International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 12 (2015) pp. 31755-31762

http://www.ripublication.com

Multi Objective Virtual Force Particle Swarm Optimization In Wireless Sensor Networks

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Abstract

Coverage and connectivity are one of the most important performance metrics in sensor networks because it reflects how well a sensor field is monitored and being able to communicate the information sensed by the sensor. We introduce the maximum coverage deployment problem in wireless sensor networks and analyze the cost efficiency, guaranteed connectivity and maximum coverage for given sensors. Random deployment is the simplest way to deploy sensor nodes but may cause unbalanced deployment. So, we need a more intelligent way to deploy the sensors. We propose an efficient multi-objective VF_PSO algorithm. Here we consider cost, coverage and guaranteed connectivity and also use crowding distance technique for obtaining optimal solution.

Keywords - Maximum coverage, sensor deployment and WSN.

I. INTRODUCTION

The Wireless Sensor Network is built of "nodes" which can be of few to several hundred and these nodes are connected to one or more sensors. Each sensor network node consist several parts for its perfect functionality. It consists of radio transceiver with a connection to an external antenna or internal antenna , a microcontroller, an electronic circuit as an interface with the sensors and an energy source, usually this energy source will be a battery or an embedded form of energy harvesting.

A sensor node might vary from that of a shoebox down to the size of a grain of dust in size. The cost of sensor nodes also varies similarly, ranging from a few to thousands of rupees. It depends on the complexity of the individual sensor nodes. Cost and size constraints on sensor nodes result in corresponding constraints on resources such as memory, computational speed, energy, and communications bandwidth. So, it is very important to deploy given sensors in a manner to achieve maximum coverage.

This paper is organized as follows. Section 2 includes key concepts; Section 3 includes related work in wireless sensor network; section 4 introduces proposed methodology; section 5 includes simulation results; section 6 includes performance analysis and section 7 gives the conclusion on this paper.

II. KEY CONCEPTS

A. Maximum Coverage

Coverage in wireless sensor networks is usually defined as a measure of how well and for how long the sensors are able to observe the physical space. Distance is an important factor for sensing. Sensing power decreases with the increase in the distance between nodes and targets. Sensors get charged up by batteries; hence they can be used for a limited period of time. Hence energy conservation and coverage preserving protocols are required to make the battery work longer.

B. Sensor Deployment

A sensor network deployment can usually be categorized as either a sparse deployment or a dense deployment. A sparse deployment has a relatively few number of sensor nodes in the given field of interest while a dense deployment would have large number of nodes. The dense deployment model is used in situations where it is important to have multiple sensors cover an area or when it is very important for every event to be detected. Sparse deployments may be used when the cost of the sensors are too high that makes a dense deployment prohibitive or when you want to achieve maximum coverage using minimum number of sensors.

C. Wireless Sensor Network

Wireless sensor networks are a rapidly growing area for commercial development and research. To monitor a given field of interest for changes in the environment, Wireless sensor networks are used. They are very useful for environmental, scientific and military applications to name a few. Coverage is one of the most active areas of research in wireless sensor networks. Coverage in wireless sensor networks is usually defined as a measure of how well and for how long the sensors are able to observe the physical space.

III. RELATED WORK

A. Genetic algorithm

Genetic algorithm (GA)[2] is a search heuristic that mimics the process of natural selection. This heuristic is commonly used to generate useful solutions for search problems and optimization. Genetic algorithms resembles the larger class of evolutionary algorithms (EA), which generate solutions to optimization problems using techniques inspired by natural evolution, such as mutation, selection, inheritance, and crossover. In order to optimize the coverage problem Genetic algorithm provides a proper deployment of sensors. The genetic algorithm optimizes the operational modes of sensors nodes for transmitting signals.

In the existing genetic algorithm, normalization method is used for an effective coverage deployment of sensors. However the existing algorithm is limited in some cases due to the following reasons:

- Poorly known fitness functions will generate bad chromosome blocks in spite of the fact that only good chromosome blocks cross-over.
- There is no assurance that a genetic algorithm will find a global optimum solution.
- Genetic algorithm being artificial intelligence technique cannot give constant optimization response times.
- Genetic algorithm applications which are performed in real time systems are limited because of random solutions and convergence.
- Only coverage is considered in the existing system but cost is not considered. The deployment should be achieve low cost and high coverage deployment

IV. PROPOSED METHODOLOGY

A. Multi objective Virtual Force Particle swarm optimization (MVFPSO)

Multi objective Virtual Force Particle swarm optimization (MVFPSO) is a computational method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality.

PSO[8] optimizes a problem by having a population of candidate solutions, in this case dubbed particles, and these particles are moved around in the given search-space by using a simple mathematical formulae over the particle's position and velocity. Each particle is further moved based on its local best known position and global best known position. They are updated as better positions are found by other particles.

PSO is also similar to evolutionary computation techniques such as Genetic Algorithm (GA). The system is first initialized with a population of sensor nodes and searches for optima by updating them in each generation. However, unlike GA, PSO has no evolution operators such as crossover and mutation.

However PSO requires more computation time which will lead to a poor performance. Computation time can be reduced by deploying a WSN dynamically. This problem can be resolved by integrating the PSO algorithm with Virtual force algorithm. VFA is one of main approaches for coverage performance improving in dynamic deployment.

In PSO, Velocity of particles will be updated by using the historical optimal solution. In the case of VF_PSO the velocity will be calculated by using Virtual forces of sensor nodes in addition to the historical information of the particle's.

And also in our work the multi objective optimization problem is taken into consideration to resolve the optimization problem when handling with multiple objectives. The multiple objectives considered in this problem are coverage, cost of deploying sensors and guaranteed connectivity. We will use crowding distance in order to find the fitness value of multiple objectives.

a. Initializing the Particles

In the current approach, the system is initialized with a population of random solutions and searches for optima by updating generations. In this case the initial positions of the mobile nodes are initialized. Each particle is also initialized with initial velocity. The velocity and positions are updated with various iterations.

b. Calculate Fitness Values

In the proposed approach, we need to calculate three fitness functions f1(x), f2(x) and f3(x). Here f1(x) is used to calculate the overall cost of the hardware, f2(x) is used to calculate the maximum coverage of the node and f3(x) is used to calculate guaranteed connectivity.

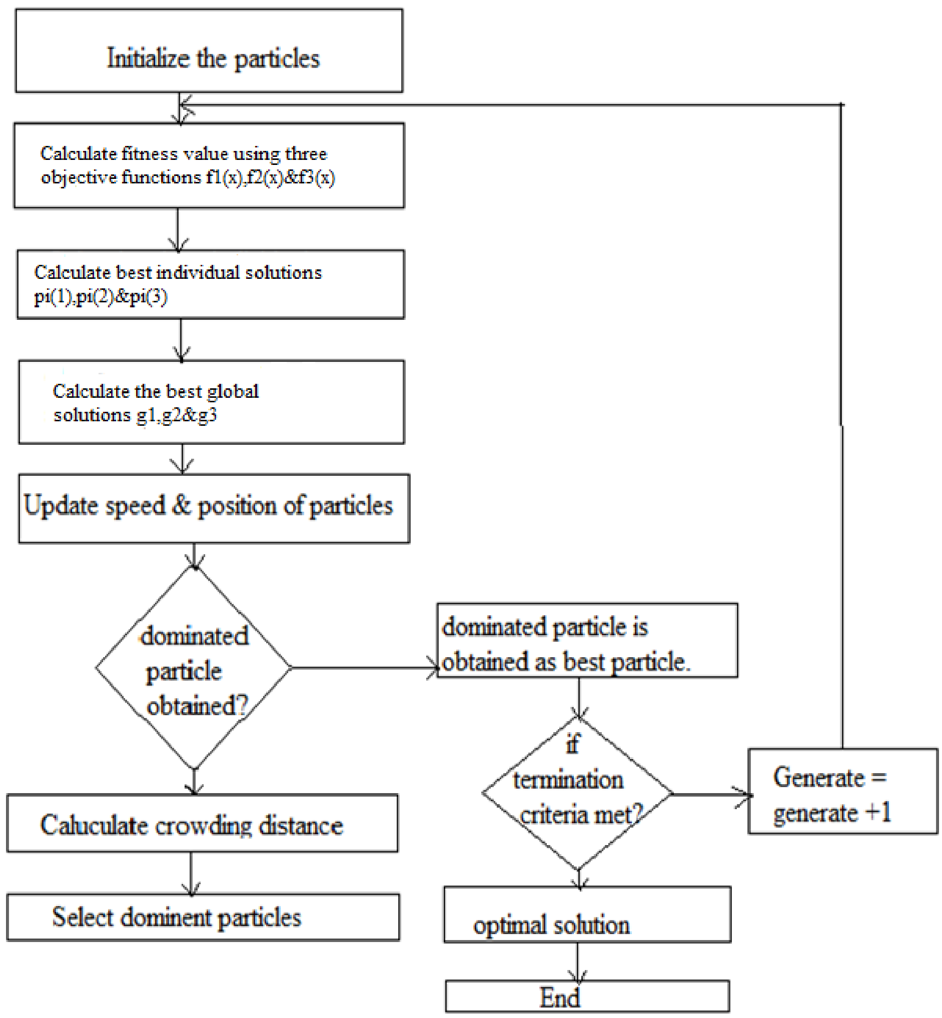

Fig 1 Architectures of multi-objective VF_ PSO algorithm

c. Calculate Best Individual and Global Solutions and Update Particles
PSO optimizes a problem by having a population of candidate solutions, in this case dubbed particles, and moving these particles around in the search-space according to simple mathematical formulae over the particle's position and velocity. Each particle's movement is influenced by its local best known position and global best known position. They are updated as better positions are found by other particles. Here we find individual and global solutions for the above three objective functions.

d. Calculate Crowding Distance
If dominated particle obtained in two fitness function, the dominated fitness particle is selected as best particle otherwise take top k particles based on their two fitness value. Calculate crowding distance between those k particles, then select dominant particle from crowding distance to obtain pareto optimal solution.

V. SIMULATION RESULTS
The functions f1(x), f2(x) and f3(x) are given below.

$$f_1(x) = \text{MIN} \sum \alpha_i + \beta_i + E_i$$

where
α_i = hardware cost
β_i = Battery cost

This function attempts to minimize the deployment cost of sensors.

$$f2(x) = \text{MAX} \sum \frac{n * \pi * r^2 - \sum_{i=1}^{n} \text{overlapi}}{\text{width} * \text{length}}$$

The above function maximizes the coverage.

$$f3(x) = \sqrt{\frac{(A(\log_n + \gamma_n))}{(\pi n)}}$$

A = coverage area
n = number of sensor nodes
γn = interfering neighbouring sensor nodes
If the f3(x) value is maximum the guaranteed connectivity is high. Otherwise it has low guaranteed connectivity.

VI. PERFORMANCE ANALYSIS

Multi-Objective Virtual Force PSO algorithm (MVFPSO) is used to solve maximum coverage sensor deployment problem. Compared to GA, the advantages of MVFPSO are that it is easy to implement and there are few parameters to adjust. When compared to GA, MVFPSO is more efficient. The performance metrics for MVFPSO are throughput and packet delivery ratio.

A. Packet Delivery Ratio

Packet delivery ratio is the fraction of packets sent by source that are received by the destination

$$\text{Packet delivery ratio} = \frac{\text{No of packets received by destination}}{\text{No of packet sent by source}}$$

. Fig 5.1 Delivery Ratio

B. Throughput

Throughout is the total number of packet forwarded through the network within particular amount of time

$$\text{Throughput} = \frac{\sum \text{Total no of packets transmitted`}}{\text{Total no of nodes}}$$

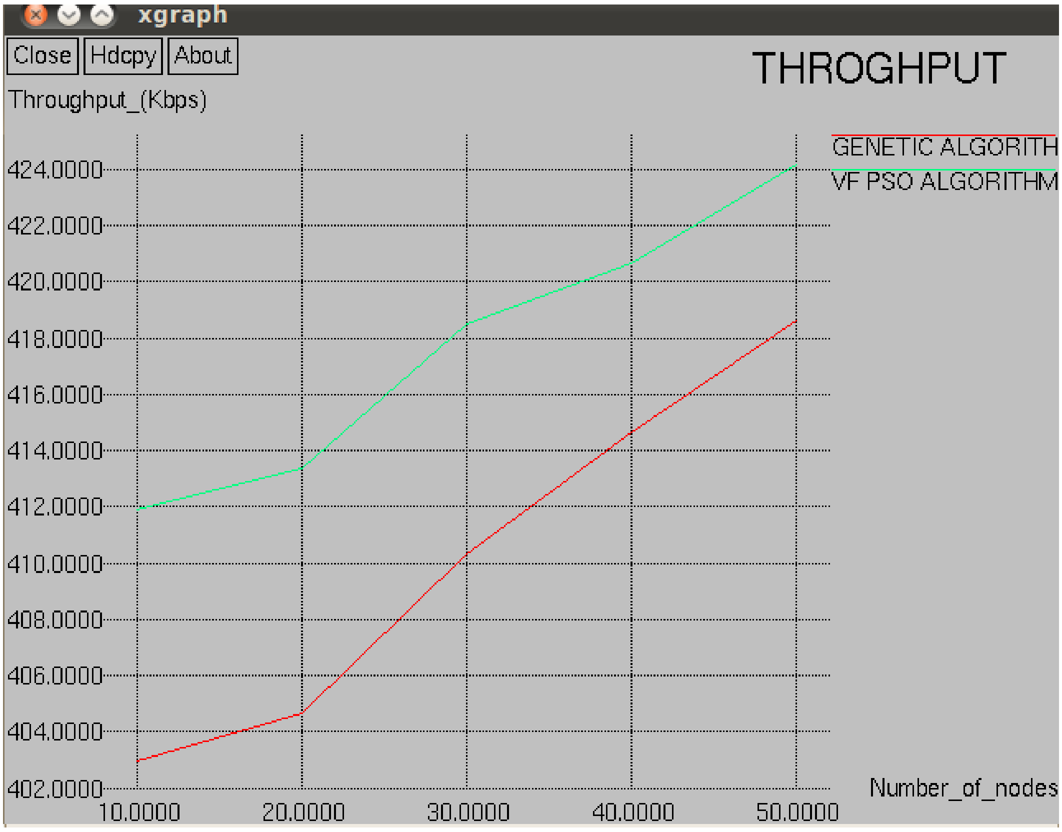

Fig 5.2 Throughput

VII. CONCLUSION

To deploy the wireless sensors efficiently to cover a wide range of target area with a minimum number of sensors we used genetic algorithm using a normalization method for an effective coverage deployment of sensors. The problem occurs in existing system is that due to poorly known fitness functions which generate bad chromosome blocks in spite of the fact that only good chromosome blocks cross-over. And since there is no absolute assurance that a genetic algorithm will find a global optimum (It happens very often when the populations have a lot of subjects). Like other artificial intelligence techniques, the genetic algorithm cannot assure constant optimization response times Genetic algorithm applications in controls which are performed in real time are limited because of random solutions and convergence. So, to obtain the maximum coverage deployment in wireless sensor network than the existing work, we go for another algorithm known as multi-objective virtual force Particle swarm optimization.

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