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# Swarm Intelligence Based Ant Colony Optimization (ACO) Approach for Maximizing the Lifetime of Heterogeneous Wireless Sensor Networks

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**Abstract**
This paper attempts to undertake the study of maximizing the lifetime of Heterogeneous wireless sensor networks (WSNs). In wireless sensor networks, sensor nodes are typically power-constrained with limited lifetime, and thus it is necessary to know how long the network sustains its networking operations. Heterogeneous WSNs consists of different sensor devices with different capabilities. We can enhance the quality of monitoring in wireless sensor networks by increasing the coverage area. One of major issue in WSNs is finding maximum number of connected coverage. This paper proposed a Swarm Intelligence, Ant Colony Optimization (ACO) based approach. Ant colony optimization algorithm provides a natural and intrinsic way of exploration of search space of coverage area. Ants communicate with their nest-mates using chemical scents known as pheromones, Based on Pheromone trail between sensor devices the shortest path is found. The methodology is based on finding the maximum number of connected covers that satisfy both sensing coverage and network connectivity. By finding the coverage area and sensing range, the network lifetime maximized and reduces the energy consumption

**Keywords—** Wireless Sensor Networks (WSN'S), Ant Colony Optimization, Connective Coverage, Network Lifetime.

## I. INTRODUCTION

The wireless sensor networks (WSNs) technology have been widely applied in military[1], industry, agriculture[2] and many other areas .In the WSNs, a lot of nodes operate on limited batteries, making energy resources the major bottleneck. Therefore, an economical and frugal management for improving the maximizing lifetime of wireless sensor is important. Wireless sensor networks (WSNs) consist of sensor nodes equipped with their own battery having limited lifetime, which makes the operations of network available only within a limited amount of time. It is crucial to examine and estimate how long the network is properly functioning, or network lifetime, after which the deployment of additional sensor nodes is inevitable so as to ensure the network connectivity and maintain the networking operations of interest, but requires lots of cost and effort. Hence, there has been much work on analyzing the network lifetime under a certain consideration and devising an algorithm or network protocol to prolong the network lifetime.

The existing methods for prolonging the lifetime of WSNs focus on the issues of device placement[5], data processing ,routing[6][7], topology management[11], and device control Device placement is a fundamental factor in determining the coverage, connectivity, cost and lifetime of a Wireless Sensor Network (WSN). In a WSN where devices are densely deployed, a subset of the devices can address the coverage and connectivity issues. The rest of the devices can be switched to a sleep state for conserving energy. Using device placement and routing techniques, finding coverage is difficult, because device in the sense sensors, when using heterogeneous WSNs connectivity problem occurs. In routing as router table increase finding coverage between the sensors are difficult. 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. But this also led to failure result .Later introduced hub-spoke topology [11]. This also teds some problem.

A number of methods have been proposed for finding one connected cover from a WSN. The connected cover obtained may be optimal under certain criteria, such as minimum size or minimum energy consumption. Nevertheless, generating a sequence of optimal connected covers by repeating the above methods may not lead to lifetime maximization. Maximizing the number of connected covers is a more direct way to maximize the network lifetime.

The problem of finding the maximum number of connected covers is difficult because each connected cover must fulfil sensing coverage and network connectivity simultaneously. Its sub problem of maximizing the number of subsets that fulfil sensing coverage is already in the non-deterministic polynomial time (NP) complete complexity class. Many methods focus on solving the above sub problem but ignore the issue of connectivity .These methods are able to maximize the lifetime of WSNs while maintaining both sensing coverage and network connectivity with a premise that the devices are identical and have a transmission range that is at least twice the sensing range. However, they cannot ensure the network connectivity when the required premise is not satisfied.

In existing system, it very difficult to use different sensors with different functionality and capabilities .All sensors sent monitored information to single sink as shown in fig
1, Due to this there May overlapping, collision may occur in networks. It's also difficult to find the maximize number of connected coverage and sensing range. It uses the greedy algorithm [8], which can be used for only in Homogenous Wireless Sensor Network. Finding optimal path between sensors and sink is difficult.

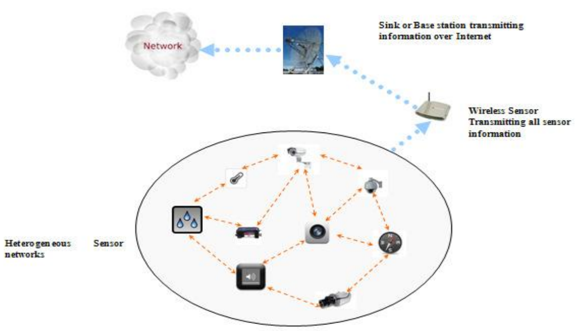


Fig 1: System Architecture of current WSNs

The proposed ACO-based approach for maximizing the number of connected covers (ACO-MNCC) first transforms the search space of the problem into a construction graph. Each vertex in the graph denotes an assignment of a device in a subset. Heuristic information is associated to each assignment for measuring its utility in reducing constraint violations. Pheromone is deposited between every two devices to record the historical desirability of assigning them to the same subset. In each iteration, the number of subsets is adaptively determined as one plus the number of connected covers in the best-so-far solution. The ants thus concentrate on finding one more connected cover and avoid constructing subsets excessively. A local search procedure is designed to refine the solutions by reassigning redundant devices. The ACO-MNCC is applied to 33 heterogeneous WSNs with different characteristics. Experimental results validate the effectiveness and efficiency of the proposed approach.

## II. PROPOSED SYSTEM

This paper proposes first ACO-MNCC based approach for maximizing the lifetime of heterogeneous WSNs by finding the maximum number of connected covers. Heterogeneous WSNs means sensor with different capability, how it works and how it maximizes the network lifetime.

Ant Colony Optimization (ACO) technique is an optimization technique to solve optimization problem [38] [40]. It has been developed for combinatorial optimization problems. ACO are multi-agent system in which the behavior of each single agent, called ant, is inspired by the behavior of real ants. In ACO, ants are stochastic constructive procedures that build solutions while walking on a construction graph. Such constructive search behavior makes ACO suitable for solving combinatorial optimization problems [40]. Besides, ACO utilizes search experiences (represented by pheromone) and domain knowledge (represented by heuristic information) to accelerate the search process. ACO algorithms have been successfully applied to a number of industrial and scientific problems [11]-[17]. In the fields of WSNs, ACO-based routing Algorithms have been used for improving the power efficiency in unicasting, broadcasting, and data gathering.

In This paper I also presents a new communication protocol for WSN called energy efficient ant-based routing algorithm (EEABR), which is based on the Ant Colony Optimization (ACO) met heuristic .EEABR uses a colony of artificial ants that travel through the WSN looking for paths between the sensor nodes and a destination node, that are at the same time short in length and energy-efficient, contributing in that way to maximize the lifetime of the WSN. Each ant chooses the next network node to go to with a probability that is a function of the node energy and of the amount of pheromone trail present on the connections between the nodes. When an ant reaches the destination node, it travels backwards trough the path constructed and updates the pheromone trail by an amount that is based on the energy quality and the number of nodes of the path.

## III. PRELIMINARY AND RELATED WORK

In this section, the problems of finding the maximum number of disjoint connected coverage between sensors are defined.

### 3.1 Problem Definition

Let as consider Randomly deploy a set of sensors (SE1,SE2,SE3…) and a set of sinks (SI1,SI2,SI3…) in an L × W area (| · | denotes the size of a set). Suppose, the
Sensors have a sensing range si and a transmission range rt. The sinks have a transmission range Rt larger than rt.

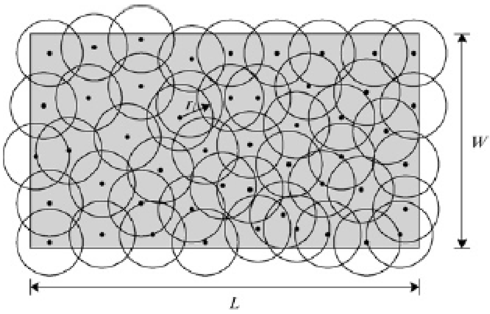


Fig 2: Illustration of complete coverage

The **collection constraint**, which requires the sinks to collect all the monitoring results obtained by the sensors in the same subset shown in fig 3.b.

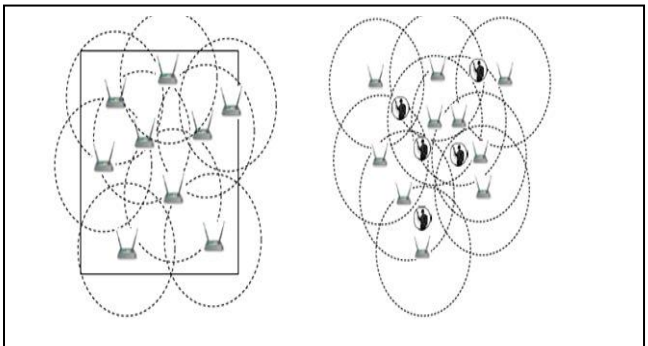

Fig 3: Two major types of coverage: area and target coverage (the big square on left denotes the covered area, the soldiers on the right denotes the covered targets)

The **routing constraint**, which requires the sinks to form a connected network for transmitting the collected monitoring results to the destination.

### 3.2 Proposed System Architecture

The sensors monitor the target and transmit the monitoring results to the sinks which are nearer to it, based on ACO-MNCC. Here I used more sinks to increase the sensor lifetime, as the sensor chooses the shortest path nearest to it as shown in Fig 4.The time of sending monitoring results can be reduced.In existing they used single sink, which lead to congestion between sensors, due to this the network lifetime decrease. The problems can be classified in the 3 types area coverage sensors cover an area, point coverage. 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 sink using the algorithm. The sink finally sent all information to destination by doing this the life time of WSNs increases.

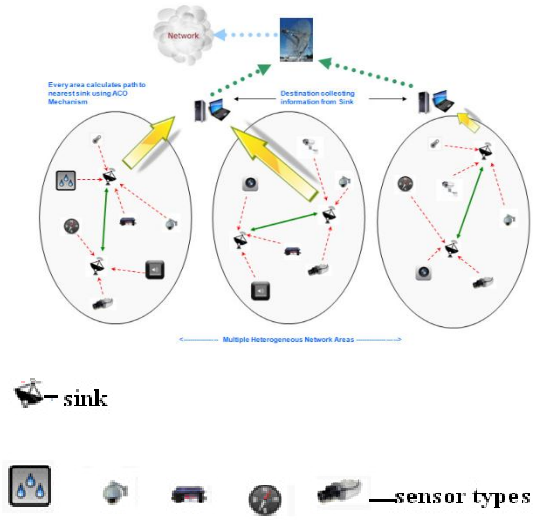


Fig 4: Heterogeneous Wireless sensor Networks – Proposed System Architecture

## IV. MODULE DESCRIPTION

### 4.1 Ant Colony Optimization algorithm concepts

Many of the existing solutions to this problem come from the field of Evolutionary Computation .After analyzing them; we noticed that these interesting developments are quite similar to ACO algorithms [11], [12]. The relation between ACO algorithms and evolutionary algorithms provides a structural way of handling constrained problems. They have in common the use of a probabilistic mechanism for re-combination of individuals. This leads to algorithms where the population statistics are kept in a probability vector. These probabilities are used to generate new solutions in iterations. The new solutions are then used to adapt the probability vector.

Real ants foraging for food lay down quantities of pheromone (chemical cues) marking the path that they follow [14], [15]. An isolated ant moves essentially guided by a heuristic function and an ant encountering a previously laid pheromone will detect and decide to follow it with high probability thus taking more informed actions based on the experience of previous ants (and thereby reinforce it with a

further quantity of pheromone). The repetition of the above mechanism represents the auto-catalytic behavior of real ant colony where the more the ants follow a trail, the more attractive that trail becomes.
Ant colony optimization is a class of optimization algorithms modeled on the actions of an ant colony. Artificial 'ants' - simulation agents - locate optimal solutions by moving through a parameter space representing all possible solutions. Real ants lay down pheromones directing each other to resources while exploring their environment. The simulated 'ants' similarly record their positions and the quality of their solutions, so that in later simulation iterations more ants locate better solutions as shown in fig 5. The technique can be used for both Static and Dynamic Combinatorial optimization problems. Convergence is guaranteed, although the speed is unknown

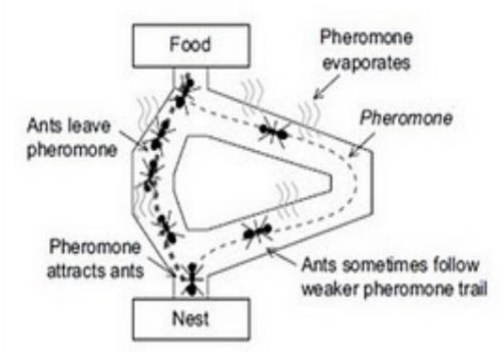


Fig 5: Ant pheromone evaporations in path

**4.2 Sensor components**
The considered heterogeneous WSNs comprise two types
of devices: sensors and sinks. Heterogeneous WSNs place the sensors and sinks in area coverage and checks the coverage to each sensor which monitors, that information are transmitted to sink**.**

**4.3 Sink utility service**
The sinks relay the monitoring results to the destination (e.g., data processing center), based on performance of ACO-MNCC routing. Finally routing between sink and destinations are performed.

## V. Ant Colony Optimization- Based Approach for Maximizing the Number of Connected Covers

In this section, we introduce the ACO-MNCC approach for maximizing the number of connected covers in a heterogeneous WSN. First, the objective function is formulated. The ants search behavior is then described.

**5.1 Objective Function**

1) Criterion for the Coverage Constraint.
2) Criterion for the Collection Constrain.
3) Criterion for the Routing Constraint

It can be observed that the objective function has two components. The first component summarizes the constraint violations of all the subsets. The second component awards the objective value based on the number of connected covers. Since the goal of ACO- MNCC is to find a solution that maximizes the number of connected covers.

**5.2 Working conditions of Ants between sensors and sink:**

In ACO, an ant's search behavior is mainly influenced by three components: the construction graph, the solution construction rule, and the pheromone management. The following sections describe the three components:

a. **Construction Graph with pictorial representation**:

Construction graph consist of different sensors and sinks. Based on algorithm of ant colony optimization the sensor finds shortest path between sinks and destination.

b. **Construction Rule:**

The construction rule of ACO guides the ants to build their own solutions by selecting vertices from the construction graph. In ACO-MNCC, the construction rule guides an ant to assign each device to a subset. The core of the construction rule, as in other ACO algorithms, is the design of pheromone and heuristic information. In ACO-MNCC, 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, after an ant has finished building its solution.

c. **Pheromone Management:**

The pheromone management in ACO-MNCC comprises the local pheromone, which helps an ant organize its coverage set with fewer sensors. The global pheromones, one of which is used to optimize the number of required sensors, and the other 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.

## VI. PERFORMANCE EVALUATION

Various performance metrics are used for comparing different routing strategies in WSNs. We have used the following:

**A. Average Energy:** The metric give the average of energy of all nodes at the end of simulation.

**B. Energy consumption:** The metric gives the energy consumption of nodes in the event area for transmitting a data packet to sink.

**C. Network lifetime:** This metric gives the time of the first node running out of its energy and How to increase the lifetime.

## VII. EXPERIMENTS AND SIMULATION DISCUSSIONS

This section of the paper discusses the simulation of the proposed routing protocol and evaluates its performance. To be able to evaluate the implementation of the proposed ACO routing, simulation was carried out in Java Agent Development Framework (JADE-1.6), a scalable discrete- event simulator Developed byJDK1.6. This software provides a high fidelity simulation for wireless communication with detailed link between sensors and sink. We compare the ACO routing protocol with sensor network. This demonstrates the increased WSNs lifetime.

Based on 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 heterogeneous WSNs, a greedy algorithm that applies the same heuristic information as ACO-MNCC is used for comparison. The effectiveness of pheromone, heuristic in- formation, and local search procedure in the ACO-MNCC is also investigated.

In this project I used java swings to represent graphical user interface(GUI) .GUI is used for representing the area map and coverage, and JADE frameworks is used for communication between sensors and sinks. In JADE container all information about the sensors can be stored. Finally configurations are set for linking JADE and JAVA as shown in fig 6

### A. Graphic User Interface (GUI)

Heterogeneous Wireless sensor Network application will be developed using Java Swing application. GUI acts a governing module of entire application and binds all other module intact as shown in fig 7, fig 8.

### B. GUI Application areas

Application has several military areas collecting various information 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 as shown in fig 7.

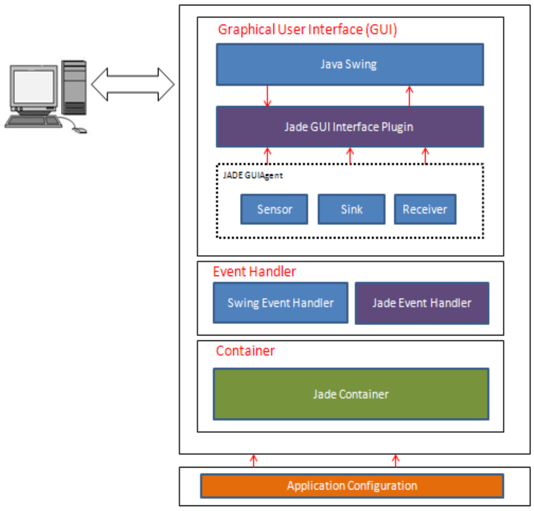


Fig 6. Technical architecture using Simulator- java agent development framework (JADE).

### C. GUI Event Handlers

As we know that 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 as shown in fig 8.

### D. 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 as shown in fig 8.

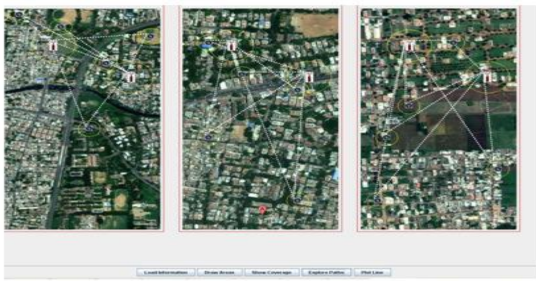

Fig 7: Application of area map and coverage of Sensor

### E. Application 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 as shown in fig 8.

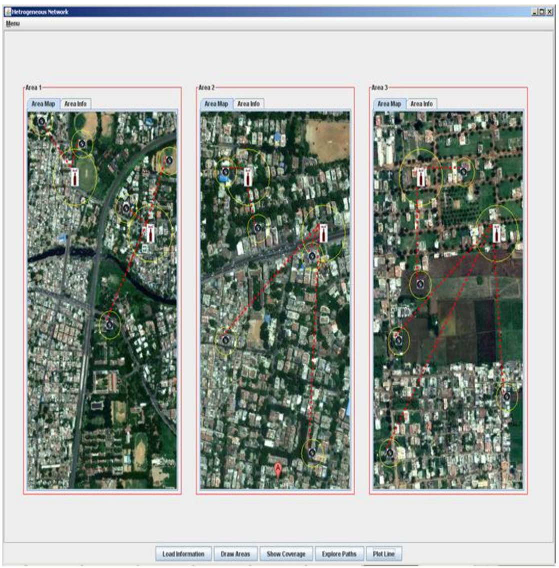

Fig 8: routing between sensors and sink using ACO algorithm.

## VIII. CONCLUSION

In this paper, we presented a new objective for maximizing the network lifetime using ACO-MNCC algorithm to increase network lifetime and balance the node power consumption and as long as possible. The idea behind the ACO-MNCC is simple using the lowest energy path always is not necessarily best for the long- term health of the network, because it would cause the optimal path quickly get energy depleted. The approach searches for the optimal solution by always pursuing one more connected cover than the best-so-far solution. This way, the approach not only avoids building excessive subsets but also improves the search efficiency by setting an explicit goal for the ants. Pheromone and heuristic information are also designed to accelerate the search process for prolonging the network lifetime. ACO-MNCC is a promising method for prolonging the lifetime of heterogeneous WSNs. Extensive simulation result clearly shows that the proposed approach provides more approximate, effective and efficient way for maximizing the lifetime of heterogeneous wireless sensor networks.

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