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Enhancing the Lifetime of Heterogeneous Wireless Sensor Network by Improved Ant Colony Optimization

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Abstract

In wireless sensor networks, sensor nodes are typically power constraint with limited lifetime and thus it is necessary to know how long the network sustains its networking operations. Heterogeneous wireless sensor networks (WSN) consists of different sensor device with different capabilities. We can enhance the quality of monitoring in wireless sensor networks by increasing the sensing range and WSNs lifetime. In homogenous WSNs it's easy to find the connectivity, since using same type of sensors, but the major issue in heterogeneous wireless sensor network is to find the maximum connectivity and sensing range, because heterogeneous WSNs consist of different sensors with different capabilities. To maximize the lifetime of heterogeneous wireless sensor networks by ant colony optimization algorithm is used. Ant colony optimization algorithm provides a natural and intrinsic way of exploration in search of coverage area. Based on pheromone and heuristic information, the ants seek an optimal path on the construction graph to maximize the number of connected covers. But the methodology is used only in area coverage and cannot be used in discrete point coverage. In order to overcome this problem, this paper addresses an improved ant colony optimization algorithm that can be applied both in area coverage and discrete point coverage.

Keywords: *Improved ant colony optimization (IACO), Ant colony optimization (ACO), connectivity, coverage, network lifetime, wireless sensor networks (WSNs).*

1. Introduction

A wireless sensor network (WSN) is a collection of nodes organized in cooperative manner. Each node controllers, Central Processing Unit (CPUs) or Digital Signal Processing (DSP) chips), may contain multiple types of memory (program, data and flash memories), have a RF (Radio Frequency) receiver (usually with a single omnidirectional antenna), have a power source (e.g., batteries and solar cells) and accommodate various sensors and actuators. The nodes communicate wirelessly and often self-organize after being deployed in adhoc fashion. Sensor network consist of a large number of sensor nodes deployed either inside or very close to the sensed phenomenon. The major work of wireless sensor network is to sense the environment and route the packet to base station. The wireless sensor network collects the data from certain domain, process them and transmit to sink. However ensuring direct communication between the sensors and sinks may force to emit their messages with high power and the resources are quickly depleted, this ensures a distinct communication.

WSN provide a simple economic approach for deployment of distributed monitor and control devices, avoiding the expensive retrofit necessary in wired systems. A fundamental criterion for evaluating wireless sensor network is network lifetime, which is defined as the period that the network satisfies the application requirement. Since most devices of WSNs are powered by nonrenewable batteries, studies of prolonging the network lifetime have become one of the most significant and challenging issues in wireless sensor networks [2]. The existing system for prolonging the lifetime of wireless sensor networks focus on the issues of Device placement, Data processing, topology management and device control. In a WSN where devices are densely deployed, a subset of the devices can already address the coverage and connectivity issues [1]. The rest of the devices can be switched to a sleep state for conserving energy. Therefore, the lifetime of a WSN can be prolonged by planning the active intervals of devices. At every point during the network lifetime, the active devices must form a connected cover to fulfill sensing coverage and network connectivity [3]. The sensing coverage and network connectivity fulfills the network lifetime.

The ACO (Ant colony optimization) methodology is based on finding the maximum number of disjoint connected covers that satisfy both sensing coverage and network connectivity [10]. But the ant colony optimization can be applied only area coverage and not suitable to discrete point coverage.

The main impact of the paper is organized are as follows:

- To maintain connectivity of sensor nodes.
- To prolong the lifetime of heterogeneous wireless sensor networks.
- To use local search procedure for improving search efficiency.
- To schedule the transmission and reception of message by ACO
- To find optimal path (minimum distance and cost) using advanced ant colony optimization.

The rest of the paper is organized as follows: In section 2 deals with related works and issues. Section 3 deals with proposed system and its implementation. Section 4 shows the architectural diagram. Section 5 presents performance analysis. Section 6 concludes the paper. Section 7 gives references included in this paper.

2. Related Works

There are several methodology has been proposed in order to increase the lifetime of heterogeneous wireless sensor networks. However, the proposed methods involve difficulties in discrete point coverage and applied in area coverage. This section addresses various limitations of different methods.

The problem of relay node placement in heterogeneous wireless sensor network has been considered at aim of minimizing the network cost with constraints on lifetime and connectivity [1]. A multi-hop routing has been performed to minimize total energy consumption and thus involves too many flows and drains out the energy much quicker [2]. A greedy heuristic algorithm has been developed to solve the problem of connected target coverage with the object of maximizing the network lifetime by scheduling the sensors into multiple set; each can maintain both target coverage and connectivity among all active sensors and sinks [3]. Normally sensor nodes are powered by batteries which cannot be generally changed or recharged. The sensor node lifetime has been increased by reducing transmission/reception of messages by simple compression algorithm that reduces memory and computational resources of a wireless sensor network node [4]. The main problem that has been considered in wireless sensor network is link failure and sensor failures. A fast fixed point algorithm has been developed to maximize the lifetime and performance of wireless sensor networks [5]. An extended ant colony optimization algorithm has been used for optimizing the component value in designing PECs, in order to satisfy the performance indexes. This algorithm can optimize the circuit both in discrete and continuous valued component and takes the component tolerance into optimization process [6]. Hybrid genetic algorithms have been introduced for lifetime maximization of wireless sensor networks. Maximizing the lifetime of a sensor network by scheduling operation of sensors is an effective way to construct energy efficient wireless sensor network [7].

2.1 ISSUES IN SENSOR NETWORKS

The major issues considered in wireless sensor network are

2.1.1 Power management

Low cost deployment is one acclaimed advantage of sensor networks. Wireless sensor networks are battery powered, thus having restricted amount of energy. In order to prolong the lifetime of wireless sensor networks, it is required to reduce energy consumption of nodes as much as possible

2.1.2 Deployment

Deployment of sensor networks results in network congestion due to many concurrent transmission attempts made by several sensor nodes. Concurrent transmission attempts occur due to repeated network floods.

2.1.3 Scalability

Large scale sensor networks consisting of hundreds or thousands of nodes will link the physical world to global communication networks for a broad set of applications. Individual nodes will have some combination of sensing, signal processing and communications capability and may self-organize for a variety of cooperative sensing and communication tasks, subject to resource constraints such as energy and bandwidth.

2.1.4 Coverage

The coverage of wireless sensor network deals with quality of service of the network, ensuring that particular sensor network is monitored or observed by at least one sensor. Since sensors have only limited resources and can't with stand in extreme environmental conditions. Such that various resources has been considered for maximization of network lifetime

3. Proposed System and Its Implementation

The main aim of this methodology is to find an optimal path by finding maximum number of disjoint connected covers that satisfy both sensing coverage and network connectivity. It can be applied in both area coverage and discrete point coverage. The proposed approach has been applied to wide variety of heterogeneous wireless sensor networks. The result shows that the approach is effective and efficient in finding high-quality solutions for maximizing the lifetime of heterogeneous WSNs.

The project has been implemented using windows XP operating system. The program can be written by using JAVA and MYSQL as back-end in eclipse. Then the result can be shown through java agent development framework (JADE).

3.1 Heterogeneous Wireless Sensor Networks Graphical User Interface

Heterogeneous Network application will be developed using Java Swing application. Graphical User Interface (GUI) acts a governing module of entire application and binds all other module intact. This module will actually pull information like multiple military areas and other sensor location, routing, etc.

Main GUI provides a space to add multiple areas; however we have just considered three areas for better user viewing. Main GUI would also have a control panel placed at bottom of the screen providing various options like 'Load Information', 'Draw Areas', 'Show Coverage', 'Explore Paths', 'Plot Line', etc. User has to first click on 'Load Information' button to load all information related to areas stored in Extensible Markup Language (XML). Upon successful load of information from XML, user can start viewing military areas, followed by network elements coverage, all possible communication between network elements and finally the most optimized path between sensor and sink.

3.2 Construction of Application Area Map and Target Coverage

Application has several military areas right from text message, pictures, videos, surveys, etc., GUI needs to provide provision in terms of displaying these areas, handle events specific to area and to perform ACO mechanism.

User has to first supply/feed information of each military area, along with much other critical information like number of network elements (sensors and sinks), network element co-ordinates in each area, area name and its picture location in hard disk, etc. Once all information is stored in XML, main GUI will utilize this information in displaying areas, coverage & plotting. Each network elements that are displayed would have a pop-up menu specific to their functionality, like use pop-up to just send messages to sink, few sensors would show menu to send pictures, videos to sink, etc.

3.3 Device Management Event Handlers in Wireless Sensor Networks

As the application has many sensors, sinks & base station all of these network may generate and receive various events like sending/receiving messages, sending/receiving pictures, etc., so separate event handling mechanism has to be coded to cater the need.

Events are sent to the component, from which the event originated, but it is up to each component to propagate the event to one or more registered classes called listener. Even handling has been handled in two ways: 1) Main GUI and network pop-up menus display events are handled by Java Swing 2) Pop-up menu events are handled through Jade. JADE Event handling would also help in message and other information sharing between various network elements. Heterogeneous WSNs application utilizes several event handling mechanisms likes Mouse click action, Button Click action, and frame restore and maximize event, components repaint mechanism and etc.

3.4 JADE Container Communication Services

As a part of JADE integration, all GUI events have to be delegated to JADE. So this module acts an interface between GUI and JADE making it possible to pass on all messages.

3.5 Heterogeneous Application Data Storage and Configuration Controllers

To place sensors, sink, base station & etc., several data has to be collected from the user. To store/load and update this information, a module will be coded in a way it makes very convenient both for application and for the user to use data.

3.6 Advantages

- Robustness
- Reliability
- Routing is easy
- Energy compaction
- Efficiency

4. Architectural Design

System architecture is the conceptual model that defines the structure and behavior of the system. It provides a way in which products can be procured; system can be developed as an architectural overview of overall system.

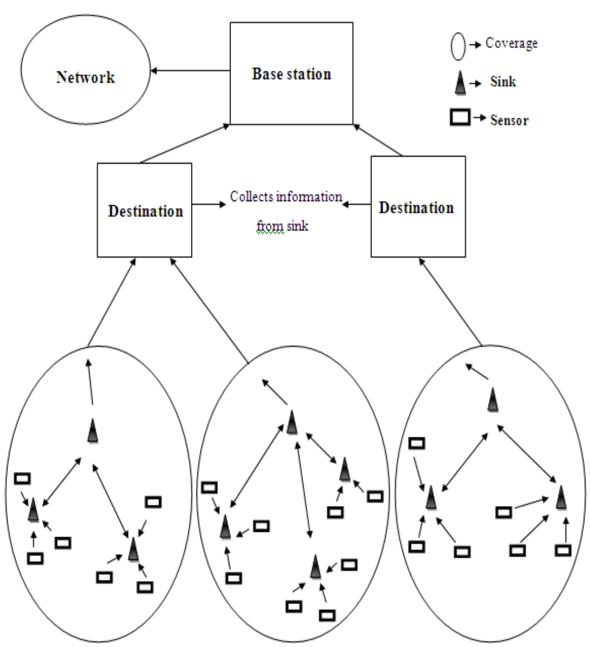

Fig.1 System Architecture

Figure.1 illustrates an architectural design for heterogeneous wireless sensor networks. The sensors monitor the target and transmit the monitoring results to the sinks which are nearer to it, based on ACO-MNCC. Here it uses more sinks to increase the sensor lifetime and network, as the sensor chooses the shortest path nearest to it. The time of sending monitoring results can be reduced due to the use of single sink, which lead to congestion between sensors and due to this the network lifetime decreases. To overcome this problem more number of sink has been used, the sinks relay the monitoring results to the destination (e.g., data processing centre).Therefore, a connected cover in the heterogeneous WSNs must satisfy the following three constraints: 1) The sensors form complete coverage to the target, 2) all the monitoring results obtained by the sensors are transmitted to the sinks, and 3) the sinks compose a connected wireless network. Once all the information transmitted to sinks by using the algorithm. The sink finally sent all information to destination.

5. Performance Analysis

In this section, a series of experiments are performed to evaluate the performance of ACO-MNCC. Since the proposed approach is the first algorithm for maximizing the number of connected covers in the heterogeneous wireless sensor networks, a greedy algorithm that applies the same heuristic information as ACO-MNCC is used for comparison. The effectiveness of pheromone, heuristic information, and local search procedure in the ACO-MNCC is also investigated.

5.1 Test cases

Two sets of heterogeneous WSNs with different scales and redundancy are employed in the experiments. For each case, a maximum number of connected covers have been generated depending upon the values. Based on an optimal solution of first case, a new case can be generated by removing redundant devices from the connected covers in the solution. The average value of maximum number of connected covers has been taken as C.

Test case 1

Figure.2 illustrates the convergence curves based upon pheromone and heuristic information. Here the curves have been drawn and illustrated based upon maximum number of connected curves, without pheromone and heuristic information. Based upon the result of case 1 the connected covers of case 2 curves have been generated.

Depending upon the maximum number of connected covers an optimal path has been generated through ant colony optimization. The curves are drawn without heuristic information and pheromone. Such that it shows the result of ACO-MNCC for both the cases and maximizes the result.

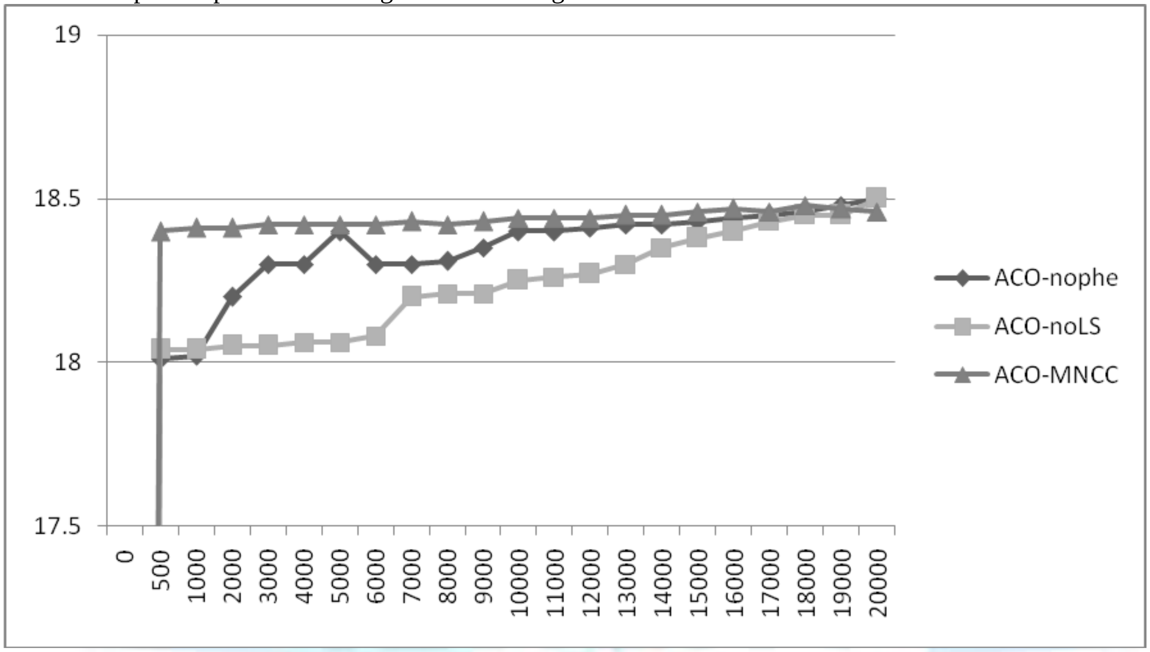

Fig.2 Convergence curves of ACO-MNCC, ACO-noLS, and ACO-noPhe on case 1.

Test Case 2

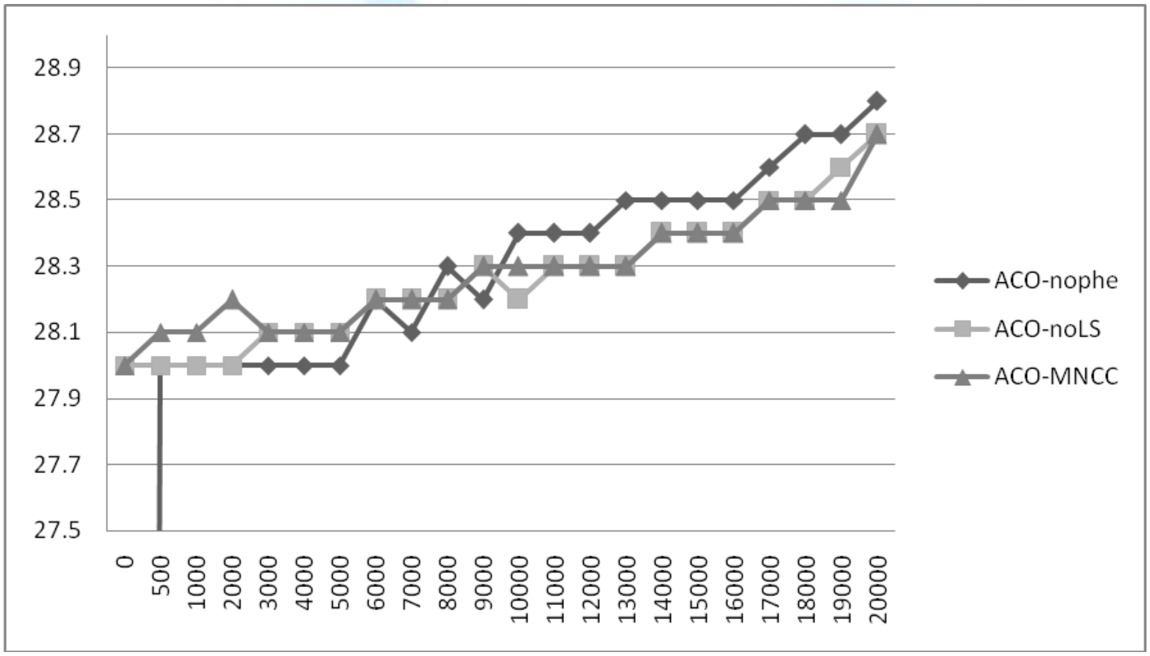

Fig.3 Convergence curves of ACO-MNCC, ACO-noLS, and ACO-noPhe on case 2.

6. Conclusion and Future Scope

This project provides a lifetime maximization of heterogeneous wireless sensor network and considered the problem of finding maximum number of connected covers. An ACO-MNCC (Ant colony optimization maximum number of connected covers) has been proposed, in order to overcome the problem of finding maximum number of connected covers. The approach searches for an optimal solution by always pursuing one more connected covers than best-so-far solution. The IACO approach improves the search efficiency by setting an explicit goal to ant. Pheromone and heuristic information are designed to accelerate search process. A local search procedure is proposed to refine the best-so-far solution in end of one iteration. The ACO-MNCC approach can be applied to both discrete point coverage and area coverage. The IACO framework can utilized for further reducing the computational time of ACO-MNCC while tacking with a large scale wireless sensor networks.

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