An ACO Approach to Maximize Lifetime of Heterogeneous WSN

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Abstract— **Wireless Sensor Networks are used in many applications. It consists of sensor nodes. Sensor nodes are powered by renewable batteries. Since it is not possible to replenish sensor node battery, it is important to conserve node energy. Plenty of work in this field is done in homogeneous WSNs, research in heterogeneous WSN still remain unexplored. The proposed approach uses ACO methodology to maximize lifetime of heterogeneous WSN. Proposed algorithm uses two types of pheromones to find shortest distance from source to destination. Based on pheromone and heuristic information, the ants seek an optimal path on the network. Further if the data packet to be sent is very small then the non participating nodes are put to low power state rather than to sleep state. This helps to reduce the power consumed during transition from active state to sleep state and vice versa. The results show that the approach is effective and efficient in finding high quality solutions for maximizing the lifetime of heterogeneous WSNs.**

Keywords— **Ant Colony Optimization (ACO), Connectivity Cover, Network Lifetime, Pheromone, Wireless Sensor Network (WSN).**

I. INTRODUCTION

Wireless Sensor Network (WSN) is a network of number of tiny sensor nodes. Sensor nodes consist of a sensor, processor, transceiver and battery. The sensor senses the surrounding, the sensed information is converted to digital form with the help of processor and finally the converted information is routed to the sink node with the help of transceiver either directly or forming a network of sensor nodes. The sensor nodes are powered by battery. These batteries are usually non rechargeable. And even if they are rechargeable, it becomes difficult to recharge them since the sensor nodes are usually deployed in remote and hostile area. The main sources of energy wastage are collision, overhearing, idle listening and over emitting. Collision results into resending of data package. In overhearing the nodes receives packets that are destined for other nodes. In idle listening the nodes listen to the channel to receive possible data traffic whereas over emitting is caused by the transmission of a message when the destination node is not ready.

Efficient utilization of Energy is a key design objective in Wireless Sensor Networks. Wireless sensor networks can be either homogeneous or heterogeneous. In homogeneous WSN, nodes are identical in terms of battery energy and hardware complexity. A heterogeneous sensor network consists of two or more types of nodes with different battery power and functionality.

A number of methods have been proposed for finding the best way to utilize the energy of the sensor nodes. Some of the methods include scheduling algorithms, Genetic Algorithms, Particle swarm optimization algorithms and ant colony optimization algorithm [15]. The main aim of the proposed protocol is to maximize the network lifetime, which can be defined as the period that the network satisfies the application requirements.

The paper is organized as follows. Section II covers the literature survey. Section III is dedicated to Proposed Approach. Section IV provides a discussion of the results of the simulation. Section V draws conclusion.

II. LITERATURE SURVEY

A. Scheduling Protocols

Scheduling protocols are Time Division Multiple Access (TDMA) protocols. They reduce energy consumption by planning the activities of the devices. If the device is used for packet transmission for a given time slot, then the radio of the device is kept in active state. Otherwise the radio of the device is put to sleep state. During sleep state, device does not do any productive work and hence energy spent is zero.

Scheduling methods requires having devices densely deployed in an interest area. Then, only a subset of the devices accomplishing the sensing task are used for routing and hence kept in active state. Others are put to sleep. Since at any time slot only subset of devices is used for monitoring an area of interest, the lifetime of the WSN is prolonged.

Thus to achieve a longer lifetime, it is important to find maximum number of disjoint subsets of devices [3, 6].

B. Ant Colony Optimization (ACO) Algorithm

ACO algorithm is based on the behaviour of real ants. While moving some ants find food deposit pheromones on the way to their nests, and the other ants follow pheromones deposited earlier by other ants. As time goes on, pheromones evaporate, opening up new possibilities, and ants cooperate to choose a path with heavily laid pheromones. In this way, ants converge to shortest path from their nest to a food source with only pheromone information [13].

ACO is based on swarm intelligence. In swarm intelligence complex collective behaviour emerges from the behaviour of many simple agents. ACO is used to solve combinatorial problems. It is a well known metaheuristic inspired by the foraging behaviour of real ants. ACO utilizes search

experiences represented by pheromone and domain knowledge represented by heuristic information to accelerate the search process. ACO has following characteristics.

1. ACO utilizes search experiences (represented by pheromones) and domain knowledge (represented by heuristic information) to accelerate the search process.
2. In ACO, ants are stochastic constructive procedures that build solutions while walking on a graph.
3. Ant act concurrently and independently.
4. High quality solution emerges via global co-operation.
5. Indirect communication via interaction with environment (stigmergy).
6. Decrease direct communication.
7. Pheromones evaporate. Thus helps to avoid being trapped in local optima.
8. Can be used in dynamic application
9. Positive feedback leads to rapid discovery of good solutions
10. Distributed computation avoids premature convergence.

ACO algorithms have been successfully applied to a number of industrial and scientific problems ACO based routing algorithms have been used for improving the power efficiently in WSNs. The existing ACO algorithm uses three types of pheromones to solve the Energy Efficient Coverage (EEC) problem. The three pheromones help the ACO algorithm to solve the EEC problem efficiently. One is the local pheromone, which helps an ant organize a coverage set with fewer sensors; the others are the global pheromones. One global pheromone is used to optimize the number of required active sensors per PoI, and the second global pheromone is used to form a sensor set that has as many sensors as an ant has selected the number of active sensors by using the former pheromone [15, 16].

III. PROPOSED APPROACH

In this section, a noval ACO algorithm for solving Energy Efficient Coverage problem is introduced. The proposed ACO algorithm differs from other ACO algorithms because of two main aspects. One is the ACO algorithm uses two types of pheromones to find the coverage cover efficiently in heterogeneous WSN and the other is introduction of low power state.

The pheromone is deposited between every two devices to record the historical desirability for assigning them to the same subset. Heavier pheromone indicates higher desirability. One pheromone called as local pheromone is updated after an ant has finished building its solution. The other pheromone called as Global pheromone is updated at the end of iteration after all the ants in a colony has finished their tour. When assigning an unassigned device to a subset the ants consider the average pheromone between the selected device and the devices already in the subset. With the two updating rules, the proposed algorithm is able to strike a balance between exploration and exploitation.

Once the optimal path found out using ACO algorithm, the packet transmission takes place. If the data packet size to be sent is smaller than the threshold set, the non participating sensor nodes are put to low power state. It has been found out that the energy consumed to switch the sensor nodes from active state to sleep state and vice versa in case of low packet transmission is comparatively more than the energy saved by putting the radio to sleep state. Hence a new state called low power state is introduced. Low power state keeps nodes radio idle. The nodes will not receive any data nor will it send any data. The energy consumed is less compared to energy spent for transition between active and sleep state [11].

IV. RESULTS

In this section, a series of experiments are performed to evaluate the performance of proposed approach. The proposed approach is compared with general scheduling approach and with ACO algorithm with three types of pheromones. The network is implemented in OMNet++. OMNeT is an integrated development environment based on the Eclipse platform, and editor, view, extensions and other features of the wizard. All simulations were implemented on a PC with an Intel Core CPU @ 2.50GHz and 4GB of RAM. The positions of sensors nodes are randomly determined for the simulation. Seven different sets are considered with 5, 10, 20, 40, 60, 80 and 100 sensor nodes. Below tables shows the number of messages transmitted and the overall network time before the network energy drops off to zero.

1: WSN for Homogeneous Nodes without ACO

No. Of Nodes	Message Count	Network Time (in m)
5	40	31.07
10	69	31.287
20	116	30.257
40	92	30.033
60	413	30.179
80	610	30.162
100	263	30.058

2: WSN with Homogeneous Nodes with ACO

No. Of Nodes	Message Count	Network Time (in m)
5	46	34
10	123	34
20	453	34
40	1193	34
60	1890	34
80	3573	34
100	5225	34

3 : WSN for Heterogeneous Nodes with ACO

| No. Of Nodes	Message Count	Network Time (in m)
5	194	40
10	315	34.60
20	1458	37.45
40	4501	37.21
60	6829	37.25
80	8601	34.7475
100	13884	35.4264

The following charts show the performance analysis of Scheduling, TPACO and Proposed Algorithm. X-axis denote the network lifetime. Y-axis denotes the energy spent for transmission of a data packet. The number of bars in the chart denotes the number of packets sent.
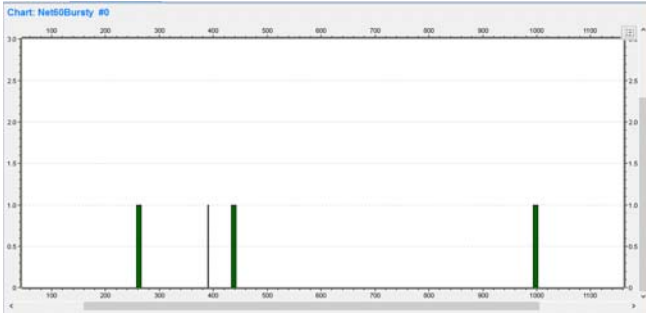
1 : Performance Analysis of Scheduling Protocol
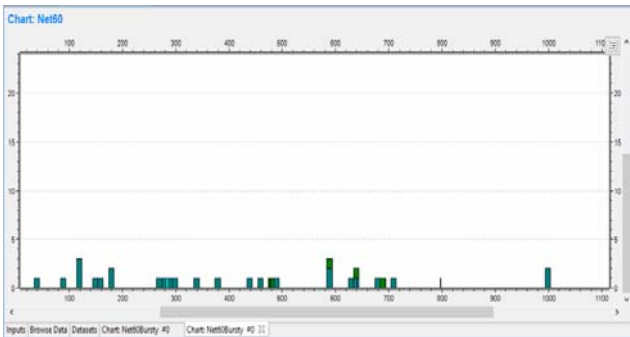
2 : Performance analysis of TPACO Protocol
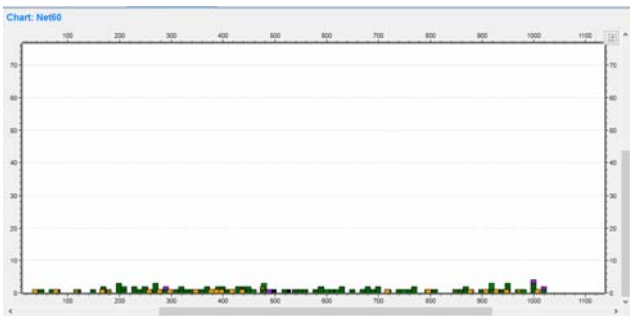
3 : Performance analysis of proposed algorithm

These simulation results indicate that the proposed algorithm outperforms the others.

V. CONCLUSIONS

In this paper, we have proposed a noval ACO algorithm. The approach searches cost effective path from source to destination. Pheromone and heuristic information accelerate the search process. With the two updating rules, the proposed algorithm is able to strike a balance between exploration and exploitation. Further the proposed algorithm introduces a new state called low power state. When data packet to be sent is very small, the energy consumed to put the nodes' radio from active to sleep state and vice versa is very high compared to energy saved by sleep state. Low power state keeps the nodes' radio in idle state and consumes less power than switching the states.

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