Comparison of Ant Colony Optimization Algorithms for Routing problems in Ad Hoc Network

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Abstract- Mobile ad-hoc network (MANET) is a dynamic wireless network which can have fixed or a variable infrastructure. Nodes have the ability to move randomly and arrange themselves in a haphazard order. Multicasting or broadcasting is the type of strategy that can be adopted for the MANETs since they are dynamic in nature. By using Ant Colony Optimization (ACO), performance of mobile ad-hoc networks has and can be improved in numerous ways. Swarm Intelligence which is the study of combined behavior of decentralized and self-organized systems can be an artificial one or a natural one. Ant Colony Optimization (ACO) is one of the most recognized and widely used Swarm Intelligence based routing methodology. In this paper, we have compared different Ant Colony Optimization based algorithms which are Ant Net, Ant-Hoc Net, Ant Routing Algorithm (ARA), and Probabilistic Emergent Routing Algorithm (PERA) on the basis of various parameters such as year of implementation, proposed by, scheme followed , path , types of ants , ant structure, routing table structure , parameters considered in choosing next hop ,pheromone evaporation and traffic statistics structure.

Keywords: MANET, ACO, Ant Net, ARA, Ant-hoc Net, PERA**.**

I. Introduction

A mobile ad-hoc network (MANET) [1] is a type of network which consists of set of movable nodes that communicate over a radio link and which doesn't require any type of fixed infrastructure. These type of network are quite flexible and these are suitable for numerous applications and situations, hence they help in an establishment of momentary communication without any kind of pre-installed infrastructure. Since it has the limited transmission range within the wireless interfaces, hence the communicating traffic has to relay over number of intermediary nodes which helps enable the communication among different nodes. Hence, these type of networks are also called as mobile multi-hop ad-hoc networks. Nodes not only fulfill the functionality of different hosts, but also act as a router, forwarding the packets to other nodes. Beside, one of the classical application for disaster and military purposes, it can also be deployed in mobile ad-hoc networks for multimedia applications. However, the performance of such type of networks needs to be improved before they can actually be realized. With the upcoming radio technologies, like, IEEE 802.11a and Bluetooth, the realization of multimedia applications over mobile ad-hoc networks can be easily possible. The main difficulty in mobile ad-hoc networks which is still prevalent is the finding of a route or a path between the communicating end-points, which are being provoked through the mobility of nodes. In the text one may find number of different approaches which tries to handle this kind of problem [1, 2], but there is no such individual routing algorithm which can fit in all type of cases.

The scheme of routing used in MANET can be divided into two major categories – Proactive and Reactive. In proactive protocols [3], a node in the network maintains the routing information of all other nodes in the network by periodically exchanging the routing information. The proactive or a table driven routing protocol maintain the routes between all pair of nodes. It uses a periodic broadcast advertisement to keep the routing table up-to-date. But this kind of approach suffer from the problems such as increased overhead, lack of flexibility to react to dynamic changes and reduced scalability, like in Ant Net and Termite while the nodes using reactive protocols, delay the route acquirement until the demand for a particular route is made like in ARA. Hybrid protocols uses the combination of both proactive as

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well as reactive activities in order to gather the information regarding the routes or paths to the destinations in a network – nodes using ZRP e.g. ANSI. In the following paper we compare various ACO based routing algorithms on the basis of several parameters.

The remaining paper is organized as follows: in Section 2 we present the basics of various Ant Colony Optimization algorithms- Ant Net, ARA, Ant Hoc Net and PERA. Subsequently in Section 3 we compare the algorithms. In Section 4, various Simulation Parameters are discussed. Finally, a conclusion is given in Section 5.

II. ACO Based Routing Algorithms

A. Ant Net

Ant net, a proactive routing algorithm is based on Ant Colony Optimization principle [4]. This algorithm is proposed for wired datagram network. A routing table is maintained and in addition to this, ant net has the task to maintain the node movement statistics based on distribution of traffic in the overall network. The attributes of routing table are destination node, next hop node and a measure of goodness of using the subsequent node to forward a data packet to destination. The Pheromone values are normalized to one that is a basis for goodness measure. To update routing tables, Ant Net makes use of two homogeneous movable agents: Forward and Backward Ants. These homogeneous mobile agents are smaller in size and are light packets which contains source and destination IP addresses packet ID and a stack that grows dynamically which consists of Node ID and Node Traversal Time. When an FA is received for the first time by a node, a record is created in its routing table by that node. Routing table has triple values in its entry which are destination address, next hop and the pheromone value. Pheromone is deposited on the edges by the ants during the route finding process. In this algorithm, ants deposit a constant amount $\Delta\psi$ of pheromone, i.e. the amount of pheromone of the edge e (i; j) when the ant is moving from node i to node j is changed as follows:

$$\psi_{i;j} = \psi_{i;j} + \Delta\psi \quad (1)$$

Next node is selected heuristically by the forward ant based upon the pheromone value in routing table. The forward ants also collect the information on the distribution of traffic in the network. On reaching the destination, the forward ant generates backward ant and dies. The path of the forward ant is retraced by the backward ant in opposite direction. The routing table is updated by the backward ant at each and every node and an additional table which contains the statistics of the distribution of traffic in the network.

B. Ant Routing Algorithm (ARA)

It is the one of the reactive protocol for mobile ad-hoc networks [5]. Routing table in ARA [6] consists of pheromone values to choose the next hop as a neighbor for each and every destination. With time, the pheromone values present in the routing table decays and if the pheromone value reaches its lower threshold, the nodes enter the sleep mode. Route discovery is performed using set of two agents, forward and backward ants respectively, having the unique sequential numbers, which prevents redundancy of packet that are being flooded throughout the network by source node and the destination nodes. The forward and backward ant updates the routing table consisting of pheromone values at every node all along the route from the source to the destination. After obtaining the route discovery for the destination, the source does not generate new agents for the destination but instead data packets perform the route maintenance process. In ARA, the selection of next hop is decided by probabilistic vs. dynamic routing. In this the selection of the next hop for the data packet is always done in accordance to the amount of pheromone values, i.e. a node i selects a neighbor j with probability P (i:j) as follows:

$$P_{i;j} = \begin{cases} 1 & \text{if } \psi_{i;j} \text{ is maximum} \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

ARA is extended to use probabilistic routing, i.e. a node i selects a neighbor j with probability.

$$P_{i;j} = \frac{\psi_{i;j}}{\sum_{k \epsilon N_i} \psi_{i;j}} \quad (3)$$

Ni is the set of one step neighbors of node i.

The ARAstat denotes the ARA with the probabilistic routing. The advantage of this algorithm is that, in this the load is being distributed over the already existing routes to the destination.

C. Ant Agents for the hybrid multipath routing [Ant Hoc Net]

Ant Hoc Net [7] is a combination of reactive and proactive protocol components, which are used for the ad-hoc networks. It creates route for open data session only. This is carried out by ants in a phase of Reactive Route Setup. Here the reactive forward ants are being delivered to the destination nodes by the particular source node in order to find multiple routes or paths while backward ants set the actual route. Though the data sessions are open, still paths are being monitored, improved proactively and maintained using different type of agents, called as proactive forward ants.

D. Probabilistic Emergent Routing Algorithm (PERA)

In PERA [8], the ants are being broadcasted in the direction of the destination as soon as the session starts. It works according to on-demand way. Numerous paths are being set up, but the one having the maximum pheromone value is used by the data and the other paths are available for the backup [8]. The maintenance and route discovery is done by flooding the networks with ants. Forward as well as backward ants are used for filling the routing table with the respective probabilities. These probabilities being entered reflects the likelihood of neighbor being forwarding the packet to the particular destination. Many paths are created between the source and the destination node. First and foremost step is to, discover the neighbors using the Hello messages, but the entries are being added up in the routing table only after receiving the backward ants from their respective destination. Each neighbor of the specific node receives an equiprobable value for the destination. This value gets increased as soon as backward ant returns from the node, and it establishes a path in the direction of the destination. As ants are being flooded, sequence numbers are used by the algorithm to avoid the replica of packets, only the one with the greater sequence number from the preceding hop is being taken into account. Forward ants having the lower sequence number are being dropped. This is much similar to the AODV, but it discovers number of routes instead of discovering only one like in others. Data packets are routed in accordance to the highest probability in the routing table for the next hop.

III. Comparison of Routing Algorithms

Comparison between various ant based algorithms is provided in Table 1., which is given at the end of paper due to size restraints.

IV. Simulation Parameters

The parameters that can be taken into account for analyzing the performance of different ant based algorithms are defined below [9, 10]. Basically there are two different types of traffic, which are:

1. Session Oriented: In this type of traffic, for a given session every packet has same destination.
2. Session Less: Here, the destination of every packet is selected from the uniform distribution.

The parameters that can be considered are:

- Average Throughput: It is defined as the measure of the amount of traffic successfully received at the respective destination in a unit time interval. This value should be as large as possible for a routing algorithm.
- Packet Delay: Ideally, this value should be as small as possible for a good algorithm.
- Session Delay: In the session-oriented traffic, time is one of the important parameter which is needed for completion of a session. The application layer present at the receiving node receives the packets only after obtaining all the packets in a predefined order. Packet delay factor ignores this waiting time and hence it favors multipath algorithms which can deliver the packets in out-of-order manner but with comparatively smaller delays.
- Sessions Completed: This is defined as the, number of sessions that are being completed without any guidance or supervision from the transport layer protocols. It also has the ability to report the way packets are being deleted due to occurrence of congestion.
  - Packet Delivery Ratio: This ratio tells us about the number of data packets that have successfully reached their respective destinations.
  - Packet Drop Ratio: It's defined as the amount of data packets that are being dropped because either the queue buffers were full or their respective time to live timers (TTL) has expired.
  - Packet Loop Ratio: It's the number of data packets that follow a particular cyclic path,

which is a type of error in an algorithm and must be reported.

- Routing Overhead: This parameter depicts the control overhead in the routing algorithm. It's the ratio of bandwidth being occupied by routing packets and the total bandwidth being available in a network.

Suboptimal Overhead: This is the difference between the bandwidth being consumed when data packets are being transmitted from all the particular sources to their respective destinations and plus the bandwidth that had been consumed if the data packets have had followed the shortest hop count path.

CRITERIA	ANT NET	ARA	ANT HOC NET	PERA
YEAR	1997	2002	2004	2003
PROPOSED BY	Gianni Di Caro	Mesult Gunes, Udo Sorges and I.Bouazizi	Gianni Di Caro, Frederick Ducatelle LM Gambardella	John S Baras, Harsh Mehta
SCHEME	Proactive	Reactive	Hybrid	Proactive
PATH	Single	Multipath	Single	Single
TYPES OF ANTS	Forward Ant, Backward Ant	Forward Ant, Backward Ant	Reactive Forward Ant and Backward Ant, Proactive Forward Ant and Backward Ant	Forward Ant, Backward Ant
ANT STRUCTURE	Source IP address, Destination IP address, Sequence num, field to identify as FA or BA, memory [node addresses and trip time]	Source IP address, Destination IP address, Sequence num, Hop count	Source IP address, Destination IP address, Next Hop IP address, Stack [Node id, Node traverse time], Hop count, Sequence No	Source IP address, Destination IP address, Stack [Node id, Node traverse time], Hop count, Sequence No
TABLE BASED	Yes	Yes	Yes	Yes
ROUTING TABLE STRUCTURE	Destination address, Each neighbor, Pheromone value	Destination address, Next hop, Pheromone value	Goodness of next hop, Destination address, Next hop	Destination address, Next hop, Probability
PARAMETERS CONSIDERED IN CHOOSING NEXT HOP	Pheromone	Pheromone	Pheromone	Pheromone
PHEROMONE EVAPORATION	Yes	Yes	Yes	Yes
TRAFFIC STATISTICS STRUCTURE [MEAN VARIANCES BEST VALUE]	Used	Not Used	Used	Used

V. Conclusion

We conclude that Ant Net is the one that works best for the fixed as well as for the packet switched wired networks among all above compared algorithms. While in case of wireless networks Ant Hoc Net is the one showing the highest efficiency as compared to other ant based algorithm. The reason for this is that it has higher chances of discovering new paths based upon the probability, but it requires much more resources for its implementation and it 's more costly in comparison to other algorithms ,this is because there is lot of ant traffic being generated. PERA is less expensive than others and hence it's much better. Also, it is much efficient in terms of

maintaining and exploring new routes and paths. ARA is very much like PERA, but in case of ARA, forward and backward ants both together updates the pheromone value

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