# Cluster Head Selection Using Modified ACO

**Varsha Gupta and Shashi Kumar Sharma**

**Abstract** WSNs have limited computation power, battery life, and memory resources. In this paper, an approach is introduced to selection cluster head by using swarm intelligence. This proposed approach is based on LEACH clustering algorithm. Modified version of ant colony optimization by using residual energy as a parameter is employed over LEACH algorithm for effective cluster head selection. This approach reduces the amount of energy consumption. The proposed technique work in three stages: Cluster members transmit their data directly to their cluster heads, cluster heads transmit their data to leader, and leader transmits data to the base station. The result shows that LEACH-MA algorithm improves the average energy consumption effectively.

**Keywords** LEACH · ACO · Pheromone · Sensors

## 1 Introduction

A wireless sensor network (WSN) is a large collection of tiny self-aware, analyzable sensor devices that can perceive environmental parameters and detecting emergency events in various different applications. The three key elements of WSN, i.e., monitoring, computing, and communication whose combination in one sensor device provides ample number of remote sensing applications [1, 2]. Due to its vast and distinguishable applications, efficient design and implementation of WSNs [3, 4] makes it an influential area of research. In sensor network, there are three main components which are the sink, monitored events, and sensor nodes from a few to

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several hundreds or even more than hundreds. Due to mobility of node, routing of data becomes more challenging since stability of route is more important factor, in addition to energy, bandwidth, etc. A sensor network device consists of different components: a radio transceiver with an internal and an external antenna, a memory unit, an electronic circuit for interfacing with the sensors and a power source, and generally a lithium (Li-ion) battery which is non-renewable. A sensor node may change in size and cost, depending on the complexity and some factor such as energy, memory, computational speed, and communications bandwidth of the individual sensor nodes.

Base station provides strong processing unit and storage capacity, and it acts as an access point to each sensor node in the network. The aim of WSN is to sense environment, collect data, and communicate that data to the base station or sink node. The remaining paper is distributed as follows: Sect. 2 described related work, Sect. 3 explained the background, Sect. 4 discussed proposed algorithm and its implementation, and Sect. 5 presented simulations and results analysis, and conclusions are provided in the last section.

## 2 Related Work

Numbers of important issues are related to develop low power wireless sensor application, i.e., using available energy in the most efficient way, without compromising performance [5]. Sensor nodes use batteries as power source and have quite limited lifetime. So efficiency of energy management becomes a key requirement in wireless sensor network design [6]. Due to the nodes of WSN have limited power constrain and WSN are deployed in challenging conditions, a radio device is employed for wireless communication to transmission of data to sink node [1]. The routing protocols in sensor networks could be classified into three categories: flat-based, hierarchical-based, and location-based routing. LEACH protocol is grouped in hierarchical routing approaches of wireless sensors networks [7]. LEACH [8] protocol is an organizing, by itself, robust clustering protocol [7]. LEACH is the earliest proposed single-hop cluster routing protocol in WSN; it can save network energy greatly compared with the non-cluster routing algorithm [9]. The effectiveness of LEACH protocol in cluster head selection is not optimized because of the probability model. An improved clustering algorithm is proposed which takes node's residual energy and location information into account, optimizes the selection method of the threshold for electing cluster head, and improves optimal cluster head selection strategy, that is, normal nodes select the effective cluster head on the basis of cost function [9]. If the number of cluster heads can be optimized, the energy consumption of the sensor nodes can be more evenly distributed in the WSNs. It can avoid extra energy consumption of single node to untimely death, which directly affects the network life cycle [10]. Ant colony algorithms (ACOs) are speculative procedures for searching. The essential component of ACO is the pheromone model, which is used to equally sample the search space [11]. Ant colony algorithm is applied on routing mechanism for finding the best path from cluster heads to base station by which the energy consuming of cluster heads node was decreased [12]. Applying the concept of an enhanced ant colony in WSNs, for finding the optimal paths from the source nodes to the base station, where each node maintains its probabilistic routing table, because of that, it also called as pheromone tables [13]. On the basis of the death of first node, ant colony applied on LEACH protocol in the WSN [14]. Proposed algorithm is dedicated to the survival of the network lifetime, which affects the performance of LEACH protocols in terms of energy consumption.

# 3 Background

## *3.1 Ant Colony Algorithm*

The basic concept of ACO [11] is taken from the behavior of real ants. Initially, each ant traverses the area surrounding their ant hill in random manner while searching for food. When ant finds a food source, then they estimate the quantity and the quality of the food and carry some of food back. While going back to their ant hill, each ant deposits a chemical pheromone on the path. The amount of pheromone is deposited, which may depend on the quantity and quality of the food. This pheromone amount will guide other ants to find the food source. As a result of this phenomenon, the optimal solution derives rapidly [13]. By using this behavior of the ants, optimal cluster head can be selected.

## *3.2 Network Environment*

A sensor network can be considered as a directed graph G(V,E), where V is the set of sensors nodes and E is the set of path connecting nodes in the network.

In this paper, the number of assumptions is adopted which are given below:

1. 100 sensor nodes are uniformly distributed within a monitoring area. Each sensor nodes has its unique identification.
2. All sensor nodes are static, or there is less mobility factor after being deployed.
3. The sensor nodes energy is non-renewable.
4. Sensor nodes are unaware from their exact location; there should not be any computation for finding the location.
5. Data transmission is performing on a node-to-node link.

# 4 Implementation and Proposed Algorithm

Using the concept of ant colony algorithm in WSNs, each node calculates its probability by using the pheromone to be elected as a cluster head.

In this section of paper, the basic idea of proposed algorithm is summarized. Initially, modified ant colony optimization is explained, and then, proposed LECH-MA algorithm is described.

## 4.1 Modified Ant Colony Algorithm

As explained in Sect. 1, wireless sensors devices are power constraint, i.e., the cluster head selections should be determined not only in terms of probability, but also in terms of the power and distance between node and the base station. For an instance, it would be preferable to choose a longer distance node with high energy than a shorter distance node with very low energy.

According to proposed algorithm, the working of ants is given below: First of all, each ant selects its next cluster head on the basis of initial rule, and then, each ant elects the optimal cluster head by the use of revising rule.

1. Initial rule:
   Suppose the ant is placed on cluster head node i, the probability of an ant choosing the next node j as cluster head according to Eqs. (1) and (2):

$$\mathrm{Prob_i}(t) = \frac{\mathrm{dist_i} * \alpha + [ph_\mathrm{i}(t)] * \beta}{\sum_{1=0}^{N_\mathrm{i}} \mathrm{dist_i} * \alpha + [ph_\mathrm{i}(t)] * \beta} \tag{1}$$

where

| | |
|---|---|
| $\mathrm{Prob}_i$ | gives the probability of each node to be selected as a cluster head; |
| $\mathrm{dist}_i$ | is the distance of node. |

$$\mathrm{ph}_i = \frac{\tau_{i.j}^{\alpha} * [\eta_i(t)]^{\beta}}{\sum_{1=0}^{N_i} \tau_{i.j}^{\alpha} * [\eta_i(t)]^{\beta}} \tag{2}$$

| | |
|---|---|
| $\tau_{ij}$ $(t)$ | is the pheromone intensity; |
| $N_i$ | is set of nodes in the cluster; |
| $\alpha$ and $\beta$ | are control parameters; and |
| $\eta_{\mathrm{ij}}$ | is a heuristic function, and it can be defined as Eq. (3) |

$$\eta_i = \frac{1}{I\mathrm{e} - e} \tag{3}$$

where

$I_e$ is the initial energy level of the nodes;

$e$ is the actual energy level of nodes. This enables an ant to make a decision according to residual energy that means if a node has a low power, then it has low probability to be chosen as the head of cluster

2. Revising Rule:

When ants traverse in search of next possible cluster head, the amount of pheromone on the elected node $\tau_{i,j}$ $(t)$ is revised according to Eq. (4).

$$\tau_{i,j}(t+1) = (1-\rho)\tau_{\mathrm{i,j}}(t) + \rho\Delta\tau_{i,j}(t) \tag{4}$$

where

$\rho$ is the parameter for the local pheromone corrosion;

$\Delta\tau_{ij}$ $(t)$ is pheromone enhancement.

## *4.2 Description of LEACH-MA*

Proposed algorithm low energy adaptive cluster hierarchy routing based on modified ACO (LEACH-MA) is improvement over LEACH protocol. LEACH uses a probability model for taking the decision of cluster head selection. In proposed approach, the distances as well as energy as parameters are combined to judge an effective cluster head on dual stage.

The proposed algorithm has the following steps:

For each round:

1. According to LEACH [8], CHs and the CNs are selected from each cluster.
2. Each node has to calculate its pheromone value that depends on the energy of the node and find the probability which depends on the pheromone and the distance to chosen as CH.
3. Update final set of cluster heads on the basis of comparison between the probability and threshold factor of CH and the CNs of the cluster.
4. Update pheromone value of selected CHs.
5. TDMA schedule is assigned to each node by its CHs, assigned time schedule is used to transfer the data from CNs to CHs.
6. Find maximum probability of CHs and select CH as CH Leader.
7. CH sends data to their CH leader.
8. CH leader transmitted data to the sink node.

## 5 Analysis of Simulations Results

In this section, we have discussed the analysis of simulations results.

### *5.1 Simulation Environment*

The proposed algorithm is simulated using MATLAB.

The simulation is tested for random 100 node network. The location of base station was selected at (50,175) in network.

The reference network used in simulation has 100 nodes, in a 10 × 10 square field. Each node has 0.5 J of initial energy. The packet size is 2,000 bits, and 0.05 % of the nodes are selected as cluster heads.

### *5.2 Simulation Results*

To prove the advantage of the proposed algorithm, we have compared it with LEACH. The results of simulation for the system lifetime and energy consumption as a function of round are shown in Figs. 1 and 2. Table 1 shows the comparison of lifetime of both approaches, and Table 2 shows the comparison of energy consumption by using both algorithms (Figs. 3 and 4).

The proposed approach proved that slow energy consumption of the network and it increases the lifetime of the network.

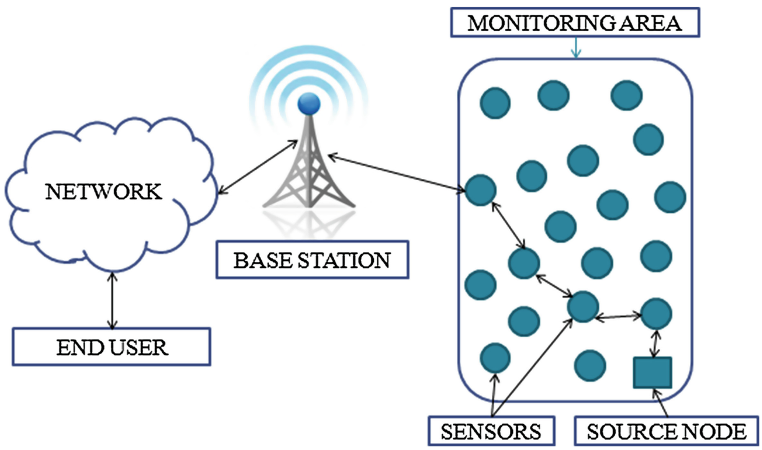


**Fig. 1** Architecture of WSN

**Fig. 2** Flow diagram

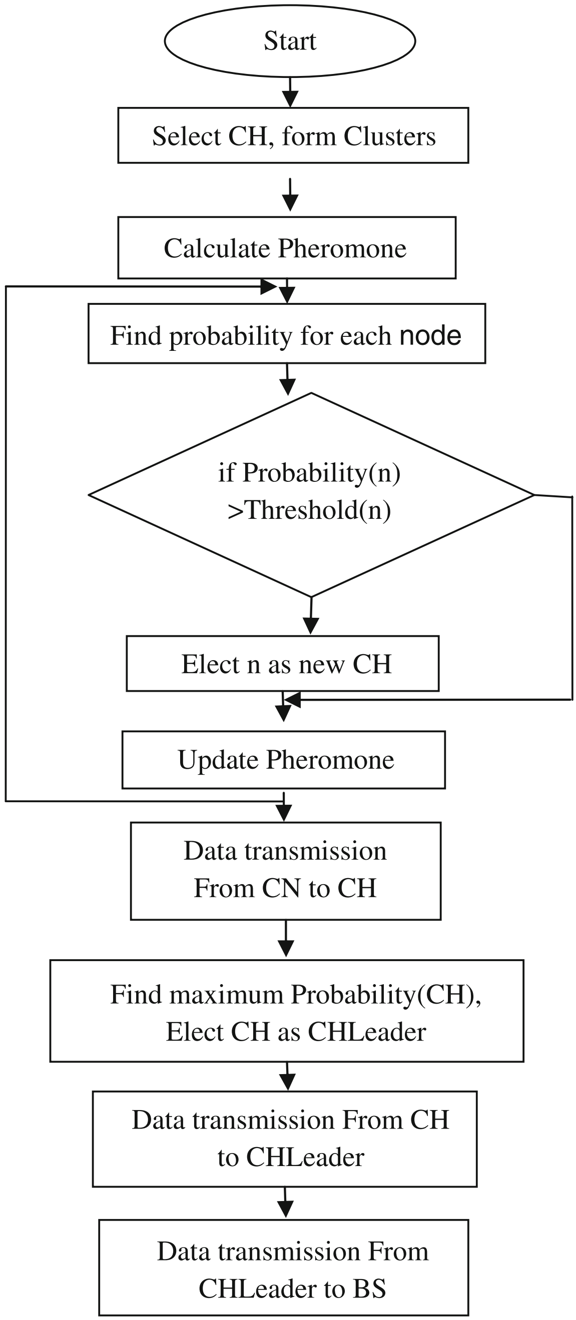

**Table 1** Lifetime of network

| Methodologies | Number of rounds | | |
|---|---|---|---|
| | First node die | Half node die | Last node die |
| LEACH | 55 | 165 | 230 |
| LEACH-MA | 100 | 260 | 345 |

**Table 2** Energy consumption

| Methodologies | Number of rounds |
|---|---|
| LEACH | 225 |
| LEACH-MA | 280 |

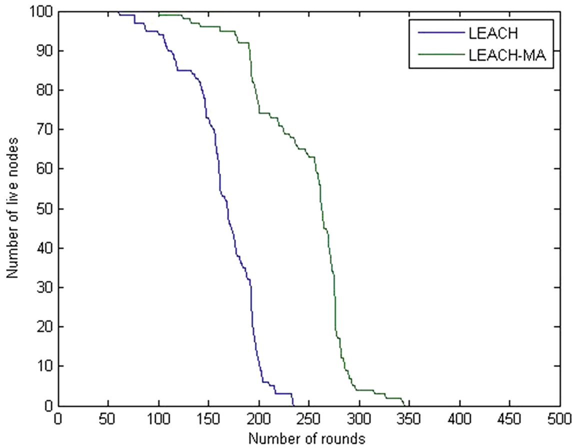


**Fig. 3** Comparison between numbers of live nodes versus number of rounds in terms of network lifetime

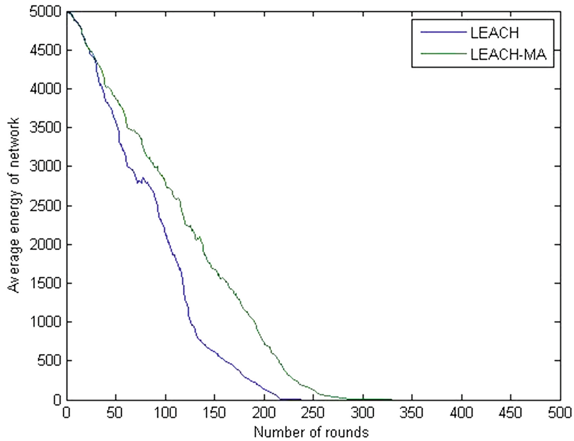


**Fig. 4** Comparison of average energy of network versus number of rounds the energy consumption

## 6 Conclusion and Future Work

On the basis of LEACH protocol, this paper proposes a modified ant-based cluster head selection algorithm for effective cluster head selection on dual phase. This algorithm considers the residual energy and distance factors as parameters, to improve cluster head selection. The main goal of LEACH-MA is to enhance network lifetime as well as to improve the power consumption of the network. Simulation results show that LEACH-MA is more energy efficient than LEACH. As the WSN has data redundancy, how to design and realize routing protocol with optimal data aggregation will be our future research work.

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