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Energy Optimization in Ad-hoc Networks Using Ant Colony Optimization

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Abstract*— MANET is known for its dynamic nature, heterogeneous devices and limited resources without any supportive infrastructure. Mobile devices in MANET have constrained resources like memory, energy, bandwidth etc. that must be optimally used in situations it is needed. The lesser a node uses these resources, lesser the energy consumption the network has. Various improvement methods have been proposed. Ant colony optimization is a population based autocatalytic technique of finding the best optimal solution in accordance with the natural actions of ants. Using ACO (Ant Colony Optimization) we need to update the local information only. This paper proposes an optimization of ad-hoc network in terms of energy utilization using ACO.

***Keywords*— MANET, energy optimization, ACO, ant colony, pheromone, ad-hoc network.**

I. INTRODUCTION

Since its inception in 1970s, mobile ad-hoc networks (MANET) have gained worldwide popularity due to its infrastructure less model and ready to use behavior. The devices are getting shorter, smarter and furnished with wireless capabilities in today's era due to which MANET is gaining popularity. The devices in MANET vary in size, platform, operating system, speed etc. Each node is an independent router. In ad hoc network, all the nodes move freely and independently, so topology is highly dynamic. Maintaining continuous communication between these devices without a centralized infrastructure is a challenging task. Moreover, the problem of limited resources amplifies the challenges. Node energy is one of the limiting resources need to be taken care and to be utilized efficiently to improve network lifetime. A novel routing approach based on ACO is presented in this paper using energy parameters for pheromone updating. Section II of this paper gives the background about ant colony optimization. In section III related work in this field is described. In section IV proposed algorithm is discussed. Section V summarizes the conclusions and future scope in this field.

II. BASIC ACO

The basic concept of ACO [13] is taken from the behavior of real ants. This soft computing paradigm is based on swarm intelligence. It is a population based search technique used for solving many combinatorial problems. Initially, each ant traverses the area in random manner while searching for food leaving a chemical substance in its path. This chemical substance is called pheromone which is the basis of local information at each node. The amount of pheromone is deposited depends on the number of ants on that path and length of that path. The shorter path will receive higher amount of pheromone. The newer ants will take a path which has higher pheromone concentration and will further reinforce the path they have taken. This colony behavior is auto catalytic. Ants are simple agents that interact via indirect communication known as stigmergy. Stigmergy is an indirect form of communication where individual agents leave signal by changing the environment and other agents sense them to drive their own behavior. The idea behind ant algorithms is then to use a form of artificial stigmergy to coordinate societies of artificial agents.

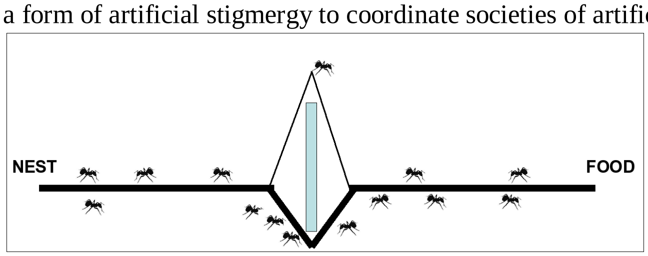

Fig -1: Ant Colony Behavior [16]

The above behavior can be used in networking. A network can be viewed as directed graph foraging the path taken by ants. The real ants can be foraged by using small ant packets. The chemical substance "pheromone" can be foraged defining the probability value at each node. The pheromone trails in ACO serve as distributed, numerical information which the ants use to probabilistically construct solutions to the problem being solved and which the ants adapt during the algorithm's execution to reflect their search experience [1]. The main advantage of ant packets over route request packet (RREQ) is that ant packets update only the local information. So a lot of computation, memory and energy get conserved. By using this behavior of the ants, optimal path can be selected.

III. RELATED WORK

Authors in [2], Selcuk Okdem and Dervis Karaboga, proposed a routing approach using an Ant Colony Optimization algorithm for Wireless Sensor Networks consisting of stable nodes. They also implemented it to a small sized hardware component as a router chip. S. Prasad, Y.P.Singh, and C.S.Rai [3] gave idea on a novel proactive routing algorithm called Probabilistic Ant Routing, in mobile ad hoc networks, which is inspired by Ant Colony Optimization (ACO) framework and uses "ants" for route discovery, maintenance and advancement. Their algorithm is based on a modification of the state transition rule of ACO routing algorithm that results in maintaining higher degree of exploration along with congestion awareness in the search space. This leads to reduced end-to-end delay and also lowers the overhead at high node density.

Authors in [4] gave an exposition of the basic problem-solving paradigm of ACO was given. They compared the differences between ACO and traditional routing algorithms along the issues of routing information, routing overhead and adaptively. Furthermore, the issue of stagnation in ACO algorithms was discussed, and the state-of-the-art approaches for mitigating stagnation were analyzed, compared and critiqued. Survey and comparison of three major groups of research (and their ramifications) in applying ACO in routing and/or load-balancing were given.

Arun Kumar et.al [5] proposed a load balancing and congestion control in mobile ad-hoc network using ant colony optimization. They described Max-Min ant system, Multi agent Ant Colony algorithm.

Authors in [7] presented the Ant Colony Optimization for MTSP and Swarm Inspired Multiple Data Transmission with Congestion Control in MANET using Total Queue Length. The proposed algorithm using path pheromone scents constantly updates the goodness of choosing a particular path by measuring the congestion using hop-distance and queue length into the network.

Authors in [8] described Ant Colony based routing for mobile ad-hoc networks towards improved quality of services. Their proposed algorithm combines the idea of Ant Colony Optimization (ACO) with Optimized Link State Routing (OLSR) protocol to identify multiple stable paths between source and destination nodes. They mainly focused on multipath routing for multimedia traffic to guarantee a stable route.

Hong, Sung-Hwa et al. [9] proposed the WSN (Wireless Sensor Network) algorithm which is applied sensor node that has low power consumption and efficiency measurement. Moreover, the efficiency routing protocol is proposed in this paper. The proposed algorithm reduces power consumption of sensor node data communication.

Kuila, Pratyay, and Prasanta K. Jana[10] proposed Energy efficient clustering and routing algorithms for wireless sensor networks based on particle swarm behavior. Snehal Sarangi, Biju Thankchan [14] proposed a scheme for sensor networks which results in energy efficient routing across the network. The concept of this model is based on the fact is greater the distance travelled to send data more is the consumption of sensor energy. The algorithm is done by using concept of PSO and compared with the results of genetic algorithm.

IV. PROPOSED ALGORITHM

In this section, the actual ACO algorithm is modified for energy optimization. The basic idea is to define new heuristic function based on residual energy of node to be visited by the ant packet. Moreover, the pheromone updating scheme is also dependent here on residual energy. This algorithm ensures that the maximum energy node is selected for routing. The algorithm works as follows:

Initially the source will broadcast ant packet over the network.

Each ant packet form node (i) while travelling the network selects the next node (j) on the basis of probability function, as in (1)

$$p_{ij} = \frac{[\tau_{ij}]^{\alpha} * [\eta_{ij}]^{\beta}}{\sum_{k \in N_i} \left[[\tau_{ik}]^{\alpha} * [\eta_{ik}]^{\beta} \right]} \qquad (1)$$

Where:

α and β are control parameters

p_{ij} is the probability of node j to be selected by ant coming from node i

τ_{ij} is the pheromone intensity

N_i is the set of nodes

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η_{ij} is the heuristic function based on local information, we define here it on the basis on residual node energy as in (2)

$$\eta_{ij} = \frac{e_j}{I_j} \quad (2)$$

Where:

e_j is the residual energy of node j

I_j is the initial energy of node j

Each ant packet received by any node updates the pheromone (local information), as in (3), on the basis on residual energy.
Revised pheromone:

$$\tau_{ij}(t+1) = (1-\rho)\tau_{ij}(t) + \Delta\tau_{ij}(t) \quad (3)$$

Where
ρ is pheromone evaporation rate
$\Delta\tau_{ij}(t)$ is pheromone enhancement

$$\Delta\tau_{ij}(t) = \begin{cases} \frac{e_j}{L}, \textit{if node j is selected} \\ 0, \textit{otherwise} \end{cases} \quad (4)$$

where
L is the length parameter while travelling form node i to node j

So the best route is selected having the higher energy nodes so that overall energy efficiency of the network can be enhanced.

V. CONCLUSIONS AND FUTURE SCOPE

This paper presents a novel approach of increasing network lifetime using ACO technique. We used artificial ants to update local information on the basis of residual energy. The amount of pheromone updated is based on the residual energy on that node which increases the probability of higher energy node to be selected. This autocatalytic approach is self organizing and needs very little handling. Thus an efficient route can be discovered in terms of energy consumption.
As future work, it is planned to test the algorithm in different network conditions and improve it keeping other factors in mind. The pheromone updating parameters can be further enhanced. It will be interesting to implement this algorithm on hardware to find out its efficiency.

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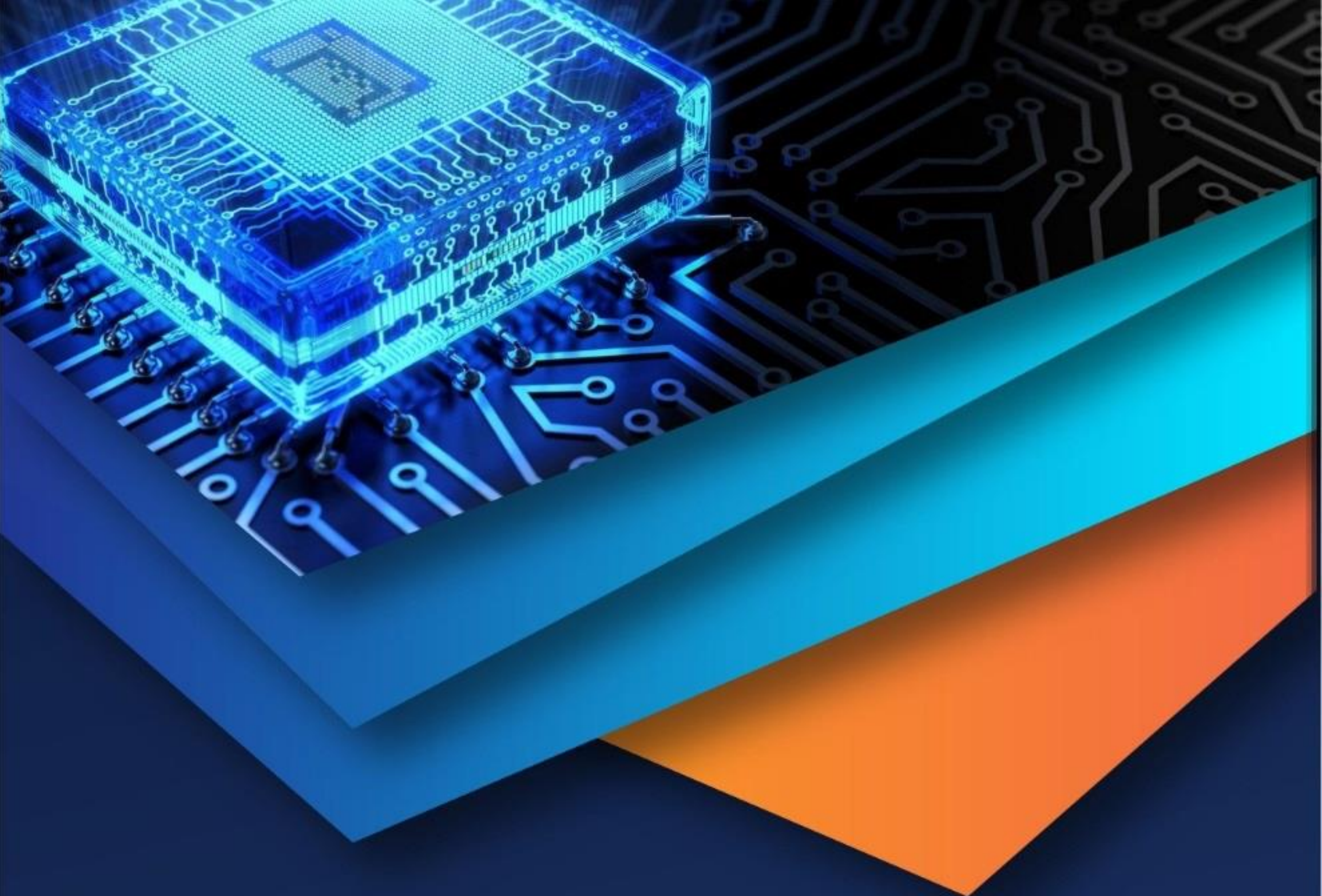

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