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A Fuzzy Based Optimization for Routing in Wireless Sensor Networks

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ABSTRACT

Most of the Wireless Sensor Networks (WSN) protocols have only a single research objective. The basic task of multi-objective routing is to find a route in the network which has sufficient resources to optimize network parameters and satisfy multiple constraints. The computation of routes involves tradeoffs between energy consumption, path loss and detection accuracy. The main objective is to maximize the total detected signal energy while minimizing the energy consumption and path loss. A new hybrid multi-objective decision making algorithm employing weighing function and particle swarm optimization is proposed for fuzzy based selection of wireless networks. The performance is compared with the PSO. Thus from the simulation results we show that the hybrid optimization technique provides efficient and accurate decisions for node routing.

Key word: Fuzzy, PSO, Wireless Sensor Networks.

Introduction

In wireless sensor networks each node do not save a fixed energy, even the shortest path of the network takes a huge energy which leads to the permanent failure and reduce the lifetime of the network. So energy consumption of the network should be considered as the major factor. In most of the protocols the energy consumption is considered as a single objective problem. In this paper the energy consumption is considered as the multi-objective optimization problem. Chen and Nahrstedt, 1999 proposed a routing algorithm with minimum cost to meet the constraint of delay and bandwidth. Zhichao and Jianjiang, 2008 established a routing model of nonlinear objective under the condition of linear constraint. Krishnamachari et al., 2002 proposed the GITDC algorithm which considers the nodes routing problem between the different nodes. Usually in multi-objective routes, the main considerations of several optimization objectives include network delay, delay jitter, hop count, and data packet loss rate, and constraints e.g. bandwidth. On the basis of PSO optimization algorithm, a improved hybrid multi-objective decision making algorithm employing weighing function and particle swarm optimization is proposed. We can control the parameters of size; and join the positive and negative feedback in the network; consider the routing of the energy consumption, network delay, packet loss rate, and guarantee hybrid algorithm for fast search capability and the global skilled performance. At the same time, the simulation show that the algorithm make network latency, energy consumption, packet loss rate relatively lower.

Due to the flexibility and cost effectiveness, wireless sensor networks (WSNs) is used for numerous applications including environmental monitoring, facility monitoring, and military surveillance for tasks such as target detection. In distributed detection problems, transmission of non-critical data consumes battery power and network bandwidth. Algorithms based on local closest first (LCF) and global closest first (GCF) heuristics Qi et al., 2001 have been used to compute sensor routes. They provide a better result for small network sizes with systematically deployed sensors. The performance deteriorates as the network size increases and the sensor distributions become more complicated. These approaches consider only spatial distances whereas the major factor in target detection is the detected energy level and link power consumption. Satisfactory routes cannot be obtained when some of these factors are ignored. One of the main challenges in the design of MADSNs is the security of the data as the mobile agent visits different nodes. The data collected by the mobile agent from the sensors are susceptible to physical attacks by hostile agents. The main advantages of using mobile agents are presented by Lange and Oshima, 1999 these include: reducing latency in data transmission, autonomous and asynchronous operation, energy efficient distributed information retrieval, and parallel processing. The conditions under which a MADSN performs better than a distributed sensor network are analyzed in Wu et al. 2004 These conditions include: data transfer rate in the network, the overhead ratio between distributed sensor network and the mobile agent based distributed sensor network and the total number of sensor nodes. Wu et al. 2004 combine three objectives: the communication cost, the path loss, and the detected signal energy level into a
single optimization problem using a genetic algorithm that outperforms the LCF and GCF strategies. Though this provides a good result, it has been demonstrated that combinatorial optimization is unsuccessful for optimizing multiple objectives since it produces only a single solution. A more appropriate approach is to model the mobile agent routing problem as a multi-objective optimization problem. A multi-objective optimization approach optimizes all objectives simultaneously and obtains multiple tradeoff solutions even for non-convex problems without the need for combining multiple objectives using a weight vector. The main advantages of a multi-objective optimization approach when compared to classical optimization techniques are discussed in Shukla and Deb, 2005. The main goal of a multi-objective optimization algorithm is to discover a set of mutually non-comparable solutions called the Pareto-front which characterizes the tradeoff between multiple objectives. Multi-objective evolutionary algorithms simultaneously pursue the search for multiple solutions with varying emphasis on different objective functions. They have recently been applied to solve various multi-objective optimization problems Deb, 2001; Coello and Lamont, 2004 employs a hybrid multi objective decision making algorithm employing weighing function and particle swarm optimization for solving the routing problem.

Problem Identification and Proposed Solution:

Selection of Nodes:

Fuzzy if-then rules are applied to many fields such as control systems, decision making, pattern recognition and system modeling. The algorithm of fuzzy rule-based inference consists of three steps.

1. Fuzzy matching: Degree for input basic steps and the fuzzy rules conditions are calculated
2. Inference: Depending upon the matching degree, the rule’s conclusion is calculated
3. Combination: The conclusion of all the fuzzy rules is combined and a final conclusion is provided.

The components included in fuzzy logic system (FLS) are fuzzifier, rules, inference engine and defuzzifier. In figure 2.1 the input is given to the FLS and the output is given based upon each rule. The output is in the form of crisp value given by the defuzzifier. Rules of FLS are given by experts or it can be extracted from numerical data. Rules are expressed in the form of IF-THEN statements where IF part is the antecedent and THEN part is the consequent. Fuzzification is the process of providing crisp input fuzzy. Singleton fuzzification is widely used. The membership functions (MFs) is used to exemplify the fuzziness for a particular fuzzy set. Using the mathematical structure the restrictions in the shapes of fuzziness can be minimized and can be developed to standard terms related to the shape of MFs.

![Fig. 2.1: Fuzzy logic system](image)

Initially for each sensor, the node degree, link quality, residual energy and traffic rate are estimated in order to ensure the coverage, connectivity, network lifetime and traffic load, 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 as shown in figure 2.2.
Routing:

In general, the more the number of sensors visited, the higher is the data accuracy of the route. However, it is important to compute an appropriate route such that the detection accuracy is maximized with a low cost in terms of total energy consumption and path loss. The routing problem is formulated as a multi-objective optimization problem where the three objectives are: (a) minimize energy consumption, (b) minimize path loss, and (c) maximize total detected signal energy. These objectives are described below.

3.2.1 Energy Consumption:

Sensors are equipped with limited battery power and the total energy consumption of the sensor network is a critical consideration. The energy consumption of a path $R$ is the sum of the energy expended at each sensor node along the path. The total energy consumption $E(R)$ is given by:

$$ E(R) = \sum_{k=1}^{l} \left\{ \left( t_{nk} + t_{jk} \right) \times H_{jk}^2 \right\} + \left( P_{jk} \times t_{m} \right) $$

(1)

3.2.2 Path loss:

The path loss represents the signal attenuation due to free space propagation, and should be minimized to guarantee reliable communication. The well-known Friis free space propagation model expresses the relation between the power $P_{rj}$ received by sensor $j$ and the power $P_{ti}$ transmitted by sensor $i$ as:

$$ P_{r} = \frac{P_{t} \times G_{r} \times G_{j}}{4\pi^{2} \times d_{ij}^{2} \times \beta} $$

(2)

The path loss associated with the corresponding wireless link is (in dB):

$$ PL_{i,j} = 10 \times \log \left( \frac{P_{r}}{P_{t}} \right) $$

(3)

The total path loss along a path is the sum of the path losses associated with each link along the path. The total path loss for a path $R$ is calculated as:

$$ PL(R) = \sum_{i=0}^{l-1} PL_{i,j} = \sum_{i=0}^{l-1} PL_{i_{i},j_{i+1}} $$

(4)

3.2.3 Detection Accuracy:
High detection accuracy is also an important goal for accurate inference about the target. The signal energy $e_i(u)$ measured by a sensor $i$ is

$$e_i(u) = \frac{K_0}{1 + ad_i^2}$$

(5)

The sum of the detected signal energy along a path $R$ is defined as

$$DE(R) = \sum_{j=1}^{l} e_j(u)$$

(6)

4. Hybrid Multi Objective Optimization Model Using Particle Swarm Optimization:

Algorithm: The Proposed Hybrid Multi Objective Decision Making Algorithm employing Weighing function and Particle Swarm Optimization.

The main objective of this algorithm is to perform the best selection of access network and to maximize the percentage of the satisfied users. It is important to design a suitable decision making algorithm for the selection of best nodes. In this algorithm, a new weighing function is introduced and Particle Swarm Optimization is used for the maximizing the percentage of satisfied users. The proposed multi-objective decision making algorithm employing Weighing function and Particle Swarm Optimization algorithm is as follows:

Step1: The good, bad and the normal nodes are selected by the fuzzy logic controller with the inputs as the node degree, link quality, residual energy and traffic rate.

Step2: Call Particle Swarm Optimization algorithm MOPSO with input arguments energy consumption, path loss and detection accuracy. The output from MOPSO is the percentage of satisfied users ($\%$)

Multi-objective PSO:

1. Initialize the positions for all the particles.
2. DO WHILE:
   (a) Add random numbers in the interval $[0 \, 1]$ to position the particle.
   (b) Constrain the position so that it does not exceed the grid size.
3. Initialize the velocity of each particle.
4. Evaluate the objectives.
5. Store the position.
6. Initialize the memory of each particle.
7. WHILE: max no of iterations has not yet reached
   For each particle DO:
   (a) Compute the velocity
   $$v_{id} = w_{id}v_{id} + c_1 \cdot \text{rand.}(p_{id} - x_{id}) + c_2 \cdot \text{rand.}(p_{gd} - x_{id})$$
   (7)
   (b) Compute the new position by adding the velocity to the previous position
   $$x_{id} = x_{id} + v_{id}$$
   (8)
   (c) Constrain the position so that it does not exceed the grid size
   (d) WHILE: the particle has not formed a network
       (i) Add random numbers in the interval $[0 \, 1]$ to position the particle.
       (ii) Constrain the position so that it does not exceed the grid size.
   (e) Evaluate the objective values of the current position.
   (f) Compare the new position with members in the memory
   (g) Update the memory by inserting all the current non dominated positions and eliminate any dominated locations.
   (h) When the new position dominates the local best, replace the local best
   (i) Locate the member that dominates the fewest particles in this iteration as the global best.
   (j) Increase the loop counter
8. Return the memory as the non dominated solution set.
5. Simulation Results:

Simulations were performed with different sizes on sensor networks. The sensors are uniformly distributed in the network. The figure 5.1, figure 5.2, figure 5.3, figure 5.4 shows the variation of the number of hops, detection accuracy, energy consumption and path loss with network sizes. From figure 5.1 the number of hops in the route and from figure 5.2 the detection accuracy increase with the size of the network. Due to the reduction of the number of hops the energy consumption and the path loss gets reduced as shown in figure 5.3 and figure 5.4. The hybrid multi objective decision making algorithm with particle swarm optimization performs an efficient routing.

Fig. 5.1: Network size Vs no of hops

Fig. 5.2: Network size Vs detection accuracy

Fig. 5.3: Network size Vs path loss
Conclusion:

In this paper, we have proposed a hybrid multi objective decision making algorithm with particle swarm optimization for network routing. The main objective is to maximize the total detected signal energy while minimizing the energy consumption and path loss. Initially for each sensor, the node degree, link quality, residual energy and traffic rate are estimated in order to ensure the coverage, connectivity, network lifetime and traffic load, respectively. A fuzzy logic table is created for all these four parameters. Depending upon the high and low values of node degree, link quality, residual energy and the traffic rate, the node are classified as good, bad and normal nodes. Using multi-objective PSO algorithm we obtain the solutions with lower energy consumption and path loss while maximizing the detection accuracy for networks of various sizes. Thus from our simulation results we have proved that the hybrid multi objective decision making algorithm with particle swarm optimization 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 routing.

Reference


