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A Review of Development of Routing Protocols using Ant Colony Optimization in MANET

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Abstract— MANET is multi-hop routing network having flexible network architecture and variable routing paths. The Ad-Hoc network has challenging issues, which can be categorized as energy consumption, routing, overheads, limited bandwidth. To solve these problems many researchers have done research and recently came up with new class of routing algorithms which is based on Swarm Intelligence along with basic routing protocols in MANET. Inspiration for Ant Colony optimization algorithm is self-organizing behavior of ants which come under Swarm Intelligence. The foraging behaviour of ants consent to find the shortest path from the nest to a food source, by deposition of a chemical substance called pheromone. This paper gives review of some ACO based routing algorithms in MANET which improve the performance of network.

Keywords— Ant Colony Optimization, MANET, Swarm Intelligence, Multi-hop routing, Pheromone.

I. INTRODUCTION

MANET consists of entirely of wireless nodes, placed together in an ad hoc manner and without the support of a fixed communication infrastructure. All nodes are mobile, and can enter or leave the network at any time. Data are forwarded among the nodes of the network in multi-hop fashion. MANET routing algorithms can be classified as proactive, reactive or hybrid. Proactive algorithms try to maintain up-to-date routes between all pairs of nodes in the network at all times. The advantage is that routing information is always readily available when data need to be sent, while the main disadvantage is that the algorithm needs to keep track of all topology changes, which can become slightly difficult when there is more number of nodes or mobility of node is more. Examples of proactive algorithms are Destination-Sequence Distance-Vector routing (DSDV) and Optimized Link State Routing (OLSR) [1]. Reactive algorithms only maintain routing information that is strictly necessary. They set up routes on demand when there is need of a new communication session start, or when a running communication session falls without route. This approach is generally more efficient, but can lead to higher delays as routing information is often not immediately available when needed. Examples of reactive routing algorithms include Dynamic Source Routing (DSR) and Ad-hoc On-demand Distance-Vector routing (AODV). And last, hybrid algorithms use both proactive and reactive elements, trying to combine the best of both worlds [1]. MANET have limitations like low battery power, changing topology, high mobility, etc.

Due to some limitations in the MANET, recently new class of algorithms came up based on “swarm intelligence”. These algorithms are nature inspired from biological, natural self organizing system. The Ant colony optimization (ACO) algorithm belongs to a class of Swarm Intelligence (SI). At very first it was used to solve Travelling Salesman Problem (TSP). This algorithms is based on behavior of ants, their food searching mechanism inspired all researchers to find shortest route in communication network which was further implemented for ad-hoc networks. While walking from food sources to the nest and vice versa, ants release a chemical substance (the pheromone) on the ground, and the direction chosen by the following ants is the path marked by a stronger pheromone concentration. Figures 1 (a) & (b) shows the Double Bridge experiment that illustrate the mechanism of finding shorter path to reach the food source sooner as compare to ants on the long path. Ants on reaching the destination; start a new route backward towards the source nest by following the same path and biases the path by depositing more pheromone on the shortest path. As time progresses, the pheromone on non-optimal paths evaporate while the pheromone on near-optimal paths is reinforced [2].

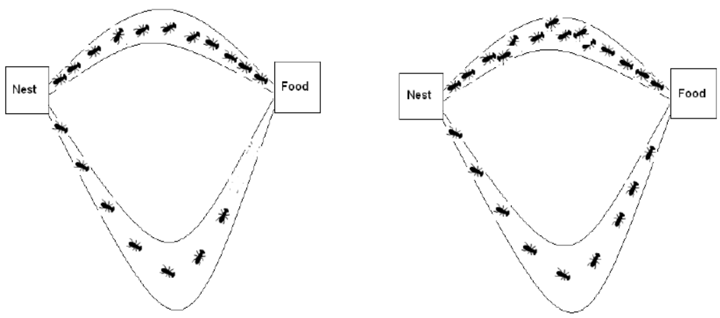

Fig. 1(a) & (b) Double Bridge Expeiment [2]

Several algorithms were introduced based on ant colony problems in recent years to solve different problems. Some of them are given in following section.

II. RELATED WORK

A. *ARA – The Ant-Colony Based Routing Algorithm*

Mesut Gunes proposed the protocol called as the Ant-Colony-Based Routing Algorithm (ARA) to reduce the overhead for routing. The ARA is on-demand routing algorithm for multi-hop ad-hoc, mobile networks which is based on the ant colony based Meta heuristic [3]. The biggest challenge in the Mobile Ad hoc networks is to find a path between the communication end points, with node mobility.

ARA mainly consists of three parts route discovery, route maintenance and route failure handling. New routes are generated in route discovery mechanism using Forward Ant (FANT) and Backward Ant (BANT). FANT has unique sequence number that used to distinguish duplicate packets along with source address of the FANT. The sender broadcasts a forward ant and will be forwarded by its neighbours (v_j) as shown in fig. 2 below.

When FANT comes at the node does entry of destination address, next hop, pheromone value in the routing table. The node makes out the source address of the FANT as destination address.

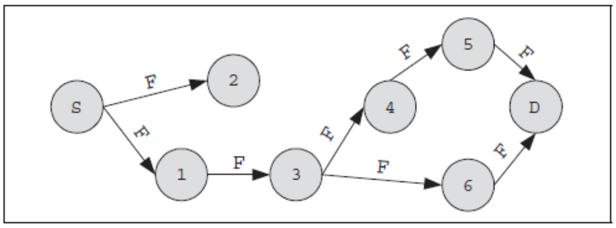

Fig. 2 Route Discovery Phase: A sender (S) sends forward ant (F) toward the destination node (D). [3]

When FANT comes at the node does entry of destination address, next hop, pheromone value in the routing table. The node makes the source address of the FANT as destination address, the address of the previous node as the next hop, and computes the pheromone value depending on the number of hops the FANT needed to reach the node. [3] When the FANT reaches the destination node (v_D), the information of the FANT is extracted by the destination node then destroys it. Then create a Backward Ant (BANT) and sends it to the source node as shown in fig. 3 below.

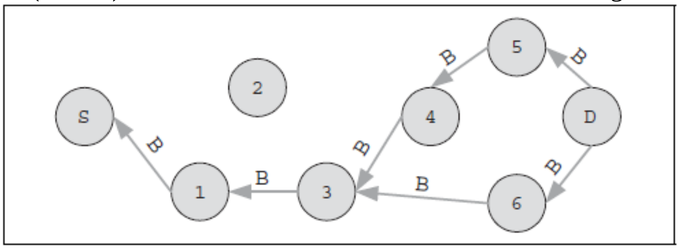

Fig. 3 Route Discovery Phase: The backward ant (B) is send by the destination node toward the source node [3]

The BANT does the same task as the FANT. Multi-path routing is also supported by ARA because the backward ant creates two pheromone tracks toward the destination node.

The improvement of routes is done in Route Maintenance. To maintain the path subsequent data packets are used after path established by FANT and BANT. The initial pheromone values (ϕ) are updated by $\Delta\phi$ in the record (v_D, v_j , ϕ) at node at each hop. Simultaneously evaporation process of the real pheromone begins by regular decreasing of the pheromone values as given by equation below.

The last phase of ARA is routing failures handling. ARA handles routing failures after getting a Route Error message at the node for a certain link. It first set the pheromone value to 0 to deactivate this link then an alternative link is searched by node in its routing table. If there a second link found, it sends the packet via this path. If the packet does not reach at the destination node, the source will start a new route discovery phase [3].

This paper concludes that overhead of ARA is very small, as there are no routing tables which are interchanged between the nodes. As only a unique sequence number is transmitted in the routing packets so Forward Ant and Backward ant packets don't transmit much routing information. Data packets perform most of the route maintenance, so they don't need to transmit additional routing information.

B. *An ant swarm-inspired energy-aware routing protocol for wireless ad-hoc networks*

Sudip Misra et al. proposed an energy-aware routing protocol called as an Energy Aware Ant-based Routing protocol (EAAR) for wireless ad-hoc networks [4]. This protocol includes the effect of power consumption in routing a packet and also gives the multi-path transmission properties of ant swarms so increases the battery life of a node.

The algorithm used in this paper reduces energy consumption and discovers good path right from start. Here remaining power of node is considered to help in reducing dead nodes. EAAR has parts like route discovery, route maintenance and link failure. The AntHocNet [7] algorithm is inspiration for basic structure of the path discovery mechanism but functionality is different. First a source node s, starts a communication with a destination node d, it broadcasts a reactive forward ant, say F_d. Initialize a "seen" set S of every node as NULL. To find a path between s and d, at each node, an ant is either uni-casted or broadcasted; depending on whether or not the current node has routing information for d. journey information is stored in an array, J, which each packet maintains. The proposed algorithm is as below in fig. 4 [4]:

1. Broadcast all the request packets.
2. After receiving any route request:
   for all routes R_i in S of node check:
   if the route travelled by the request is present or not in R_i.
   if the route is present in R_i or the hop count is less than 1.5 times the highest in the set S then
   if the route is present in R_i OR the hop count is less then
   add route in set S and rebroadcast it.
   else
   discard it.
3. After reaching the destination, the route request is converted to the route reply, the path travelled is stored, and the pheromone PH in the routing table of each node of path is added is calculated as:
   PH= MBR/HOPS
4. When the source receives the first reply, the delay of the first packet is made 5 times in order to receive more packets and the routing table is updated.
5. Data transmission is initiated with each packet, selecting next hop with probability P_{nd} from all available, by taking the pheromone values from routing table.

$$P_{nd} = \frac{(T^i_{nd})^\beta}{\sum (T^i_{jd})^\beta}$$

6. On each transmission, the pheromone is reinforced and others are evaporated.
7. On link failure, Step 1 is repeated from the node that has data to send, but no neighbours available.

Fig. 4 EAAR Algorithm [4]

This paper concludes that EAAR algorithm decreases dead nodes over the network and uses whole network keeping less hop count as much as possible.

C. An Ant-Swarm Inspired Energy-Efficient Ad Hoc On-Demand Routing Protocol for MANETs

Isaac Woungang et al. proposed an energy-aware routing protocol for MANETs called as ant colony optimization based energy-efficient ad-hoc on-demand routing protocol (ACO-EEAODR) [5]. The main factors that affect the battery power utilized during network transmission are packet size, the hop count, and the length to the link between two nodes. In EEAODR, the route selection is performed by using control packets which carry information about the needed route and tries to find the path that uses the minimum battery power of each node.

In EEAODR, when node requests for data transfer, first valid saved valid paths are checked. If no valid path is found, a Route Request (RREQ) is sent out to all neighbouring nodes. The node checks for duplicate packet then checks its own route table to search for a valid path to the desired destination. If a valid path is found, same RREQ is routed to that valid path. Otherwise, a new RREQ is formed and broadcasted again. When a RREQ receives at the destination, it waits for a round trip time. After receiving all paths, the optimal path gets selected. Then it sends a Route Reply (RREP) packet to the source node and stores other paths that were less optimal than the chosen path for the future. This way, the energy is not consumed in path selection every time. Finally, the data is transmitted via the selected path through which the destination node had sent the RREP.

ACO-EEAODR Protocol is slight modification of EEAODR as follows:
The network is represented as a unidirectional graph. The cost function is used to calculate the most energy-efficient path given in equ. (1) [5]:

$$COST = [\alpha * (hopCount)] + \left[(1-\alpha)\frac{1}{\sum(node.power)}\right] \quad (1)$$

A node will prefer hopping to a node with a higher battery power, rather than a node with a shorter path length. Once all RREQs are received at the destination node or the Round Trip time is up, the evaluation function is used to perform path selection then RREP is sent through the best path. Now pheromone deposition takes place. The pheromone values are updated as given in equ. (2) [5]:

$$Pher_{new} = Pher_{old} + \left[\frac{1}{\max Power - node.power}\right] \quad (2)$$

Where,
$Pher_{new}$: new pheromone value to be assigned to the node,
$Pher_{old}$: current pheromone value of the node,
maxPower: maximum battery level that a node can acquire
node.power: current battery level of the node.
Next hop for ants is decided by Probabilistic transition rule that uses the local heuristic and pheromone.

Algorithm steps are as follows:

1) *At source node:*
   - If need for data transmission occurred then check path from source to destination is available or not.
   - If available, load the path from route table into the array Path, Send data using Path and Update route table
   - Else broadcast RREQ to neighbours, start wait Timer for RREP. When wait Time is timeout go to Source.

2) *At intermediate node:*
   - When RREQ received at the node, compare destination IP address in RREQ packet with node's IP address. Then add this entry to rreqList and entry timer starts. When timer time outs discard RREQ. If it is intermediate node add path at the node else it is destination and create new RREP packet. Path travelled by RREQ packet is used for RREP to reach source node.

3) *At destination node:*
   - BestPath is selected by calculating optimal path by using rreqList, custom entry time, μ, τ where custom entry time, μ, τ are set by network administrator.
   - Now backupPaths are calculated using rreqList and custom entry time.
   - Create new RREP, path followed b y RREP is bestPath and RREP.backups are backupPaths.

As a result ACO-EEAODR performs better in case of no. of nodes increases and network lifetime. This paper concludes that whenever a new data transfer request is generated, ACO-EEAODR tries to select a route that contains the nodes with higher energy level. Even though this approach does not guarantee that the selected routing paths to be the shortest ones, it guarantees that the network will last longer.

D. An Ant Colony Optimization Algorithm for the MANET Routing Problem Based on AODV Protocol

The main goal in the design of the protocol was to reduce the routing overhead, response time, end-to-end delay and increase the performance. Ahmed M. Abdel-Moniem et al. proposed the new modified protocol as the Multi-Route AODV Ant routing algorithm (MRAA) [6]. The MRAA handles events like neighbour connectivity, route establishment request, route establishment reply, route expiry, connection loss and local repair.

1) *Neighbour connectivity:* When a packet from a new neighbour has just arrived, then add a route to the new neighbour in the routing table with initial pheromone value 0, update the pheromone and increase the number of available active neighbours for this node by1 else update the expiry time of the connection for this neighbour.
2) *Route Establishment Request:* first check node is the source node. If it is then check, if the route to destination exists or not. If there is no highest pheromone neighbour then broadcast the forward ant to all available active neighbours, else if the route to destination does not exist but there exists an active neighbour with highest pheromone then send the forward ant to that neighbour. If there is an intermediate node then update the memory and do same procedure as above. Else if it is the destination node send a backward ant to the source to give it the feedback of the route.
3) *Route Establishment Reply:* Here backward ant agent is send to inform the source with a route to destination and apply pheromone as it returns back. If there is source node then calculate the pheromone value of the arriving backward ants using following equ.(3) [6]:

$$P = \frac{N_h}{N_n} + \frac{L_c}{100} + T \quad (3)$$

For each neighbour update the pheromone entry in pheromone array, find the highest pheromone valued neighbour and update the route entry for that destination. Else if it is an intermediate node then update the reverse memory of the backward ant. If the route to destination exists then pheromone value of that neighbour to that destination increases using the following equ. (4) [6]:

$$P_n = .75 * P_o + .25 * P \quad (4)$$

And decrease the pheromone value of all other neighbours using the following equ. (5) [6]:

$$P_n = .75 * P_o - .25 * P \quad (5)$$

At last find the highest pheromone valued neighbour, update the route entry for that destination to make the node forward packets to that highest valued neighbour. Else if there is destination node then initialize the reverse memory of the backward ant, copy the memory of arriving forward ant to the memory of backward ant, and make the backward ant follow the same path which is stored in its memory to source.

4) *Route Expiry:* When route expiry timer timeouts, remove that destination from the pheromone array, remove the routing table entry, and decrease number of active destinations.
5) *Connection Loss:* After some interval if no packets come then reset the pheromone value of that neighbour, withdraw the routing table entries that route through that neighbour. If any other available neighbour has a nonzero pheromone value to that destination, update the routing table and decrement number of active neighbours.
6) *Local Repair:* If some request packet comes and no routing entry exists for it, then do Automatic Repair using Multi-Ant Routes then, queue all packets to the destination using this new neighbour in the route, otherwise use default built-in AODV Local Repair strategy [6].

This paper concludes that MMRA algorithm performs better than AODV as in the conventional AODV, when an existing route is disconnected; a source node performs a route discovery procedure. In this protocol a source node can send data packets to its corresponding destination through one of backup routes pre-established.

III. CONCLUSION

This paper reviews different methods to solve different problems in Mobile Ad hoc networks using Ant Colony Optimization technique. Ant Colony Optimization has multiple properties that optimize the performance of routing protocols and increases the network efficiency.

The future work we can do to improve the life time of network by using Ant Colony Optimization along with conventional routing protocols by using node's energy properly. We can try to use whole network for routing combining multi-path transmission properties of ant swarms with threshold for hop count and energy parameter.

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