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Performance Comparison of ACO Algorithms for MANETs

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Abstract- Mobile Ad Hoc Network (MANET) is a dynamic multichip wireless network which is established by a set of mobile nodes on a shared wireless channel. One of the major issues in MANET is routing due to the mobility of the nodes. Routing means the act of moving information across a network from a source to a destination. The challenging task in MANET is to find most efficient routing due to the changing topology and the dynamic behavior of the nodes in MANET. It has been found that Ant Colony Optimization (ACO) is a special kind of optimization technique having characterization of Swarm Intelligence (SI) which is highly suitable for finding the adaptive routing for such type of volatile network.ACO algorithms are inspired by a foraging behavior of group of ants which are able to find optimal connection of the ant's nest with the source of food. ACO routing algorithms use simple agents called artificial ants which establish optimum paths between source and destination that communicate indirectly with each other by means of stigmerg . Ants-based routing algorithms have attracted the attention of researchers because they are more robust, reliable, and scalable than other conventional routing algorithms. Since they do not involve extra message exchanges to maintain paths when network topology changes, they are suitable for mobile ad-hoc networks where nodes move dynamically and topology changes frequently .In this paper comparison and simulation of different ACO based routing algorithms is presented.

Keywords- MANET, ACO, Routing, Ant, ABC, ANTHOCNET,ANTNET

I. INTRODUCTION

A Mobile Ad-Hoc Network (MANET) is a collection of wireless mobile nodes forming a temporary network without using centralized access points, infrastructure, or centralized administration. All nodes have routing capabilities and forward data packets to other nodes in multi-hop transmission. Nodes can enter or leave the network at any time and may be mobile, so that the network topology continuously changes. MANETs can be used in wide range of future applications as it has the capability to establish networks at anytime, anywhere without the aid of any established infrastructure. Unfortunately nodes in MANETs are limited in energy, bandwidth. Hence the primary challenge is to design effective routing algorithm that is adaptable to the changes in the behaviour and topology of the MANETs [1].

Routing in MANET is a Dynamic Optimization Problem as the search space changes over time. A MANET routing algorithm should not only be capable of finding the shortest path between the source and destination, but it should also be adaptive, in terms of the changing state of the nodes, the changing load conditions of the network and the changing state of the environment. The routing policy is defined as the rule that specifies what node to take next at each decision node to reach the destination node. Due to the time varying nature of the topology of the networks, traditional routing techniques such as distance-vector and link-state algorithms that are used in fixed networks, cannot be directly applied to mobile ad hoc networks. The constraints of MANETs demand the need of specialized routing algorithms that can work in a decentralized and self-organizing way. The routing protocol of a MANET must Dynamically adapt to the variations in the network topology. . An ideal routing algorithm is one which is able to deliver the packet to its destination with minimum amount of delay and network overhead. The nodes update the routing tables by exchanging routing information between the other nodes in the network.

The routing scheme in a MANET can be classified into three major categories Proactive, Reactive and hybrid [3]. The proactive or table driven routing protocols maintain routes between all node pairs all the time. It uses periodic broadcast advertisements to keep Routing table up-to-date. The reactive routing protocols create routes only when the source node wants to communicate with the other nodes in the network. When a node requires a route to a destination, it initiates a route discovery process within the network. Once a route has been established, it is maintained by a route maintenance procedure until either the Destination becomes inaccessible along every path from the source or until the route is no longer desired. Hybrid routing protocols uses the combination of both proactive and reactive Protocols. The big challenges while designing a routing protocol for MANETs are effective routing, congestion avoidance, energy consumption and load balancing. Most of the already existing protocols like AODV,DSDV and DSR attempt to solve one challenge – Effective Routing – and provide algorithms for minimal end-to-end delay,

maximum throughput, etc .So, there is a need for a routing protocol which can perform overall network management in addition to just packet routing.

Ant colony optimization (ACO) is a population-based meta- heuristic approach introduced by Marco Dorgio[2]. As the name suggests the technique was inspired by the behaviour of real ants [4, 5] .The social organization of the ant is genetically evolved commitment of each individual to the survival of the colony. It is a key factor behind their success. Moreover, these insect societies exhibit the fascinating property that the activities of the individuals, as well as of the society as a whole, are not regulated by any explicit form of centralized control. Ant colonies are able to find the shortest path between their nest and a food source by depositing and reacting to the trail of pheromone to help guide future ants towards optimal paths to food [6,7].The basic principles driving this system can also be applied to many combinatorial optimization problems like routing in data networks [8,9].

II. THE ANT COLONY OPTIMIZATION MET HEURISTIC (ACO)

The Ant colony optimization is based on the foraging behaviour of ants. When ants search for food, they wander randomly and upon finding food return to their colony while laying a chemical substance called pheromone. These pheromones are dropped at regular intervals to act as a trail. Also the pheromones slowly disappear over time. So they act as a guiding trail to other ants which begin to follow this path. In the same way, ants which trace a particular path strengthen the scents of pheromones on the path. In this way, a number of paths might exist from the nest to the food source. Also the shortest path will be the one with the highest pheromone scent (due to shorter round-trip time) (see Fig 1) and also naturally the path with the highest concentration of ants. Subsequently more ants are attracted by this pheromone trail, which reinforces the path even more. This autocatalytic behaviour quickly identifies the shortest path.

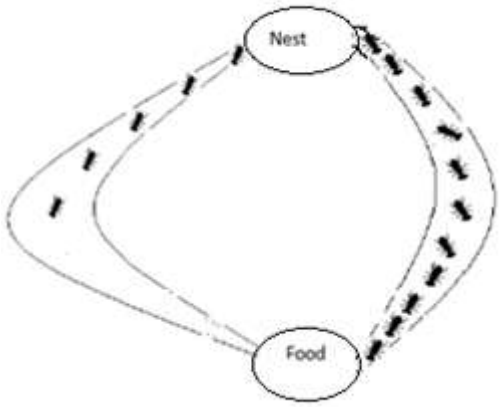

Figure 1 (a)

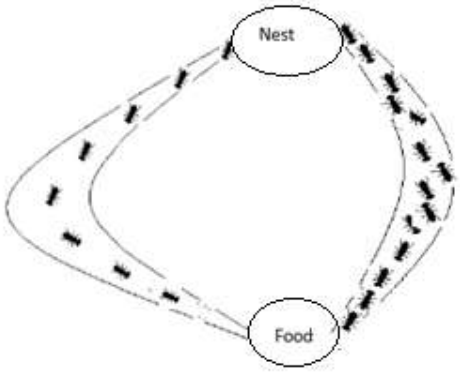

Figure 1 (b)

Figure1. (a) Double Bridge Experiment – Ants on shorter path reaches to food source earlier. (b) Ants on the shorter path return to nest before the ants on longer path

III. ANT COLONY OPTIMIZATION (ACO) BASED ROUTING ALGORITHMS

The Ant Colony Optimization due its nature can be applied to the routing of MANETs. As the MANETs routing can be classified into Proactive, Reactive and Hybrid categories, similarly ACO applications over MANETs can also be categorized into similar categories.

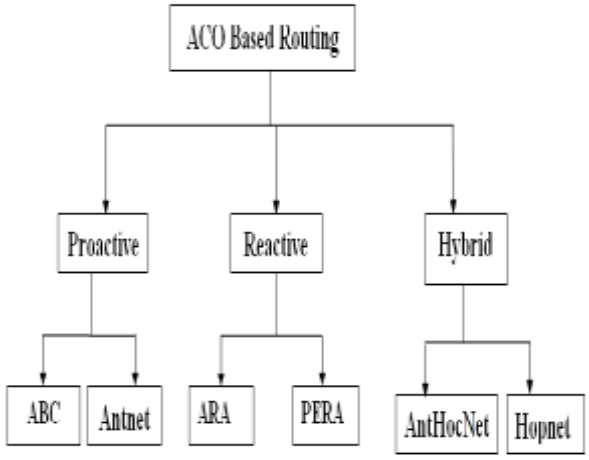

Figure2. Categorization of Ant Based Routing Protocols for MANETs

IV. PROACTIVE ACO BASED ROUTING PROTOCOL

A. Ant Based Control (ABC)

Ant based control (ABC) is another ACO based ant algorithm designed for telephone networks. It shares

many similarities with Ant Net, but also incorporates certain differences. The basic principle relies on mobile routing agents, which randomly explore the network and update the routing tables according to the current network state. In the ABC routing scheme, there exist two kinds of routing tasks [10] exploratory ants which make probabilistic decisions, and actual calls which made deterministic decisions .Ants move from node to node, selecting the Next node to move using the probabilities in the pheromone tables for their destination node. Up on arriving a node, they update the probabilities of that node's pheromone table Entries corresponding to their source node. They update the table to increase the probability pointing to their previous node. The increase in these probabilities is a decreasing function of the age of the ant, and of the original probability.

In this method when an ant arrives at a node, the entry in the pheromone table corresponding to the node from which the ant has just come is increased according to the formula,

$$P = (P(old) + \Delta P) / (1 + \Delta P) \quad (1)$$

where P is the new probability and ΔP is the probability of increase

B. Ant Net

It is a proactive routing algorithm proposed for wired datagram network based on the principle of ant colony optimization [11].Ant Net can be used in Wavelength Routed Optical Networks (WRON) [12] and Optical Packet-Switching (OPS) networks. The original Ant Net framework uses the delay introduced by each hop as the metric for routing .In Ant net each node maintains a routing table and has an additional task of maintaining the node movement statistics based on the traffic distribution over the network. This is not applicable in circuit-switching networks, where the main metric is generally the number of hops. The ant used in this algorithm carry in its memory the node identification of each node that it passes by. As stated above, the ants lay down a thin layer of signalling chemical called pheromones while travelling to find food. The other ants detect these pheromones and follow the same path of the chemical mark. The thicker the pheromone trail, the more likely other ants will follow the path. In fact, all of the ant's movements are based on immediate reactions to its surroundings or to its fellow ants. This indirect communication or stigmergy makes ants to represent a highly structured and complex social organization.

An entry in the routing table is having triple values, ie, destination address, next hop and pheromone value. Ants deposit pheromone on the edges during the route finding process. The ants deposit a constant amount of pheromone $\Delta \Psi$.When the ant is moving from node i to node j then the amount of pheromone on the edge e(i,j) updates as,

$$\Psi_{i,j} = \Psi_{i,j} + \Delta \Psi \quad (2)$$

Based on pheromone value in the routing table, the forward ant selects next node heuristically .The forward ants are also used to collect information about traffic distribution over the network. Upon reaches the destination, forward ant generates the backward ant and then dies. The backward ant retraces the path of forward ant in the opposite direction .At each node backward ant updates the routing table and additional table containing statistics about traffic distribution over the network.

V. REACTIVE ACO BASED ROUTING PROTOCOL

A. The Ant-Colony-Based Routing Algorithm (ARA)

ARA is a purely reactive MANET routing algorithm. It does not use any HELLO packets to explicitly find its neighbours. This algorithm (ARA) presents a detailed routing scheme for MANET's, including route discovery and maintenance mechanisms [13]. Route discovery is achieved by flooding forward ants to the destination while establishing reverse links to the source. A similar mechanism is employed in other algorithms such as AODV. As flow through the network, routes are maintained primarily by data packets .If any failure occurs an attempt is made to send the packet over an alternate link. Or else, it is returned to the previous hop for similar processing .If the packet is eventually returned to the source, a new route discovery sequence is launched.

B. Probabilistic Emergent Routing Algorithm (PERA)

In Probabilistic Emergent Routing Algorithm (PERA) [14, 15] the routing table stores the probability distribution for the neighbouring nodes. This algorithm works in a reactive way, with ants being broadcast towards the destination at the start of a data session [16].Here multiple paths are available, but only the path with highest pheromone value is used by the data, other paths are used for back up. The route discovery and maintenance performed by flooding the ants on the network. Both forward Ant and Backward Ant are used to fill the routing table with probabilities. Multiple paths between source and destination is available.Though,neighbors are found using HELLO messages ,entries are made on the routing table after receiving a backward ant from destination node. For the destination each neighbour receives an equiprobable value. As backward ant comes from the nodes, this value is increased establishing a path towards destination. The drawback of this routing protocol is that at each node, both forward and backward ants are broadcast which leads to huge number of duplicate ants in the network.

VI. HYBRID ACO BASED ROUTING PROTOCOL

A. Ant Agents for Hybrid Multipath Routing (AntHocNet)

AntHocNet [17] is a multipath hybrid routing algorithm for mobile ad-hoc networks that combines both proactive and reactive components. The structure of AntHocNet is quite similar to that of Ant Net-FA with the addition of some components specific to MANETs those results in the presence of several types of ant-like agents. Algorithm maintains routes only for the open data sessions. This is done in a Reactive Route Setup phase, where reactive forward ants are sent by the source node to find multiple paths towards the destination node.AntHocNet uses a proactive method to update the quality of the route. Nodes periodically broadcast information about the best pheromone values. The neighbouring nodes on receiving the information then make changes to the existing pheromone values of the routing table entries to every destination over the broadcasting nod e. backward ants are used to actually setup the route. While the data session is open, paths are monitored, maintained and improved proactively using different agents, known as proactive forward ants. Neighbourhood discovery is done through the periodic broadcast of Hello messages. A link error may be detected when a Hello message is not received from a neighbour for a timeout period. In the case of packet sending failure, AntHocNet checks for alternative routes. If alternative routes are not found then a route repair process is initiated. The node also broadcasts a link failure notification to inform its neighbours about the change in routing information [18].

B . Hopnet

HOPNET is a multipath hybrid ACO routing protocol based on ant hopping from one zone to next, consists of local proactive route discovery within a node's neighbourhood and reactive communication between the neighbours [20].The HOPNET algorithm consists of the local proactive route discovery within a node's neighbourhood and reactive communication between the neighbourhoods. The network is divided into zones which are the node's local neighbourhood. A routing zone consists of the nodes and all other nodes within the specified radius length measured in hops. A node may be within multiple overlapping zones and zones could vary in size. The nodes can be categorized as interior and boundary (or peripheral) nodes with respect to the central node. Each node has two routing tables: Intrazone Routing Table (IntraRT) and Interzone Routing Table (InterRT). The IntraRT is proactively maintained so that a node can obtain a path to any node within its zone quickly [19].

VII. COMPARISON OF DIFFERENT ACO BASED ROUTING ALGORITHMS

ABC Routing was developed for wired telecommunication Networks and it assumes symmetric path costs between nodes. In ABC the best path takes all call setup scheme, which means that if the best route is congested, no call can be placed until the ants can change the probability distribution .Like in Ant Net, each node s periodically sends out ants to randomly chosen destinations. Each ant has an associated age, which is increased proportionally to the load of each visited node. While travelling from its source s to its destination d, the ant updates the pheromone for the path backward to s, based on its age. This is an important difference with Ant Net: ants update pheromone about the path to their source while going forward, and no backward ants are used. This is possible because of the assumption of symmetric path costs. There is no path statistics are used to evaluate path quality measurements reported by the ants, and that no local heuristic is used to help guide the ants .Ant net outperform a number of standard routing algorithms for constant bit rate traffic.AntNet was developed for packet switched wired networks. HELLO messages are used initially to discover the neighbours.

The main drawback of the Ant Net algorithm is that it requires long delays to propagating routing information, since routing tables are only updated by backward ants. The algorithm does not confer how ants acquire accurate timing information, but presumably all nodes in the network will need to have synchronized clocks for the timing information to be accurate. PERA is better in terms of less cost and also efficient in maintaining and exploring new paths .In PERA, HELLO messages are broadcasted each time any node moves to a different position so that node can discover its new neighbours. ARA is similar to PERA but in ARA both forward and backward ants update pheromone value. In ARA entry in the routing table for each node is created when a forward ant arrives at that node. Pheromone value is the number of hops required by the forward ant to reach the current node from the destination. The difference with PERA is that both forward and backward ants leave pheromone behind: forward ants update pheromone about the path to the source, while backward ants update pheromone about the path to the destination. Another difference is that also data packets update pheromone, so that paths which are in use are also reinforced while the data session is going on. This comes down to repeated path sampling, so that ARA keeps more of the original ACO characteristics than PERA.Anthocnet requires more number of resources as compared to other ACO based algorithms. This is because there are two forward ants and two backward ants. Structure of ant is similar but number of ants generated varies with other ACO based algorithms. Amount of control traffic generated due to ants is more than other ant based algorithms. HOPNET is more scalable than AntHocNet because, in beginning AntHocNet is not hybrid at an instant. Means, at start

AntHocNet is a completely reactive protocol and once, the new route has been found it becomes a proactive protocol for all known routes and proactive protocols are not good for large networks or not scalable. However, HOPNET does not change its state for inter-zone routing or for intra-zone routing.

VIII. SIMULATION AND RESULTS

We use NS2 to simulate our proposed protocol in our simulation; the channel capacity of mobile hosts is set to the same value: 2 Mbps. We use the distributed coordination function (DCF) of IEEE 802.11 for wireless LANs as the MAC layer protocol. It has the functionality to notify the network layer about link breakage. In our simulation, 50 to 150 mobile nodes move in a 2000 meters x 2000 meters region for 150 seconds simulation time. We assume each node moves independently with the same average speed. All nodes have the same transmission range of 250 meters. In our simulation, the speed is set as 5m/s. The simulated traffic is Constant Bit Rate (CBR).Simulation parameters are given below.

No Of Nodes	50,75,100,125 and 150
Area size	2000 m x 2000m
MAC	802 .11 b
Radio Range	250m
Simulation Time	150 sec
Traffic Source	CBR
Packet Size	512 KB
Mobility model	Random Way Point model
Speed	5 m/s
Initial Energy	0.5 Joules

Simulation of various ACO algorithms are performed, and the performance metrics considered are Throughput and Average end to end delay.

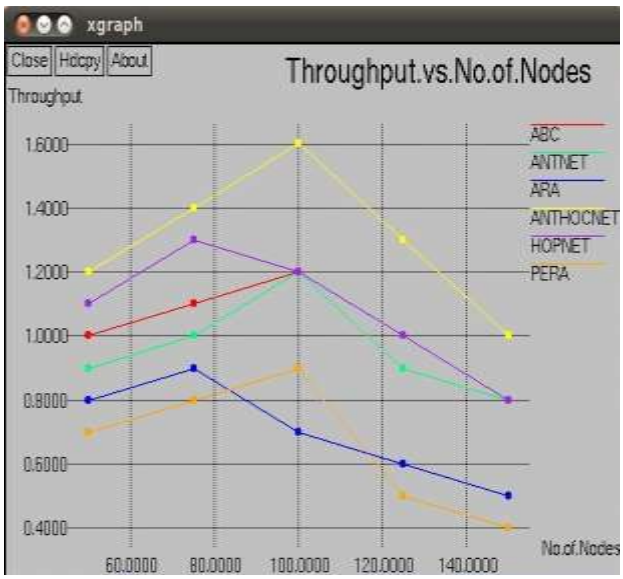

Fig.3. Throughput Vs No.of Nodes

From fig 3 it is clearly shown that ANTHOCNET has better throughput ,comparing with other ACO algorithms

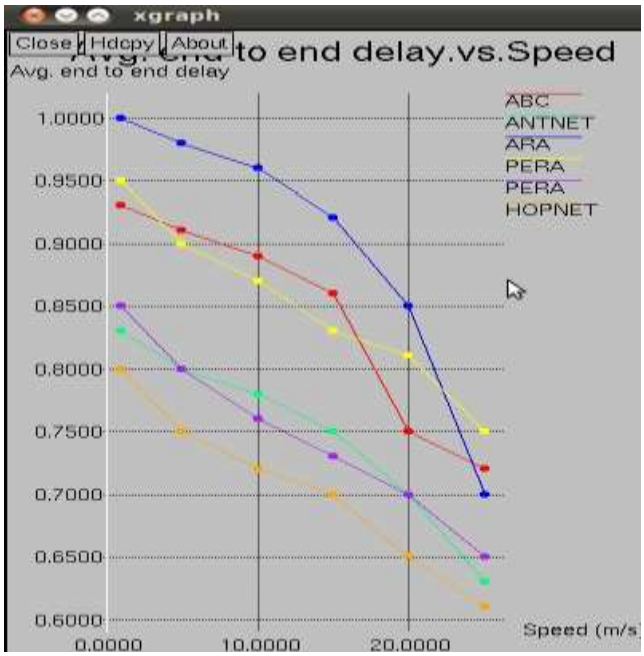

Fig 4. Average end to end delay Vs Speed.

From Fig.4 it is clear that Hybrid routing protocols like HOPNET and ANTHOCNET have lower Average end to end delay

IX. CONCLUSION

In this paper we have presented comparison and simulation of various ACO based routing algorithms to solve the routing problem in MANETs.ACO algorithms tend to provide features such as adaptively and robustness which essentially deals with the challenges of MANETs. In this paper various categories of ACO based algorithms like proactive,

reactive and hybrid are analysed in detail. The agents in ACO routing algorithms communicate indirectly through the stigmergy and provide positive feedback to a solution by laying pheromone on the links. Moreover, there is negative feedback through evaporation and aging mechanisms, to avoid stagnation. ACO routing algorithms allow for direct agent-to-agent communication which makes them more suitable for MANETs.

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