PSO) is relatives of calculative models outstanding by evolution. The purpose of PSO is to be responsible for the best compound of problem under the presumption set of the role. An adjustment problem includes a fitness function which delineates the problem. PSO by Kennedy and Eberhart was initially intended for simulating the social behavior [15].

A difficulty of optimizing the PSO which have a population of candidate solution, tagged particles and active these particles nearby in the search-space similar to be common arithmetical formulae. The pursuits of the particle are aimed by establishing the best positions in the search-space which are considered as the best positions that are established by the particles [15].

The public paces are needed to solve a fact result question with PSO. Among them, there are two principal parts that are a problem conditional, and they are particle encoding and fitness function (Evaluation Function). In this section, apart from particle encoding and fitness function, several accesses in formation, inertia weight, velocity, constriction factor and acceleration coefficients methods in solving WNSN deployment with PSO will be discussed. The particle Swarm Optimization presented for the *d*th dimension of position and velocity of *i*th particle with following:

$$V(t+1) = \omega.v(t) + C1.(ld(t) - xd(t) + C2.(gd(t) - xd(t)) \quad (1)$$

$$xd(t+1) = xd(t) + vd(t+1)$$

3.2 Parameters for PSO

There are several main parameters for PSO model ϖ , c1, c2, V_{max} and swarm size *S*. All these parameter can determine how it optimizes the search space for function and get optimal result in most problems. However, some parameter setting do not assure in finding the solution for different problem. Thus, a suitable setting from problem to problem should be put.

- The Inertia Weight ϖ

The inertia weight controls the motion of the particle: If $\omega <<1$, only small motion is kept from the earlier time-step; thus sudden alterations of the path are potential with this condition. Actually, the velocity depends on ϖ , when $\varpi = 0$ the velocity completely lost and particle should move without the knowledge of last velocity. On the other hand, if $\varpi > 1$ we have a similar result as C_1, C_2 is small, particle can barely change control and turned around, which of executing large area for exploration as well as lack of enthusiasm in finding the optimal solution [16].

- Velocity V_{max}

The rate V_{max} concludes the biggest change on particle movement in the search space during loop. In fact, a full search rang of the particle situation will be set as maximum velocity. However, with the use of inertial gravity in velocity will update recipe maximum velocity to some degree and it has become unnecessary. In spit of this fact, greatest velocity can improve the search for the optimal compound.

- Swarm size

It is to a certain extent, a shared in the PSO papers to minimize the quantity of particles to the range 20-60. Kenedy [15] showed that there was a slight evolvement of the optimal worth with expanding swarm size; a larger swarm increases the quantity of fitness function valuation to focus on an error limit. The population size of swarm obtained a great result on the show of the PSO algorithm.

- The Coefficients $C_1$and C_2

Kennedy [15] presented the popular method of selecting for acceleration coefficients C_1 and C_2 C_1=C_2 =1.494. However, there are other setting for C_1 and C_2 as discussed in other papers and the range is [0, 4]. Ratnaweera [16] investigated the result of varying acceleration coefficient with the time.

4.3 Fitness Function

Fitness function is a specific type of aim function that measures the optimality of a solution in PSO. Depend on the goals of the research, fitness function could be designed differently, however all of them consist of objective to evaluate the solution in a particle swarm optimization. As it was mentioned in previous, the objective of this paper is to leverage mobile node to improve network coverage. While there are different definitions for coverage, in this research the fitness function coverage could be defined as following equation:

$$d(s_i, s_j) = \sqrt{|x_i - x_j|^2 + |y_{i-}y_j|^2} \quad (2)$$

Where (x, y) is the co-ordinate of the particle swarm in regulate space from (-1,-1) to (1, 1). This fitness function increases the fitness towards 0.0. If the node is not near the exact position then the fitness function will decrease by the 1000 value. In addition, the particle swarm is simulated if it is currently located within the exact location, if in this test the function returns is false then the fitness is reduced by 1000. If the particle is not found in the area, the fitness is reduced by 10.

The popular action of updating the function is to keep the particle toward the target area. This fitness function is useful to each particle in turn through the update of the algorithm. Therefore, if none of the above criteria are met, the swarm particle will be updated by the equation (1).

5 MOBILITY AND COVERAGE

Mobility coverage of the mobile sensor networks uses the improved PSO under limited movement. Mobile sensor utilization adjustment for *k*-coverage of sensor networks with limited mobility. Since a mobile sensor's cost is stronger than that of a fixed sensor, fractional sensors are used to move and to fill the coverage holes and end the area without the sensor. Mobility of sensor for the coverage of the hole area and the number of sensor need to move in order to heal the hole. According to the sensor specifications, it can have two radiuses; one for sensing and one for transmitting. As was mentioned before, in this paper the radius of transmitting is twice bigger than a radius of sensing and the covering expression is used for sensing coverage. A sample of both sensing coverage and transmitting coverage could be found in Figure.1.The complexity of the current simulations focus on algorithms.

The main step to improve this algorithm is to change its fitness function and enhance the PSO to improve the coverage and lifetime of mobility. The main disadvantage of this simple PSO is in its fitness function. The fitness function was designed as below: For each, overlap coverage between two sensors, one additional sensor was used. However this strategy will make all the sensors overlap. To avoid this, another

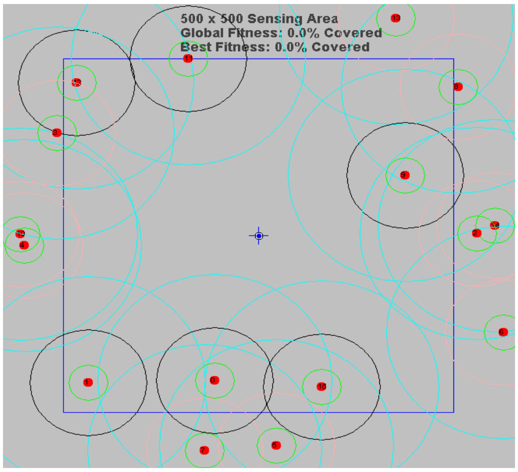

Fig. 1. Initial deployment

one parameter was added to fitness function which is one positive point for using each sensor with less overlapping.

5.1 Experimental Results

Each setup was run in 500*500 sqm as area sensing and monitoring area. Sensor nodes were deployed randomly in the sensing area and outside the sensing area. However in each instance, the global best position was chosen to be in the sensing area. The center of the sensing area is considered as the central point (0, 0) of the area.

The sensing range of sensor node is 75m and the communication range is twice of this range. At every instance, particles were initialized with acceleration parameter of 1, and a decay parameter of 0.01 which has resulted in the reduction of the swarm velocity.

The results presented here were implemented with above aforementioned parameters and values. The graph in Figure 2 shows the optimal solution for each instance. The approximate average for experiment of PSO algorithm for sensor coverage is 72. The highest result of individual implementation was found at run 5 with 76.53 % of coverage.

This experiment has best fitness coverage in run 5, 12, 18, 19 and 20 at 76.5, 75.5, 74.5, 76, 76 and 75.5 percent respectively as illustrated in Figure 2. Furthermore, the result shows that, PSO produces better results compared to the randomly deployment approach when looking optimal solution.

6 Conclution

Mobility is an important aspect of Wireless Senspr Networks as it contributes to the improvement network of the coverage. This paper has proposed a new technique for coverage enhancement by controling sensor node-movement. Traditional approaches use random deployment of stationary nodes to improve network coverage.

Thus, our solution has proved to provide better coverage. This is particularly vital for high performance applications. The high performance of the solution is attributed to the use of PSO algorithm.

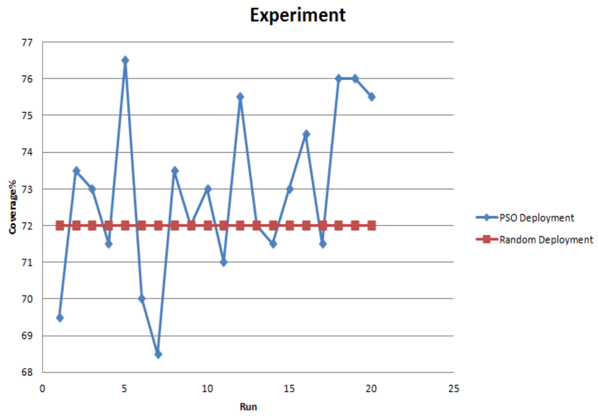

Fig. 2. Optimal solution from each run

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