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A Load Balancing Energy Efficient and Optimized Clustering in Mobile Ad hoc Network using Ant Colony Optimization

[1]Jeena John, [2] Pushpalakshmi R.

[1]PG Student, PSNA College of Engineering & Technology, Dindigul-624622, Tamilnadu, India

[2]Associate Professor, PSNA College of Engineering & Technology, Dindigul-624622, Tamilnadu, India

E-mail: [1]jeenajohnk@gmail.com, [2]pushparaman@rediffmail.com

ABSTRACT

A mobile ad hoc network (MANET) is a self-configuring network of mobile devices connected by wireless links. The optimization of energy consumption and stability of the node have been identified as key problems in mobile ad hoc networks. Clustering of mobile nodes among separate domains has been proposed as an efficient approach to address those issues. This paper presents an effective algorithm that prolongs the network lifetime by selecting cluster heads in mobile ad hoc networks using Ant Colony Optimization (ACO). The algorithm considers various parameters such as residual energy, energy drain rate, mobility factor and overall communication workload. In the simulation study a comparison was conducted to measure the performance of our algorithm with Weighted Clustering Algorithm (WCA) in terms of energy consumption, communication workload and network lifetime. The result shows that our proposed work performs better than existing one and it results in more energy efficient and stabilized clusters.

Keywords:*Ant Colony Optimization, Clustering, Mobile Ad hoc Networks, workload*

1. INTRODUCTION

Mobile ad hoc networksare collection of mobile nodes with no centralized administration. It is capable of handling dynamic topology. Nodes in the ad hoc network are mobile in nature and can enter or leave the network as they wish. Every node acts as a host as well as a router. An ad-hoc network does not have any pre-established infrastructure and it forms a temporary network. Ad-hoc networks are useful in many situations where improper communication facilities are required. It is most useful in mobile communication where fixed infrastructure is unavailable. However, clustering in ad hoc networks faces many difficulties. Many clustering approaches have been proposed to handle these problems.

Clustering in ad hoc networks provides significant support for implementation of quality of services by overcoming the network deficiencies such as lack of infrastructure, dynamic topology etc. Clustering is a process that divides the network into interconnected substructures called clusters. Each cluster has a cluster head that acts as cluster coordinator. The cluster head play the role of temporary base station within its cluster and manages inter and intra cluster communication. The clusters are maintained using specific protocols and algorithms.

Ant Colony Optimization (ACO) is a paradigm for designing meta-heuristic algorithms for the discrete optimization problems. This paper presents Ant Colony Optimization for clustering in ad hoc networks. The first algorithm which can be classified within this framework was proposed by Marco Dorigo in 1991. The ant colony optimization meta-heuristic is a parallel searching algorithm which is highly adapted to the current topology of the network. In ant colony optimization a set of software agents called artificial ants searches good solutions for the optimization problem. Here the optimization problem is transformed into the problem of finding the best path on a weighted graph. In comparison with other approaches, the ant colony optimization meta-heuristic works by using local information.

The remainder of this paper is structured as follows: In section 2, the different clustering approaches and well known algorithms based on Ant Colony Optimization are described. The cluster head selection and optimization algorithm is discussed in section 3. Simulation results obtained are discussed in Section 4. Finally, conclusion is presented Section 5.

2. RELATED WORK

Many clustering algorithms have been proposed for MANET. Some of the existing algorithms present advantages but some have drawbacks. Each of them is briefly discussed as follows. Entropy-based weighted clustering algorithm [1] overcomes the drawback of WCA by forming more stable network. In WCA high mobility of nodes increases network overhead. Entropy-based weighted clustering algorithm uses an entropy based model for selecting the cluster head. Entropy is a measure of the disorder in a network and it is an indicator of the stability and mobility of the ad hoc network. In Connectivity, energy & mobility driven weighted clustering algorithm (CEMCA) [2], the election of the cluster head is based on the parameters such as the lowest node mobility, highest node degree, highest battery energy and best transmission range.

In [3], S. Muthuramalingam et al., proposed a modified algorithm that uses Weighted Clustering Algorithm (WCA) for cluster formation. It maintains cluster based on prediction of the mobility of nodes. The node with the lowest weight is chosen as the cluster head. When compared with WCA, the algorithm results in better performance due to the use of mobility prediction mechanism in cluster maintenance phase. R. PandiSelvam and V.Palanisamy presented a stable and flexible weight based clustering algorithm for mobile ad hoc networks in [4]. The proposed algorithm is a 2-hop clustering algorithm. The performance of the proposed clustering algorithm showed that it outperformed the existing LID, HD and WCA. Mohammad Reza Monsef et al., presented an efficient weight-based clustering algorithm (EWBCA) for mobile ad hoc networks in [5]. It improves the usage of bandwidth and energy, minimizes routing overhead, and increase end-to-end throughput. The cluster head election is based on the parameters such as number of neighbors, residual power of battery, stability and variance of distance with all neighbors. Mohammad Shayesteh and NimaKarimi presented a new clustering scheme named Innovative Clustering Algorithm for MANETs Based on Cluster Stability in [6]. In this approach the node weight is calculated based on the parameters such as relative speed, stability, number of nodes moving towards a node and remaining battery. The goal of this algorithm is to reduce the number of re-clustering process, to maintain stable clusterstructure and to maximize node lifetime.

The ACO is a meta-heuristic approach which provides approximately optimized routing. Several well known algorithms which are based on ant colony optimization are discussed as follows: GPS/Ant-Line Routing Algorithm (GPSAL) [7] is proposed by DanialCamra et al. In GPSAL, the routing is based on the local information. GPSAL algorithm provides better performance with less routing overhead. Mohammad Golshahi et al presented a hybrid routing algorithm for MANETs in [8] named as Node Neighbor Number Algorithm (NNNA) which has reactive as well as proactive behavior. The performance of NNNA algorithm is better in situation with high speed moving, outspread and dense networks.

John S. Baras and Harsh Mehta presented a reactive algorithm named as Probabilistic Emergent Routing Algorithm (PERA) [9] inspired by swarm intelligence. This algorithm decreases routing overhead and improves the efficiency of the route discovery. Ant Routing Algorithm for Mobile Ad-hoc networks (ARAMA) algorithm [10] was proposed by O. Hussein and T. Saadawi. ARAMA is a self configured routing protocol for MANET that combines both on-demand and table based routing features. It promises the extension in node lifetime. Ant-based Dynamic Zone Routing Protocol (AD-ZRP) [11] was proposed by Alexandre Massayuki Okazaki and Antonio Augusto Frohlich. The AD-ZRP is a multi-hop and self-configuring reactive routing approach which is based on ACO and ZRP. AD-ZRP causes lower routing overhead due to the reduction of ants in the network. It has higher data packet delivery ratio and lower brokenroutes ratio. Tiago Camilo et al., presented a new energy constrained routing protocol based on Ant Colony Optimization for Wireless Sensor Networks, named as Energy-Efficient Ant-based Routing algorithm (EEABR) in[12]. This approach results in the reduction of communication load and the energy consumption. LEACH-P is an energy aware routing algorithm proposed by Liao Ming-hua et al. It is based on ant colony principle and applies Low Energy Adaptive Clustering Hierarchy (LEACH)[13] protocol for wireless sensor networks. This approach results in the minimization of energy consumption during the data transmission. Particle swarm optimization based secure QoS clustering algorithm proposed in [14] partition the network into clusters based on node's QoS parameters such as trust value, lifetime, and available bandwidth.

Our Contribution

The optimization of quality of services of the node has been identified as key problems in mobile ad hoc networks. Clustering of mobile nodes is an efficient approach to address those issues. Ant colony optimization can be used as a powerful algorithmic framework that can solve various types of optimization problems. In this work, we introduce an effective algorithm that prolongs the network lifetime by selecting cluster heads in mobile ad hoc networks using Ant Colony Optimization. It considers parameters such as communication workload, node lifetime, and mobility for cluster optimization. Our algorithm performs better than existing active clustering methods and it results in more energy efficient and stabilized clusters.

3. RELATED WORK

3.1 PRELIMINARIES

The network is partitioned into group of clusters. The clustering process start with set of randomly generated ordered list of cluster heads such that the cluster heads and their cluster members are always within transmission range. Due to the absence of no central administrative control in MANET, the cluster head act as coordinator in its cluster. The selection of cluster head is based on probability function computed based on different parameters. The parameters used for computation are as follows.

Node lifetime [15]**:**

$$NLT = \frac{E_r}{E_{dri}} \quad (1)$$

Where, E_r is the residual energy of node *i* and E_{dri} is the energy drain rate.

Residual energy:

$$E_r = E_{init} - (R_{si}E_{si} + R_{di}E_{ri} + R_{fi}\ (E_{si} + E_{ri})) \quad (2)$$

Where, E_{init} is initial energy, R_{ri} is packet transmission rate for sender, E_{si} is energy for sending, R_{di} is packet transmission rate for destination, E_{ri} is energy for receiving, R_{fi} is packet transmission rate for forwarding.

Drain Rate [15]**:**

$$E_{dri} = \alpha\, E_{drold} + (1-\alpha)\, E_{drnew} \quad (3)$$

Where, α is selected between 0 and 1 that gives higher priority to updated information. Total energy consumption is calculated periodically for every *T* sec by every node. The drain rate is computed by exponentially averaging the values of previous and newly computed drain rate values.

Mobility factor [16]**:**

$$M = AD_t - AD_{t-1} \quad (4)$$

Where, *AD* is the average distance.

Distance:

$$D_{A,B} = \sum \sqrt{(\,(x_2 - x_1)^2 + (y_2 - y_1)^2)} \quad (5)$$

The distance between two nodes *A* and *B* is the number of hops between them.

Average distance:

$$AD = \frac{1}{N}\sum_{i=1}^{N} D_{A,i} \quad (6)$$

Where, *N* is the degree of *A*. If *AD* = 2, then the majority of neighbors are within 2 hops.

Probability function [17]**:**

$$P_{CH(i)} = \frac{[NLT(i)]^{\eta} * \left[\frac{1}{M(i)}\right]^{\mu}, i \in cluster}{\sum_{j \in cluster} [NLT(j)]^{\eta} * \left[\frac{1}{M(j)}\right]^{\mu}} \quad (7)$$

Where, $P_{CH(i)}$ is the probability value of node computed by using node life time and the mobility of node within the cluster.$\eta$and μ are the adjustable weights of *NLT(i)* and *M(i)* respectively. The optimization of cluster head selection is carried out by dynamically varying the values of η and μ. A higher value of η increases the chance for an ant to choose the node with more lifetime as the cluster head. A higher value of μ increases the chance for an ant to choose the node with more stable as the cluster head.

Communication workload [18]**:**

$$k_v(t) = \begin{cases} k_v^M(t) + k_v^c(t), cluster\,head \\ k_v^M(t), cluster\,member \end{cases} \quad (8)$$

Where, $k_v^c(t)$ denote the communication overhead of cluster head *c* and $k_v(t)$ denote the overall communication workload for node *v* at time *t*.

The communication workload of other cluster members which is denoted as:

$$k_v^M(t) = \frac{1}{T}\sum_{t'=t-T+1}^{t} k_v^M(t') \quad (9)$$

3.2 ALGORITHM

We present anclustering algorithm based on ant colony optimization. In this algorithm, the initial process involves the random generation cluster heads. The newly elected cluster heads broadcast the cluster head messages to all the nodes that lies within its transmission range. When the node $S_i$receives the message from the cluster head S_j, it computes the node lifetime and mobility. The value of $P_{CH(i,j)}$ is computed based on node's lifetime and mobility. The node $S_i$chooses to join the cluster head S_v *(v* = max($P_{CH(i,j)}$)) having maximum probability. The node joins as the member of S_v. The overall communication workload is calculated periodically. If the value of $k_v(t)$ is high, then the cluster head is reassigned. The clustering process is repeated until all nodes are dead.

Input: Instance $x \in Iof\Pi_{opt}$
  $i \leftarrow 0$
  Initialize $popu \leftarrow initial\ population()$
  with random solutions.
  while not termination condition **do**
    Calculate node lifetime
    Calculate Mobility
    Calculate probability function
    Calculate workload, $K_v(t)$
    $i \leftarrow i+1$
  end while
    $S_{best} \leftarrow optimal\ solution$
Output: S_{best}, " candidate" to be the best found solution $x \in I$

Fig.1 ACO algorithm for cluster head selection.

4. EXPERIMENTAL RESULTS

The performance of the proposed algorithm is evaluated by the simulation using NS2. Table I list out the simulation parameters. The experiment is conducted by varying the number of nodes present in the network and its transmission range. The algorithm was iterated number of times until it results in optimal solution. The number of ants used in simulation was 20 with value of η and μ as 8 and 2 respectively.

TABLE I
SIMULATION PARAMETERS

Parameter	Value
Nodes	50 – 400
Network Size	1000 X 1000
Trans.Range	200m – 400m
MAC	802.11
Traffic	CBR
Simulation Time	100s
Mobility model	Random Waypoint
Routing Protocol	CBRP

In this experiment, we measure the energy consumption of nodes in the network with varying time. The energy consumed by each node is extracted at every 10 ms of the simulation time. From Fig.2, we can observe that as the simulation time increases the energy consumptiondecreases as well. In addition, our proposed scheme outperforms WCA. At 30 ms, the energy consumption for WCA is 175000 nJ and that for our proposed scheme is 120000 nJ.

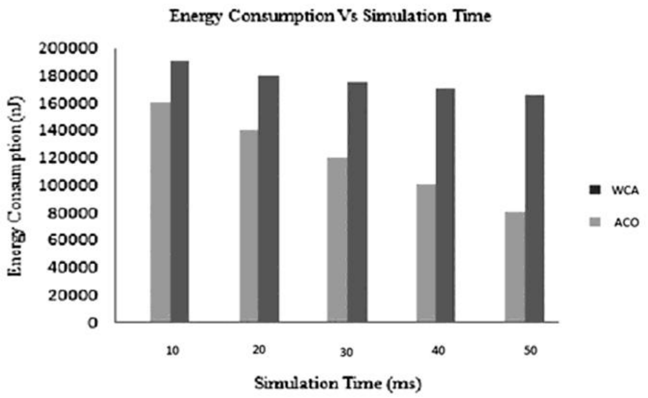

Fig.2 Energy consumption Vs Simulation time.

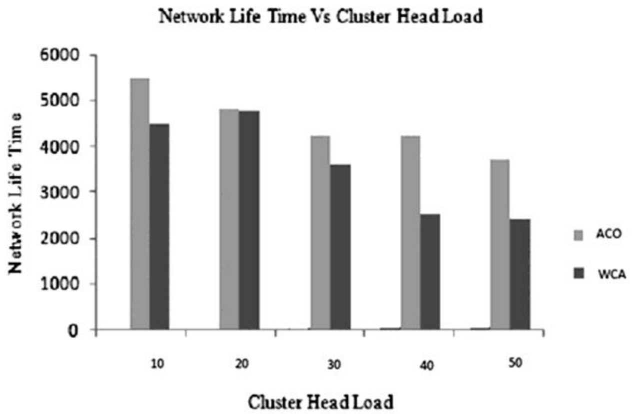

Fig.3Network lifetime Vs Cluster head load.

Fig 3 shows that the network lifetime decreases when the workload of cluster heads increases. When compared with WCA, the proposed scheme maintains a much higher network lifetime.

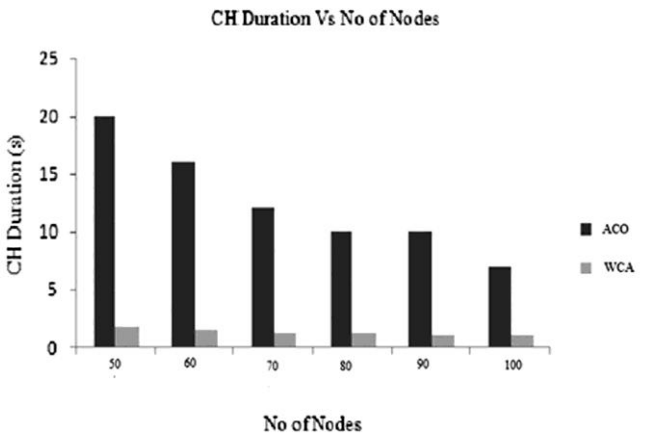

Fig.4Cluster head duration Vs No of nodes.

We first investigate the performance of clustering with respect to the number of mobile nodes, ranging from 50 to 100 nodes. We compare our algorithm against WCA. Fig 4 shows the average duration of cluster heads as we change the number of nodes in the simulation.

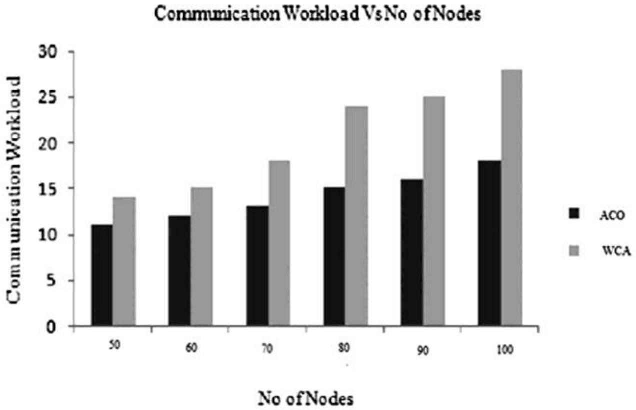

Fig.5Communication workload Vs No of nodes.

Fig 5 shows the maximum communication for cluster heads, averaged over the entire simulation run. The graph shows that our algorithm results in lower communication workload for cluster heads.

5. CONCLUSION

In this paper, we proposed an effective algorithm forselecting cluster heads in mobile ad hoc networks usingACO. The selection of cluster head is based on theprobability function which considers the parameterssuch as residual energy, energy drain rate and mobility.Re-clustering is done by considering the overall communication workload of the cluster head.This algorithm can increase the lifespan of the node inmobile ad-hoc network and hence of the whole network.We have simulated our algorithm and it is compared withWCA. Our proposed scheme outperforms WCA indifferent aspects such as energy consumption, networklifetime, duration of cluster heads and communicationworkload for cluster heads.

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AUTHOR PROFILES

Jeena Johnis a PG student of PSNA College of Engineering & Technology. **R.PushpaLakshmi**received the degree in computer science from Anna University, Chennai, in 2004. Currently, she is an Associate Professor at PSNA College of Engineering & Technology.