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Optimization of Network Lifetime in WSN using ACO Algorithm

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Abstract: ***Wireless Sensor Networks (WSNs) is the most promising technology to enable applications such as intrusion detection, target location and environment monitoring. In these applications, full coverage is highly required in a region of interest (ROI). Sensor nodes usually depend upon a battery for their energy source and in most deployments battery replacement is not feasible. Energy efficient sensing therefore attracts significant attention. Existing work has focused on full coverage problem under the probabilistic sensing model and which uses ε-FCO algorithm to fully ensure ε-full area coverage. For the sensor network to operate successfully, the active nodes must maintain both sensing coverage and network connectivity. Proposed work tackles such a challenging problem. It adopts probabilistic area coverage with connectivity and thereby maximizing the network lifetime. ACO algorithm is used in proposed work to solve this complex area coverage problem.***

Keywords: Wireless Sensor Network, Minimum Weight ε-full area coverage problem, ε-FCO, Ant Colony Optimization (ACO) algorithm.

1. Introduction

Wireless Sensor Network (WSN) is an emerging field which is accomplishing much importance because of its vast contribution in varieties of applications. WSNs are used to monitor a given region of interest (ROI) for changes in the environment. WSN is extensively used in various domains such as military applications, environmental monitoring, object tracking, target surveillance, traffic control and disaster prevention, etc. Due to this wide range of potential applications, WSN have attracted a plethora of research efforts.

A WSN consists of a number of wireless sensor nodes. These sensor nodes have three modes of operation. In the active mode, a sensor observes the environment and communicates with other sensors. In the sleep mode, a sensor cannot monitor or transmit data. In off mode, the nodes are completely turned off. A sensor can change to active mode from sleep mode to active mode whenever it receives appropriate signal from the other sensors [2].

WSNs possess a number of special characteristics that make them very promising in a wide range of applications, but they also put on them lots of constraints that make issues in sensor network particularly challenging. These issues may include topology control, routing, coverage, security, data management and many others. Among them, coverage problem is one of the most fundamental ones for a WSN. Coverage is usually interpreted as how well a sensor network will monitor a ROI. It can be thought of as a measure of quality of service [3]. This thesis focuses on coverage problem of WSN. The goal of coverage is to have each location in the physical space of interest within the sensing range of at least one sensor [2].

There are many different factors that can affect the coverage performance of WSN [2]-[4]. In addition to coverage it is important for a sensor network to maintain connectivity. Connectivity can be defined as the ability of the sensor nodes to reach the data sink. If there is no available route from a sensor node to the data sink then the data collected by that node cannot be processed. Each node has a communication range which defines the area in which another node can be located in order to receive data. This is separate from the sensing range which defines the area a node can observe. The two ranges may be equal but are often different [3].

Energy efficiency is a critical feature of wireless sensor networks (WSNs), because sensor nodes run on batteries that are generally difficult to recharge once deployed. Sensing and communications of sensor node consume energy; therefore a proper power management is needed for maximizing the network lifetime.

This thesis focus on the following considerations: evaluating and improving coverage performance of area coverage, while maintaining connectivity and maximizing the network lifetime.

2. Related Works

Qianqian Yang et al. [1] proposed a system based on probabilistic sensing model to provide full area coverage in wireless sensor networks (WSNs). They describe the probabilistic sensing model as a more realistic model for characterizing the sensing region. This work gives a brief idea about the minimum weight ε-full area coverage problem (MWFCP) and the solution ε-FCO algorithm.

Raymond Mulligan and Habib M Ammari conducted a survey on coverage problems in WSNs. Based on their findings connectivity is closely related to network lifetime. By maintaining connectivity between sensor nodes and the data sink the lifetime of WSNs can increased [3]. Various factors that affect the coverage performance of WSNs such as various deployment strategies, node types [4].

Jiming Chen et al. [5] introduce various intelligent algorithms to solve the coverage problems in sensor networks. Among all these intelligent algorithms ant colony optimization algorithm (ACO) gives the better results. R. Seidlova and J. Pozivil use such algorithms in combinational optimization tasks [6].

3. Problem Formulation and Solution

3.1 Probabilistic sensing model

The probabilistic sensing model in which a sensor is able to sense a target at a distance d away with probability λ(d), where λ(d) is a decreasing function, i.e., 0 ≤λ(d) ≤1. Under the probabilistic sensing model, the coverage is defined as the probability of point in the ROI being covered by the network. The network can provide ε-full coverage if every point can be covered with a probability larger than ε, here ε, 0 <ε< 1, is an application dependent threshold [1].

3.2 Minimum Weight ε-Full Area Coverage Problem

Given ROI R, a set of N sensors, the weight coefficient ωi associated with each sensor Si, i = 1, 2, . . . , N , the Minimum Weight ε-Full Area Coverage Problem (MWFCP) is to find a subset of sensors with the minimum aggregate weight to provide ε-full area coverage to ROI R. The weight coefficient is a parameter that is negatively correlated to the residual energy of sensor, i.e., a sensor with more residual energy has lower weight coefficient. Activating a set with minimum aggregate weight during each time slot can efficiently reduce energy and balance the energy consumption among deployed sensors to improve the network lifetime.

The MWFCP is divided into two subproblems.

1) Find a set of anchor points (APoint) that are set PS in ROI such that any point in R iswithin the coverage range of at least one point in APoint.
2) Find the minimum weight cover such that each point Pj in PS can be detected at aprobability no less than εj , where εj = εe^{krj} , and rj is the ε-coverage range of pj . Hence,the coverage of an arbitrary point p in A is guaranteed to be at least ε.

In MWFCP, a subset of sensors should be selected to minimize the total weight and guarantee ε-full coverage. MWFCP can be formulated as an integer programming problem [1]. Here ACO is developed to solve this MWFCP.

3.3 ACO algorithm

Ant colony optimization (ACO) algorithms have been successfully applied to combinatorial optimization tasks. The ACO algorithm is based on the behavior of ants in searching of food. Ants are able to find the shortest path between a food source and the nest without the aid of visual information, and also to adapt to a changing environment. It was found that the way ants communicate with each other is based on pheromone trails. While ants move, they drop a certain amount of pheromone on the floor, leaving behind a trail of this substance that can be followed by other ants. The more ants follow a pheromone trail, the more attractive the trail becomes to be followed in the near future [6].

In practical cases, ACO algorithm uses a colony of artificial ants that behave as co-operative agents in a mathematic space were they are allowed to search and reinforce pathways (or solutions) in order to find the optimal ones. The problem is represented by graph and the ants walk on the graph to construct solutions. The solution is represented by a path in the graph. After initialization of the pheromone trails, ants construct feasible solutions, starting from random nodes, then the pheromone trails are updated. At each step ants compute a set of feasible moves and select the best one (according to some probabilistic rules based on a heuristic guided function) to carry out the rest of the tour. The structure of ACO algorithm is shown below:

```
Initialize number of ants;
Initialize the ACO parameters;
while not end-condition do
    for k=0 to number of ants
        ant k starts from a random node;
        while solution is not constructed do
            ant k selects higher probability node;
        end while
    end for
    Local search procedure;
    Update-pheromone-trails;
end while
```

4. Performance Evaluation

Simulation results are conducted to demonstrate the effectiveness of our proposed algorithm in terms of networklifetime over existing algorithms.

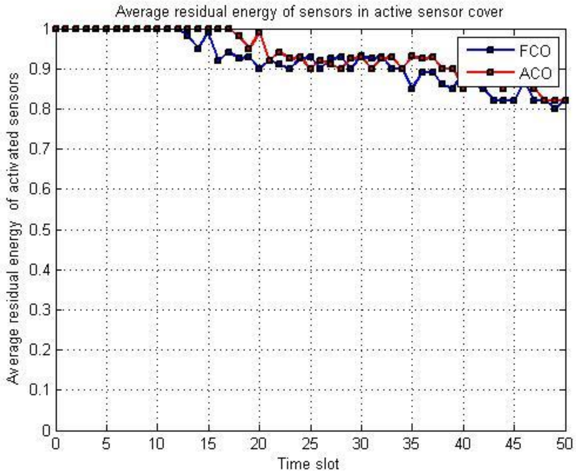

Figure 1: Average residual energy of sensors in active sensor cover

Performance of network lifetime is focused in the simulations. The operation time is divided into time slots. Atinitialization stage of each slot, algorithms are performed to select a set of sensors with a minimum aggregated weight. The selected sensors are active and the others are turned off in the current slot. Assume that a sensor does not consume any energy in its inactive state. Each sensor node has equal initial energy, which can last for ten active slots. As simulation runs, the weight associated with each sensor increases in accordance with its energy consumption. Simulation ends when the network fails to cover any point in the monitored region.

Simulations for the ε-FCO as well as ACO proposed in this paper under the same experimental setting were performed here.

The average residual energy of sensor nodes in the selected set is an important metric to evaluate the performance of algorithms and thus the results were shown in Fig. 1. We can see from Figs. 1 and 2 that ACO generally select sensors with more residual energy than the ε-FCO algorithm, leading to a balance of energy consumption among all sensors. The total numbers of active sensors, which is used to characterize energy consumption of sensor network per slot, is plotted in Fig. 2. Due to the efficiency of the applied intelligent algorithm, ACO, generally activate sensors with more residual energy and need less number of sensors to cover the all points in the given ROI.

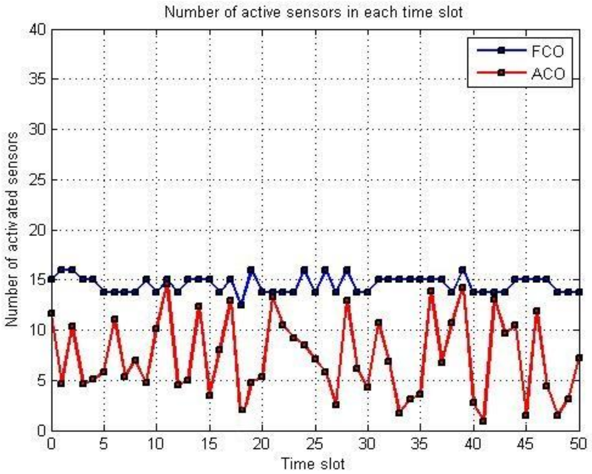

Figure 2: Number of active sensors in each time slot

5. Conclusion

The problem of maintaining both area coverage and network connectivity under energy constraint inWSN has been extensively addressed here. For addressing these problems an intelligent algorithm called ACO has been proposed. Along with the solutions, the theoretical analysis and extensive simulations prove the efficiency of proposed work.

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