Comparative Analysis of Efficient Energy Coverage Problem of WSN with ACO and ACB-SA

Barinder Paul Singh1, Rajni2, and Gurpreet Singh3
1Ferozepur College of Engineering and Technology, Ferozepur, Ferozepur, India
Email: Barinder.singh88@gmail.com
2Shaheed Bhagat Singh State Technical Campus, Ferozepur, India
3GTBKIET, Chappianwali, Malot, India.

Abstract — Efficient-Energy Coverage (EEC) has been a vital problem for Wireless Sensor Networks (WSN) due to inadequate energy utilization by non inheritable restriction of sensors effectively. So, scheduling of the activities of the devices in a WSN becomes imperative to save the networks’ limited energy and lengthen its lifetime. This paper describes Ant Colony based Scheduling Algorithm (ACB-SA) applied to a heterogeneous sensor set which represents a more realistic approach to solve the EEC problem. The simulation results to confirm the efficacy of the ACB-SA for solving the EEC problem as compared to Conventional Ant Colony based Algorithm.


I. INTRODUCTION

A Wireless Sensor Network (WSN) consists of a large number of minute wireless sensor nodes (often referred to as sensor nodes or, simply, nodes) that are, in general, densely deployed. A sensor network is composed of a large number of small and low-cost devices with sensing, transmitting and processing capabilities. Every sensor network node has usually several parts such as: a radio transceiver with an internal antenna or a link to an external antenna, a microcontroller, an electronic circuit for interfacing in the sensors and an energy source, generally a battery or an embedded form of energy harvesting. Mobile communications and wireless networking technology has seen a flourishing growth in recent years. Due to this hi-tech advancements and user specific needs, a variety of classes of communication networks have emerged such as Ad hoc Networks, Cellular networks and Sensor Networks. The Cellular Networks are the infrastructure dependent networks. Ad hoc networks are defined as the class of wireless networks that use multi hop radio relaying since the nodes are vigorously and randomly located. Ad hoc networks are infrastructure independent networks [1-3].

In Sensor Networks, Nodes measure the ambient conditions in the environment surrounding them. These measurements then transform into signals that can be processed to reveal some characteristics about the event. The gathered data is then route to a special node, called sink node (also called Base Station). After that, the sink node transmits data to the user via Internet or satellite, through a gateway. Combining the advantages of wireless communication with some computational capabilities, WSNs have an everlasting collection of potential applications in both military and civilian applications including robotic land-mine detection, target tracking, battlefield surveillance, environmental monitoring, catastrophe monitoring, wildfire detection, structural monitoring, industry, security, agriculture, traffic monitoring, home for monitoring natural phenomena etc [1].WSNs has attracted researcher’s interest in recent years because of their potential applications in the field of Micro-electromechanical Systems (MEMS) technology. The
sensors are of several types like thermal, mechanical, optical, biological, and magnetic sensors included in the device to measure properties of the environment.

Energy efficiency and sensing coverage are essential metrics to prolong the lifetime and the consumption of wireless sensor networks. A number of protocols have been developed to address these issues among which the clustering is considered a key technique in minimizing the consumed energy [4]. A few clustering protocols address the sensing coverage metric. This work proposes a general structure that addresses both metrics for clustering algorithms in wireless sensor networks. The energy limitation in WSNs is a major challenge to the expansion of many potential applications. Several research projects investigated such constraint. Hierarchical routing protocols are considered among the most important routing protocols that are intended to reduce the energy utilization in WSNs [5-7]. However, most of such protocols focused on reducing the energy consumption with no regard to the sensing coverage achieved by the network. The sensing coverage, which is an important metric in several applications such as military surveillance, represents a good measure of how efficient the deployment of the sensor nodes was and how much the network resources were utilized [8].

Main goal of the process is to examine a region to collect and pass on information to a sink node or set of sink nodes which is called as Base Station (BS) [1,3].

Forwarding the data to the BS is possible in two ways:
1) Direct Hop Communication
2) Multi hop Communication

In Time-driven network, every node sends messages at regular intervals, while in an Event-driven a node transmits messages only when sensing a phenomenon [9]. The third category is the Query-driven network approach in which the sensors send data only after receiving a query from the BS. There are also hybrid networks that unite the previous three models.

a) Time-Driven Network
b) Event-Driven Network
c) Query-Driven Network

WSNs can be classified into two categories: Structured and Unstructured. In Structured WSN, all or some of the sensor nodes are deployed in a pre-determined manner at fixed locations. The benefit of Structured WSN is that only a smaller quantity of devices can be deployed for the process with lower network maintenance and running expenses. An Unstructured WSN consists of a dense gathering of sensor nodes, which are randomly deployed i.e. in an ad-hoc manner. An ad-hoc arrangement is preferred over a pre-determined
manner when the network is composed of hundreds to thousands of nodes so as to cover a fat area or when the location is unapproachable to humans attempting to create WSN, e.g. Polar Regions, deep sea, or disaster areas such as a nuclear accident area or a war zone [10-11].

This paper is structured as follows: Section II introduces the Energy Efficient Coverage Problem which encloses the preface of conventional ACO algorithm and ACB-SA. Section III gives the explanation of Leach Protocol. Section IV describes the proposed methodology and criteria to increase the energy efficient coverage in WSN. Section V provides a discussion and outlines the results of simulation. Finally, Section VI is devoted to the conclusion of contrast between conventional ACO and ACB-SA.

II. Energy Efficient Coverage Problem

The main problem is the energy efficient coverage (EEC) that occurs mainly in unstructured WSN. To find a way out for the EEC problem is one of the vital issues in the execution of WSNs. As, sensors in most WSNs work with batteries, it is usually not viable to recharge or restore the batteries when they are exhausted. A number of techniques have been suggested to solve the EEC problem to save energy and prolong a network lifetime [12]. Among these technique, device’s movement scheduling methods, which depends on the collection of set of a smallest active sensor nodes to be wide awake to sustain the coverage of an interest area, has been revealed to be valuable [13-15].

Several scheduling algorithm like greedy algorithm (GA), particle swarm algorithm (PSO) and conventional ant colony optimization algorithms (ACO) have been projected to solve the EEC problem of WSNs. The EEC problem has been converted into a binary integer programming problem in greedy algorithm. A basic alternative of PSO algorithm works by having a population called a swarm of candidate solutions called particles where the activities of the particles are guided by their own finest place in the search space as well as the whole swarm’s most excellent recognized location[16].

The conventional ACO is entirely based on the swarm intelligence, which states that the comprehensive combined actions come into sight from the activities of various agents, like ants. The performance of the ACO algorithms is determined by its process of initialization of pheromone field. But, with the help of ACB-SA the new technique like probability sensor detection model is used rather than Boolean sensor detection model which was used in conventional ACO and was inadequate to articulate the sensors because it only describes the results of event recognition as success or failure. As a result, for more correctness the probability detection model is used [16-18].

Unlike convention ACO algorithms, the ACB-SA has also applied to a heterogeneous sensor set which is more sensible and proficient than that of homogeneous sensor set because of their capability to carry out variety of tasks due to diverse set of sensors i.e. heat, light, temperature and humidity sensors etc. The heterogeneous sensor set is also more connection oriented in between WSN and a regional system. In addition, the two user parameters α and β have been removed and there is no need to consider the values of these parameters [16-18].

A. Energy-Efficient Coverage (EEC) Problem

Given a monitored region A, a set S of sensors (S = {s1, s2 , ..., si , ... sNs}), a set P of Point of Interest (PoIs) (P = {p1, p2 , .pj , .pNI}) and a cost ci of the sensor i where (i = 1, 2, . . . , NS ), find a set C of the subsets C(tS) (tS= 1, 2, ... , TS) of sensors that covers all of the PoIs in region A with a minimum total cost for a time slot until the WSN fails to cover any of the PoIs in region A. Then TS is the lifetime of the WSN.

III. Leach protocol

Low Energy Adaptive Clustering Hierarchy (LEACH) is a Media Access Control(MAC) protocol which is based on Time Division Multiple Access (TDMA) technique and integrated with clustering. It is a simple routing protocol used in hierarchical routing technique in WSNs. The aim of LEACH is to lower the energy
utilization essential to build and sustain clusters in order to enhance the life time of a wireless sensor network [19-21].

LEACH is a hierarchical protocol in which most nodes transmit data to cluster heads, and the cluster heads aggregate the data then compresses it and forward it to the base station also known as sink node. Each node uses a stochastic algorithm at each round to conclude whether it will turn out to be a cluster head in this round or not. LEACH assumes that each node has a radio powerful enough to reach the base station or the nearest cluster head directly, but that using this radio at full power all the time would result in the loss of energy [21].

Nodes once turn out to be cluster heads cannot turn into cluster heads again for P rounds, where P is the preferred percentage of cluster heads. Subsequently, each node has a 1/P probability to become a cluster head in each round. At the end of each round, every node that is not a cluster head select the nearest cluster head and joins the cluster. The cluster head afterward creates an agenda for each node in its cluster for the transmission of data.

All nodes that are not cluster heads only are in touch with the cluster head in a TDMA style, according to the program shaped by the cluster head. They perform so by means of the minimum energy desirable to reach the cluster head, in addition to keep their radios on during their time slot. LEACH furthermore use CDMA so that every cluster uses a diverse set of Code Division Multiple Access (CDMA) codes, to reduce interference among clusters [21-22].

The efficient updating of LEACH is Universal - Low Energy Adaptive Cluster Hierarchy (U-LEACH) which is an energy efficient protocol presents a major fall in the energy use by the sensor nodes. Contrasting LEACH, in U-LEACH, the selection of Cluster head depends on the initial and the residual energy of the nodes. In every cluster, the transfer of data between the nodes takes place by the formation of a chain, initiates from the extreme node from the base station [22-23].

The LEACH's operation is divided into two phases, the setup phase and the study phase. In setup phase, the clusters are planned and CHs are selected. In the steady state phase, the real data is transferred to the base station. The period of the steady state phase is longer as compare to the period of the setup phase to reduce overhead [23].

IV. PROPOSED METHODOLOGY

Energy efficiency is the most essential concern in a sensor network where each node consumes some energy with every transmission over the network. Energy efficiency is mandatory to improve the network life. A primary design concern in sensor networks is energy efficiency. The sensors are small-sized, inexpensive and more often deployed in unreachable regions; as a result, they are supplied only by a small battery which is not viable (or very costly) to recharge. The present work is defined in the similar manner to get better network life and to achieve the energy efficient routing, so that the network existence and network throughput will be enhanced.

A. Criteria to increase the energy efficient coverage in WSNs:

There are two main problems that focus on the solution to the EEC problem :Sensing Coverage Problem and Network Connectivity Problem. The sensing coverage problem requires variety of the WSN. On the other hand, the network connectivity problem demands that devices form a completely linked network to the gateway or base station location. These two issues cannot be eliminated completely by using conventional ACO algorithms.

Therefore, it is important to search for new techniques that can give a better solution to this problem of efficient energy coverage. Ant-Colony-Based Scheduling Algorithm is a good choice for solving this problem because of many advantages.
The two main issues can be eliminated by the implementation of ACB-SA algorithm because of the use of probability sensor detection model. The detection is more accurate than that of Boolean sensor detection model of conventional ACO algorithm. Also, the use of heterogeneous sensor set in case of ACB-SA is much more advantageous in probabilistic detection model than that of homogeneous sensor set of conventional ACO algorithm as the heterogeneous sensor set facilitates the superior network connectivity between a WSN and central system. The heterogeneous sensor set can also carry out a variety of tasks because of the use of dissimilar sensors having the properties to sense heat, humidity, moisture in the environment and temperature conditions etc.

In this work, we also have implemented EEC using Hierarchical routing on the basis of LEACH Protocol and found the appropriate values of Average Network Lifetime and p-values using ANOVA Test in MATLAB.

V. Simulation Results and Discussion

In this section, some simulated results from the performance evaluation of the ACB-SA are being presented by using MATLAB 7.11. All Simulations have been implemented on a PC with Intel Core i3-2330M CPU operation at 2.20GHz and 2GB of RAM.

The three scenarios have been taken out with total number of sensors varying from 100 to 200 with the difference of 50 sensors from Scenario 1 to Scenario 3 having same POIs throughout the network. The three scenarios and POIs has been shown in Table I.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>No. of sensors</th>
<th>No. of POIs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>100</td>
<td>10</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>150</td>
<td>10</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>200</td>
<td>10</td>
</tr>
</tbody>
</table>

The two simulations have been carried out to authenticate the performance of the ACB-SA. In the first simulation, the network performance (mainly lifetime) of the proposed algorithm has been calculated. The second simulation has been run by means of the ACB-SA in real number space (i.e. the position values of sensors and POIs as well as characteristic values of the sensor) with a heterogeneous sensor set. The position values of the sensors and the POIs were arbitrarily chosen as real numbers within the range of the monitored region. The comparison between ACO and ACB-SA is shown in Table II.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>ACO</th>
<th>ACB-SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>42.7000</td>
<td>46.1000</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>51.9000</td>
<td>55.5000</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>98.2000</td>
<td>102.0450</td>
</tr>
</tbody>
</table>

375
In this case, the major benefit of the system is that it can utilize information collected from real devices without converting them to integers. All sensors in the WSN follow the probabilistic sensor detection model mechanism. The \( p \)-values through ANOVA test is calculated in Table III.

Table III. \( p \)-values through ANOVA test.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>( p )-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>( 8.2 \times 10^{-64} )</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>( 3.01 \times 10^{-70} )</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>( 1.2 \times 10^{-64} )</td>
</tr>
</tbody>
</table>

The graph represents the quantity of sensors of the optimized subset that was created every time period between conventional ACO and ACB-SA.

VI. CONCLUSION

In this work, we have projected a ACO algorithm that is optimized to resolve the EEC problem. The ACB-SA has innovative uniqueness differs from conventional ACO algorithms. The traditional scheduling algorithms that use the ACO algorithm just chase the lead of the preceding solutions, and they are not optimized to resolve the EEC problem. However, the performance of the ACO algorithm is determined from its ability to initialize the pheromone field and construction graph which reflect the characteristics of the problem. To improve the performance of the Ant-Colony-Based Scheduling Algorithm (ACB-SA), a new initialization method for the pheromone field and the modified construction graph has been implemented. In addition, the ACB-SA, unlike conventional ACO algorithms, does not consider what values are desirable for the user parameters \( \alpha \) and \( \beta \). The result of the first simulation verifies the usefulness of the ACB-SA over other algorithms.

The EEC problem is solved by using the ACB-SA through a more realistic approach. To attain this, a heterogeneous sensor set is used in the WSN, which was made by the arbitrary selection of parameters for the probabilistic sensor detection model. We also propounded a solution to EEC problem under real number
space. The results of the simulations reveal that the ACB-SA can resolve the EEC problem through a more reasonable methodology. Hence, it is more reliable approach.

REFERENCES