Multiobjective Sensor Node Deployement in Wireless Sensor Networks

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Abstract

In Wireless Sensor Networks (WSN), sensor node deployment is essential for maximizing the coverage and detection probabilities. But the existing optimization solution suffers from limited energy storage, node death, increased network traffic etc. To solve these issues, we propose a multi-objective PSO and fuzzy based optimization model for sensor node deployment. The objectives considered in the paper include maximizing network coverage, connectivity and network lifetime. A fuzzy rule is constructed with the input parameters such as node degree, link quality and residual energy. Depending upon the outcome of the fuzzy logic, the nodes are categorized into good, normal and bad. After the initial deployment of good nodes, the multi-objective particle swarm optimization (PSO) based technique is applied for the deployment of other nodes. Keeping the good nodes as the reference points, PSO iteration is performed such that each bad and normal node is connected to at least one good node. Thus from our simulation results we show that the fuzzy logic and the optimization technique provides efficient and accurate decisions for node deployment.

Keywords: PSO,GSO, WSN.

1. Introduction

Wireless sensor networks (WSNs) are networks of distributed autonomous nodes that can sense or monitor physical or environmental conditions cooperatively [1]. Each sensor node consists of one or more sensors, a radio transceiver, a microcontroller and an energy source. Due to its potential applications in many areas ranging from environmental observation, natural habitat monitoring, medical, industry and military applications, WSN has attracted a lot of research interests in recent years [2]. The sensor network, which is formed with multiple mobile sensor nodes, should have both exploring and exploiting capabilities. The exploration capability means that the mobile sensor nodes should cover the entire monitoring environment. The exploiting capability means that the mobile sensor nodes should get together around a certain location where concentrated monitoring is required. In order to maximize the both capabilities of sensor networks, a novel deployment strategy should be provided [3]. The deployment of mobile sensor nodes in the region of interest (ROI) where interesting events might happen and the corresponding detection mechanism is required, is one of the key issues in this area. Before a sensor can provide useful data to the system, it must be deployed in a location that is contextually appropriate. Optimum placement of sensors results in the maximum possible utilization of the available sensors [4]. Sensor deployment strategies play a very important role in providing better QoS, which relates to the issue of how well each point in the sensing field is covered [5]. The most effective approach of sensor deployment is to place sensors in such a manner that the maximal network coverage is achieved [6]. An efficient deployment of sensor nodes will reduce the construction and communication cost of the network and improve the resource management [7] The deployment process is done according to only one or two constraints: i) deployment cost (number of sensors), ii) event detection probability, iii) connectivity, and iv) energy consumption (lifetime).[8]

2. Related Works

Raghavendra V. Kulkarni, and Ganesh Kumar Venayagamoorthy[1] have presented Bioinspired algorithms PSO and BFA for segmentation of terrain images for autonomous deployment of WSN nodes from a UAV and for localization of the deployed nodes in a distributed and iterative fashion. Image segmentation for autonomous deployment and distributed localization are formulated as multidimensional optimization problems, and PSO and BFA are used as optimization tool. Hyungmin Park et al [3] have proposed swarm intelligence-based sensor network deployment Strategy. To make a reference point for each sensor node, fuzzy integral is utilized as a multi-criteria decision making process. Three criteria, such as sensor value, crowdedness and confidence, are used for partial evaluation and the degree of consideration for each criterion is represented by fuzzy measure. Global evaluation by fuzzy integral determines the best position for each sensor node independently. Nikitha Kukunuru et al [6] have presented a particle swarm algorithm to find the optimal positions of the sensors to determine the best coverage. This algorithm is an optimization technique which belongs to the fertile paradigm of swarm intelligence. It is a derivative free and is a very efficient global search algorithm with few algorithm parameters. Here, results are presented which shows that, PSO has good effect in solving coverage problem. Wen-Hwa Liao et al [7] have presented a sensor deployment scheme based on glowworm swarm optimization (GSO) to enhance the coverage after an initial random deployment of the sensors. Each sensor node is considered as individual glowworms emitting a luminant substance called luciferin and the intensity of the luciferin is dependent on the distance between the sensor node and its neighboring sensors. A sensor node is attracted towards its neighbors having lower intensity of luciferin and decides to move towards one of them. In this way, the coverage of the sensing field is maximized as the sensor nodes tend to move towards the region having lower sensor density. Nadjib Aitsaadi et al [8] have proposed a new deployment algorithm named MODA. It will be based on evolutionary and neighborhood search algorithm. The objective of our strategy is to reduce the deployment cost, to satisfy the requested quality of monitoring, to guarantee the network connectivity, and to maximize the network lifetime. Roghayeh Soleimanzadeh et al [10] have proposed three PSO based algorithms for improving the performance of dynamic deployment. In the PSO-LA algorithm, by using LA, the speed of particles is corrected by using the existing knowledge with the less number of repetitions. In the Improved PSO-LA algorithm, allocation of learning automata to each of the particles causes each particle to make decisions for determining the type of its movement without considering the movement of other particles and by using the result of its current movement in the environment.

3. Problem Identification and Proposed Solution

Existing multi-objective optimization solutions for sensor node deployment use the objective functions for maximizing the coverage and detection probabilities. But determining a combined objective function considering all these objectives for localization will be difficult and not accurate.

In this proposal, we propose to develop a multi-objective PSO and Fuzzy based optimization model for sensor node deployment. The following objectives are considered for each sensor:

1) To maximize network coverage
2) To maximize connectivity
3) To maximize network lifetime

Initially for each sensor, the node degree, link quality, residual energy and traffic rate are estimated in order to ensure the coverage, connectivity and network lifetime, respectively. These parameters are then passed on to a Fuzzy Logic Engine to form the fuzzy rules. Based on the outcome of the fuzzy rules, the nodes are categorized into 3 levels namely good, normal and bad. Then multi-objective PSO based optimization technique is applied for normal and bad type of nodes to refine the above objectives keeping the level1 (good) nodes as reference points. So at the end of the PSO iteration process, each bad and normal level node is connected to at least one good node. Since fuzzy logic is used for decision making, the accuracy of the objective functions is high.

4. Multi-objective PSO and Fuzzy based Optimization Model

4.1 Estimation of Sensor Parameters

4.1.1 Estimation of Node Degree (Nd)

Each node uses the same wireless communication module with a fixed unidirectional communication range. Nodes within the communication range C may communicate with each other and are denoted as 1-hop-neighbors. One node is taken as central node (Node zero).Node density *Nd* in the scenario is strongly linked to the node degree *deg*(K), which is the number of neighbors.

$$Nd = \frac{\deg(K)}{\pi . c^2} \qquad \text{………… (1)}$$

When shortest communication path or the shortest hop count is *n*, two nodes are considered as *n*-hop neighbors. The distance between a node pair is taken as a for the n-hop neighbors and the observed probability is Pn(a). The communication range *C* will be set to 1 (distance unit) as simple scaling, resulting in a unit-disc-graph. The probability *P*1(*a)* that two nodes with distance *a* to each other are 1-hop-neighbors is

$$P_1(a) = \begin{cases} 0 & for \quad a \le 0 \\ 1 & for \quad 0 < a \le 1 \\ 0 & for \quad a > 1 \end{cases} \qquad \text{………….. (2)}$$

as two nodes are 1-hop-neighbors if and only if they have a positive distance less equal to the communication range. [12]

4.1.2 Estimation of Link Quality (LQ)

(i) Packet delivery ratio (Pd)

The Packet Reception Ratio (PRR) is computed as the ratio of the number of successfully received packets (Ns) to the number of transmitted packets (Nt), for each window of *k* received packets.

$$PRR = Ns / Nt \qquad \ldots\ldots\ldots\ldots (3)$$

The Window Mean with Exponentially Weighted Moving Average (WMEWMA) applies filtering on the PRR metric to smooth it, thus providing a metric that resists to transient fluctuation of PRRs, yet is responsive to major link quality changes. WMEWMA is then given by the following:

$$Pd = WMEWMA(\lambda, K) = \lambda \times WMEWMA + (1-\lambda) \times PRR \qquad \ldots\ldots\ldots\ldots\ldots (4)$$

(ii) Channel Quality (Cq)

Received signal (Rs) is obtained by sampling the RSSI at the packet reception and Noise floor (F) can be obtained from the RSSI sample just after the packet reception. The signal to noise ratio can be obtained by subtracting noise floor (*N*) from the received signal (*S)* which is given by

$$SNR = Rs - F \qquad \ldots\ldots\ldots\ldots\ldots (5)$$

SNR value is averaged over k received packets to get Cq for channel assesmen.t

Link quality metric is the summation of both the packet delivery ratio and channel quality.

$$LQ = A \times Pd + B \times Cq \qquad \ldots\ldots\ldots\ldots\ldots.. (6)$$

4.2 Categorization of Nodes using Fuzzy logic

4.2.1 Fuzzification

In this work, the fuzzy if-then rules consider the parameters: Node degree, link quality, Residual energy and traffic load in order to categorize the nodes for deployment. The resulting possibilities are Good (G), Normal(N) and Bad(B). The selection criterion is such that a node should have higher node degree, higher link quality and higher residual energy. The final decision is made on the basis of the output of the intersection of the corresponding members of the fuzzy sets of the three parameters. In order to deploy the sensor nodes efficiently we have to maximize the node degree, link quality and the residual energy.

4.2.2 Defuzzification

Center of Area (COA). In this method the output is given as a crispy value. This value depends upon the output membership function of the center of gravity.

$$U_0 = \frac{\int w\mu(w)dw}{\int \mu(w)dw} \qquad \ldots\ldots\ldots\ldots (7)$$

4.3 Deployment of Sensor nodes using PSO

The multi-objective PSO based optimization technique is applied for normal and bad type of nodes. All the nodes are initialized randomly. The velocity and positions of the nodes are updated. Here the good nodes are kept as reference points. The reference point’s positions are determined such that the distance between the normal or bad node to the RN is minimal and the distance between the Base station and the RN is maximum.

5. Simulation Results

5.1 Simulation Parameters

We use a bounded region of 500 x 500 Sq m, in which we place nodes using a uniform distribution. The number of nodes is varied as 50,100,150 and 250. We assign the power levels of the nodes such that the transmission range of the nodes varies from 250 meters to 400meters. In our simulation, the channel capacity of mobile hosts is set to the same value: 2 Mbps. We use the distributed coordination function (DCF) of IEEE 802.11 for wireless LANs as the MAC layer protocol. The simulated traffic is Constant Bit Rate (CBR).

We compare the performance of our proposed PSO-fuzzy based method with the PSO method [11]. We evaluate the performance of packet delivery ratio, average end-to-end delay, average energy consumption and estimation error.

A. Based on Nodes

In our initial experiment we vary the number of nodes as 50,100,150 and 200 with transmission range 250m.

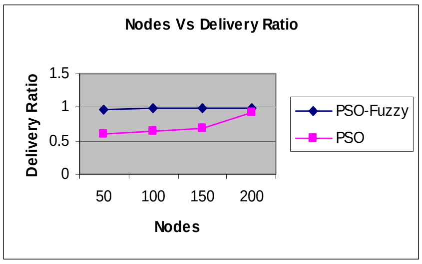

Fig 1: Nodes Vs Delivery Ratio

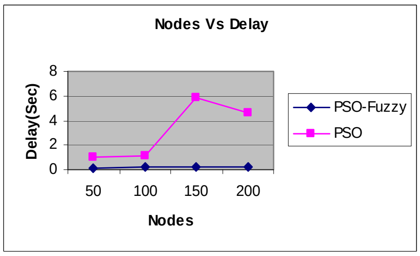

Fig 2: Nodes Vs Delay

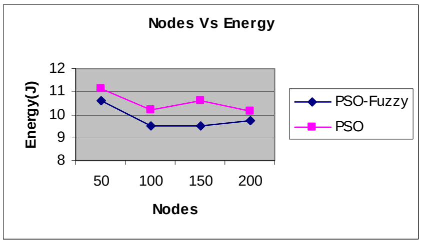

Fig 3: Nodes Vs Energy

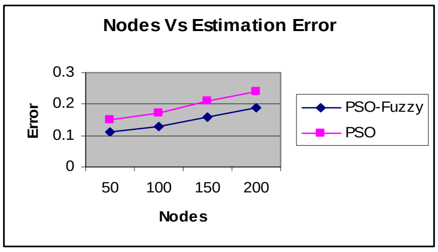

Fig 4: Nodes Vs Error

From the figure we can see that the delivery ratio is high , the delay is less, the energy consumption is low and the throughput is high for PSO-Fuzzy, when compared to PSO while varing the nodes.

B. Based on Time

In our second experiment we vary the simulation time as 10, 15, 20 and 25 sec.

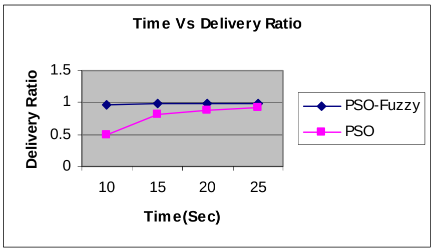

Fig 5: Time Vs Delivery Ratio

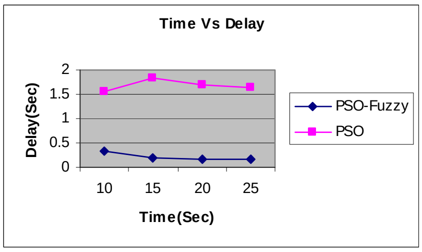

Fig 6: Time Vs Delay

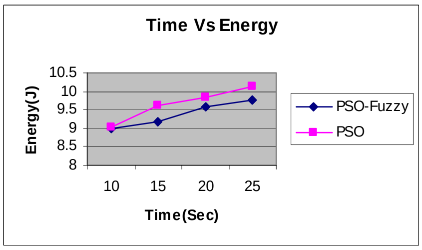

Fig 7: Time Vs Energy

From the figure we can see that the delivery ratio is high , the delay is less and the energy consumption is low for PSO-Fuzzy, when compared to PSO while varing the time.

6. Conclusion

In this paper, we have proposed a multi-objective PSO and fuzzy based optimization model for sensor node deployment. The objectives considered in the paper include maximizing network coverage, connectivity and network lifetime. Initially for each sensor, the node degree, link quality and residual energy are estimated in order to ensure the coverage, connectivity and network lifetime respectively. Depending upon the high and low values of node degree, link quality and residual energy, the node are classified as good, bad and normal nodes. The good nodes are taken as reference nodes. The reference point's positions are determined such that the distance between the normal or bad node to the RN is minimal and the distance between the Base station and the RN is maximum. The fitness function is derived using the longer and shorter distances. PSO iteration is done such that each bad and normal node is connected to one good node. Thus from our simulation results we have proved that the fuzzy logic and the optimization technique provides efficient packet delivery ratio with reduce delay, energy consumption. Also it has been shown that the technique provides efficient and accurate decisions for node deployment with low estimation errors.

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