ANT COLONY OPTIMIZED ROUTING FOR MOBILE ADHOC NETWORKS (MANET)

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Abstract - 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. Routing means the act of moving information across an internet work from a source to a destination. The biggest challenge in this kind of networks is to find a path between the communication end points, what is aggravated through the node mobility. In this paper we present a new routing algorithm for mobile, multi-hop ad-hoc networks. The protocol is based on swarm intelligence. Ant colony algorithms are a subset of swarm intelligence and consider the ability of simple ants to solve complex problems by cooperation. The introduced routing protocol is well adaptive, efficient and scalable. The main goal in the design of the protocol is to reduce the overhead for routing. We refer to the protocol as the Ant Colony Optimization Routing (ACOR).

Keywords - *Mobile ad hoc networks (MANET), Swarm Intelligence, Ant Colony Optimization Routing (ACOR).*

I. INTRODUCTION

A mobile ad-hoc network (MANET) is a set of mobile nodes which communicate over a wireless medium over single or multiple and do not need any infrastructure such as access points or base stations. Therefore, mobile ad-hoc networks are suitable for temporary communication links.

Fig. 1 : Mobile Adhoc Network

Nodes not only have to fulfil the functionality of hosts, but also each node has also to be a router, forwarding packets for other nodes. One interesting application for mobile ad-hoc networks beside the classical ones, disaster and military applications, is the deployment of mobile ad-hoc networks for multimedia applications. The biggest challenge in this kind of networks is still, the finding of a route between the communication end-points, which is aggravated through the node mobility.

This paper deals with a routing algorithm ACOR used for mobile, multi-hop ad-hoc networks to improve the performance of the existing protocol of mobile ad hoc network, which is based on swarm intelligence and especially on the ant colony based metaheuristic.

II. FUNDAMENTALS OF SWARM INTELLIGENCE

Swarm intelligence is an emerging field of biologically-inspired artificial intelligence based on the behavioural models of social insects such as ants, bees, wasps and termites. Respective algorithms are made based on ants, bees, wasps such as Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO) and Bee Swarm Optimization (BSO). It is a scientific theory about how Complex and sophisticate behaviours can emerge from social creature group. It helps in designing a framework for designing distributed algorithms which are originally derived by studying models of social insect behaviour. Swarm intelligence is a probabilistic method for building probabilistic paths between nodes based on simple rules.
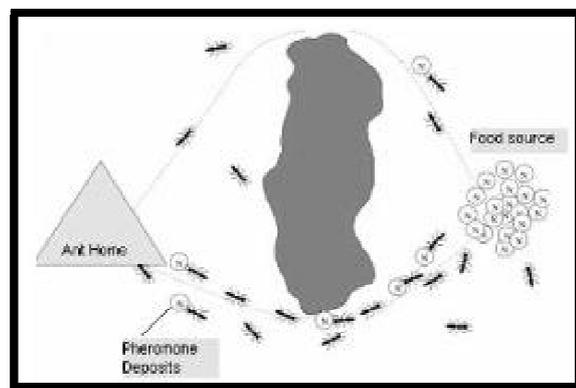

Fig. 2 Shortest Path Taken by Ant after initial searching time

In general, ant colony optimization meta-heuristic tries to solve a combinatorial problem using the collaboration of a group of simple agents called artificial ants. ACO routing algorithms establish optimum paths to the destination using a number of artificial ants that communicate indirectly with each other by *Stigmergy*. *Stigmergy* is a way of indirect communication between individuals which, in an ad-hoc network case, is done through the modification of some parameters in the nodes of the network. 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. Many ants may travel through different routes to the same food source. The ants, which travel the shortest path, reinforce the path with more pheromone that aids other ants to follow. Subsequently more ants are attracted by this pheromone trail, which reinforces the path even more. This autocatalytic behaviour quickly identifies the shortest path.

III. ROUTING IN MANETS

Routing in MANET is a Dynamic Optimization Problem as the search space changes over time. 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.

The routing scheme in a MANET can be classified into two major categories – Proactive and Reactive. 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. This approach suffers from problems like increased overhead, reduced scalability and lack of flexibility to respond to dynamic changes. The reactive or on-demand approach is event driven and the routing information is exchanged only when the demand arises. The routing is initiated by the source.

ANTNET and *ANTHOCNET* are two well known ant colony based routing algorithms. ANTNET is a proactive and ANTHOCNET is a reactive routing algorithm. They have a very high delivery rate and find routes whose lengths are very close to the length of the shortest path. The drawback of ANTHOCNET is the number of routing messages that needs to be sent in the network for establishing routes to the destination and the disadvantage of ANTNET is the time needed before a system of paths between the nodes of the network is established. This is referred to as the convergence time. Regarding the dynamic nature of mobile ad-hoc networks, a long convergence time is a significant drawback.

IV. ANT COLONY OPTIMIZATION

The simple ant colony optimization (ACO) meta-heuristic can be used to find the shortest path between a source node *vs* and a destination node *vd* on the graph *G*.

Let $G = (V, E)$ be a connected graph with $n = |V|$ nodes. The pheromone concentration, $\Phi i,j$ is an indication of the usage of the edge i, j. An ant located in node *vi* uses pheromone $\Phi i,j$ of node *vj* and *Ni* to compute the probability of node *vj* as next hop. *Ni* is the set of one-step neighbours of node *vi*. An ant located in node *vi* uses pheromone $\square i,j$ of node *vj* $\square$ *Ni* to compute the probability of node *vj* as next hop. *Ni* is the set of one-step neighbours of node *vi*.

$$p_{i,j} = \begin{cases} \frac{\varphi_{i,j}}{\sum_{j \in N_i} \varphi_{i,j}} & \text{if } j \in N_i \\ 0 & \text{if } j \notin N_i \end{cases} \quad \text{(i)}$$

The transition probabilities pi,j of a node *vi* fulfil the constraint:

$$\sum_{j \in N_i} p_{i,j} = 1, i \in [1, N] \quad \text{(ii)}$$

An ant changes the amount of pheromone of the edge $e(vi, vj)$ when moving from node *vi* to node *vj* as follows:

$$\varphi_{i,j} = \varphi_{i,j} + \Delta\varphi \quad \text{(iii)}$$

Like real pheromone the artificial pheromone concentration decreases with time to inhibit a fast convergence of pheromone on the edges.

$$\varphi_{i,j} = (1-q) \cdot \varphi_{i,j}, \, q \in [0, 1 \quad \text{(iv)}$$

A. Reasons for ACO ensembles to ad hoc networks

The reasons why ACO suits to Adhoc networks are:

a) **Dynamic topology:** This property is responsible for the bad performance of several routing algorithms in mobile multi-hop ad-hoc networks. The ant colony optimization meta-heuristic is based on agent systems and works with individual ants. This allows a high adaptation to the current topology of the network.

b) **Local work:** In contrast to other routing approaches, the ant colony optimization meta-heuristic is based only on local information, i.e., no routing tables or other information blocks have to be transmitted to neighbors or to all nodes of the network.

c) **Link quality:** It is possible to integrate the connection link quality into the computation of the pheromone concentration, especially into the evaporation process. This will improve the decision process with respect to the link quality. It is here important to notice, that the approach has to be modified so that nodes can also manipulate the pheromone concentration independent of the ants, i.e. data packets, for this a node has to monitor the link quality.

d) **Support for multi-path:** Each node has a routing table with entries for all its neighbors, which contains also the pheromone concentration. The decision rule, to select the next node, is based on the pheromone concentration on the current node, which is provided for each possible link. Thus, the approach supports multipath routing.

V. ANT BASED ALGORITHMS

A. *Ant Based Control (ABC) Routing*
Ant-Based Control is another stigmergy-based ant algorithm designed for telephone networks. The basic principle relies on mobile routing agents, which randomly explore the network and update the routing tables according to the current network state. The routing table, stores the probabilities instead of pheromone concentrations. ABC only uses a single class of ants (i.e. forward ants), which are initiated at regular time intervals from every source to a randomly chosen destination. After arriving at a node they immediately update the routing table entries for their source node, meaning that the pheromone pointing to the previous node is increased. When ants have reached their destination, they die. The increase in these probabilities is a decreasing function of the age of the ant, and of the original probability. The ants get delayed on parts of the system that are heavily used. Some noise can be added to avoid freezing of pheromone trails.

B. *Ant Colony Optimized Routing (ACOR)*
The ant colony optimization routing (ACOR) algorithm is a probabilistic technique for solving computational problems which can be reduced to finding good paths through graphs. This algorithm is a member of ant colony algorithms family, in swarm intelligence methods, and it constitutes some meta-heuristic optimizations. ACOR has two phases. They are: Route Discovery phase and Route Maintenance phase. Both of these phases use FAnt (Forward Ant) and BAnt (Backward Ant). A FANT is an agent which establishes the pheromone track to the source node. In contrast, a BANT establishes the pheromone track to the destination node.

1) Route Discovery
Each FANT has a unique sequence number to avoid duplicates. A node receiving a FANT for the first time creates a record [destination address, next hop, pheromone value] in its routing table. The node interprets the source address of the FANT as destination address, the address of the previous node as next hop, and computes the pheromone value depending on the number of hops the FANT needed to reach the node. Then the node relays the FANT to its neighbours. When the FANT reaches destination, it is processed in a special way. The destination node extracts the information and then destroys the FANT.
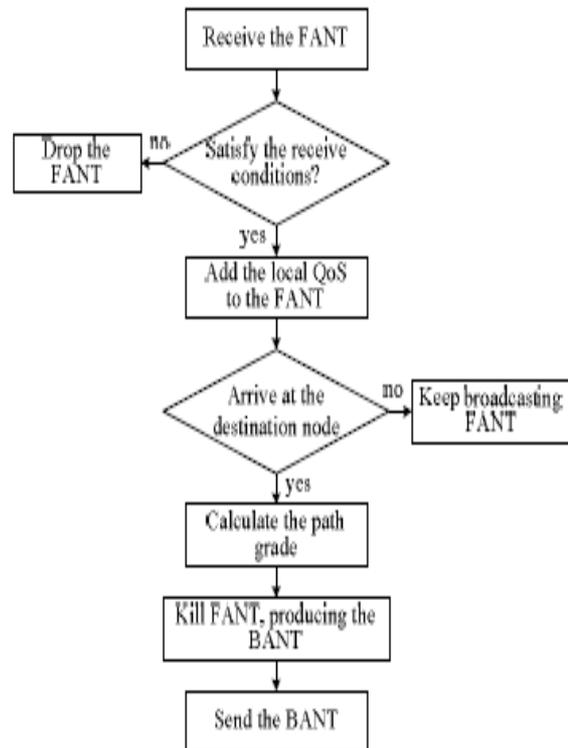

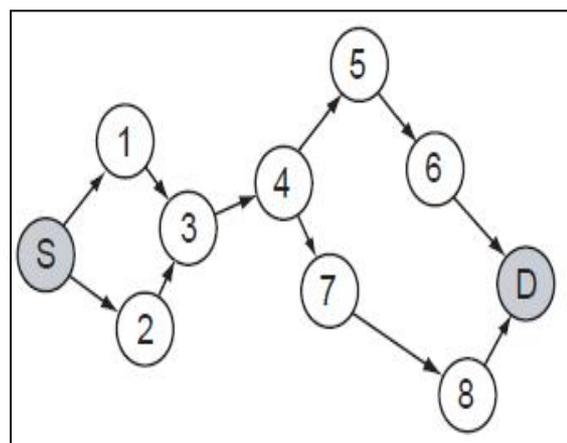**Fig. 3 The process of FANT disposing**

Fig. 4 A FANT is flooded from source to destination

A BANT is created and sent towards the source node. In that way, the path is established and data packets can be sent. Data packets are used to maintain the path, so no overhead is introduced. Pheromone values are changing
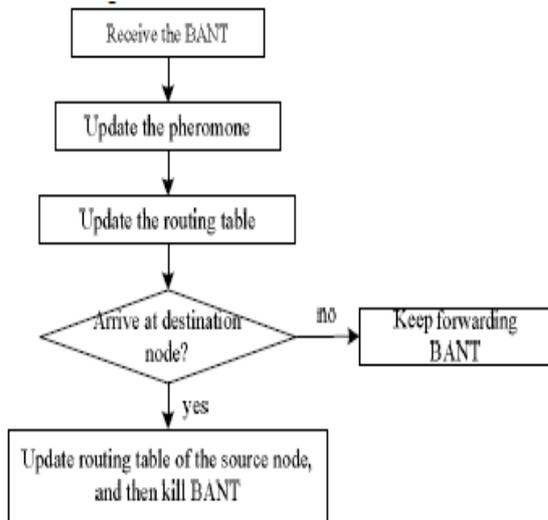

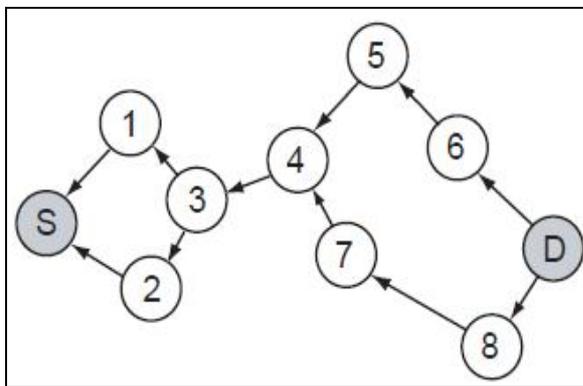**Fig. 5 The process of the BANT disposing**

Fig. 6 A BANT takes the reverse path of FANT

2) Route Maintenance

The second phase of the routing algorithm is called route maintenance, which is responsible for the improvement of the routes during the communication. ACOR does not need any special packets for route maintenance. Once the FAnt and BAnt have established the pheromone tracks for the source and destination nodes, subsequent data packets are used to maintain the path. Similar to the nature, established paths do not keep their initial pheromone values forever. When a node (relay node) relays a data packet toward the destination (destination address*)* to a neighbour node (next hop), it increases the pheromone value of the entry (destination address, next hop, pheromone value*)* by pheromone function, i.e., the path to the destination is strengthened by the data packets. In contrast, the next hop (next hop) increases the pheromone value of the entry (source address, relay node, pheromone value) by pheromone function, i.e. the path to the source node is also strengthened. The evaporation process of the real pheromone is simulated by regular decreasing of the pheromone values. The above method for route maintenance could lead to undesired loops. ACOR prevents loops by a very simple method, which is also used during the route discovery phase. Nodes can recognize duplicate receptions of data packets, based on the source address and the sequence number. If a node receives a duplicate packet, it sets the DUPLICATE ERROR flag and sends the packet back to the previous node. The previous node deactivates the link to this node, so that data packets cannot be sending to this direction any more.

3) Route Failure Handling

ACOR handles routing failures, which are caused especially through node mobility and thus very common in mobile ad-hoc networks. ACOR recognizes a route failure through a missing acknowledgement. If a node gets a ROUTE ERROR message for a certain link, it first deactivates this link by setting the pheromone value to 0. Then the node searches for an alternative link in its routing table. If there is a second link it sends the packet via this path. Otherwise the node informs its neighbours, hoping that they can relay the packet. Either the packet can be transported to the destination node or the backtracking continues to the source node. If the packet does not reach the destination, the source has to initiate a new route discovery phase.

4) Requirements of ACOR

The requirements needed to be fulfilled for routing algorithm for mobile ad-hoc networks are:

a) **Distributed operation:** In ACOR, each node owns a set of pheromone counter^2 $\Box i,j$ in its routing table for a link between node vi and vj. Each node controls the pheromone counter independently, when ants visit the node on route searches.

b) **Loop-free:** The nodes register the unique sequence number of route finding packets, FANT and BANT, so they do not generate loops.

c) **Demand-based operation:** Routes are established by manipulating the pheromone counter $\Box i,j$ in the nodes. Over time, the amount of pheromone decreases to zero when ants do not visit this node. A route finding process is only run, when a sender demands.

d) **Sleep period operation:** Nodes are able to sleep when their amount of pheromone reaches a threshold. Other nodes will then not consider this node.

Additional Requirements of ACOR are:

a) **Locality:** The routing table and the statistic information block of a node are local and they are not transmitted to any other node.

b) **Multi-path:** Each node maintains several paths to a certain destination. The choice of a certain route depends on the environment, e.g., link quality to the relay node.

c) **Sleep mode:** In the sleep mode a node snoops, only packets which are destined to it are processed, thus saving power

C. Probabilistic Emergent Routing Algorithm [PERA]

Mobile ad hoc networks are infrastructure-less networks consisting of wireless, possibly mobile nodes which are organized in peer-to-peer and autonomous fashion. The highly dynamic topology, limited bandwidth availability and energy constraints make the routing problem a challenging one. In this paper we take a novel approach to the routing problem in MANETs by using swarm intelligence inspired algorithms. The proposed algorithm uses Ant-like agents to discover and maintain paths in a MANET with dynamic topology. Multiple paths are set up, but only the one with the highest pheromone value is used by data and the other paths are available for backup. The route discovery and maintenance is done by flooding the network with ants. Both forward and backward ants are used to fill the routing tables with probabilities. These probabilities reflect the likelihood that a neighbour will forward a packet to the given destination. Multiple paths between source and destination are created.
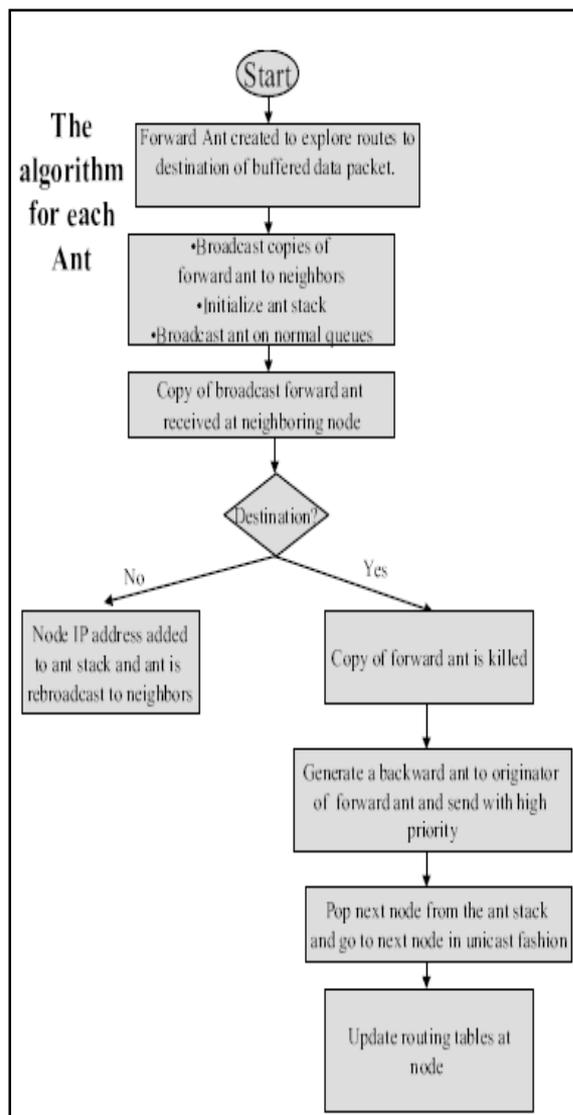
Fig. 7 Algorithm for each ant
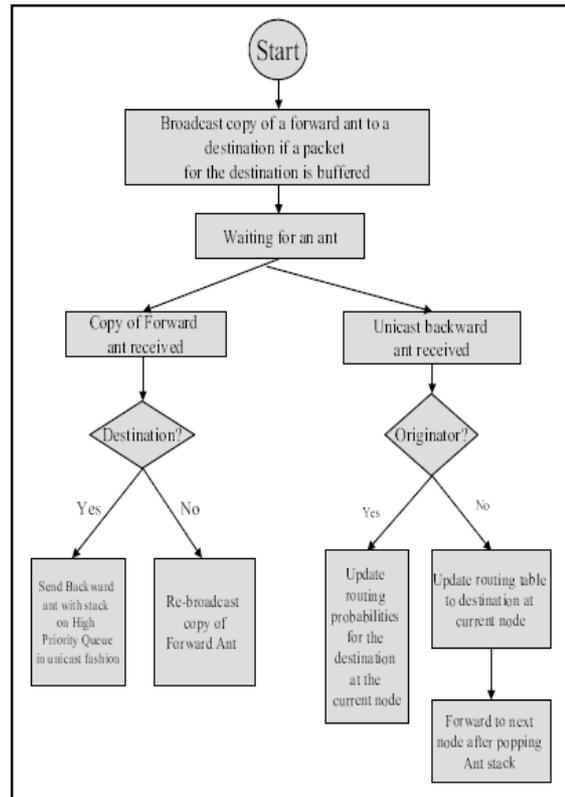
Fig. 8 Algorithm for each node

D. Ant Agents for Hybrid Multipath Routing [AntHocNet]

AntHocNet is a hybrid multipath algorithm. The algorithm consists of both reactive and proactive components. In a reactive path setup phase, multiple paths are built between the source and destination of a data session. Data are stochastically spread over the different paths, according to their estimated quality. During the course of the session, paths are continuously monitored and improved in a proactive way. Link failures are dealt locally. The algorithm makes extensive use of ant-like mobile agents which sample full paths between source and destination nodes. 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, called proactive forward ants.

E. Antnet- Ant Algorithm

In AntNet, a group of mobile agents (or artificial ants) build paths between pair of nodes; exploring the network concurrently and exchanging obtained information to update the routing tables. Ants (F-ants) are launched at regular instants from each node to randomly chosen destinations.

Ants are routed probabilistically with a probability function of:
(i) Artificial pheromone values, and
(ii) Heuristic values, maintained on the nodes
   • Ants memorize visited nodes and elapsed times

- Once reached their destination nodes, ants retrace their paths backwards (B-ants), and update the pheromone tables.

AntNet is distributed and not synchronized.
1) Role of F-ants and of B-ants
   F-ants collect implicit and explicit information on available paths and traffic load

- implicit information, through the arrival rate at their destinations (remember the differential length effect)
- explicit information, by storing experienced trip times
  F-ants share queues with data packet. B-ants fast back propagate info collected by F-ants to visited nodes. B-ants use higher priority queues

VI CONCLUSION

In this paper we presented a on-demand routing approach for mobile multi-hop ad-hoc networks. The approach is based on swarm intelligence and especially on the ant colony optimization meta-heuristic. Routing of data packets is only through optimal path which is generated by route discovery phase as defined by ACOR.

Route maintenance is done periodically to retain optimal path. This is done through data packets. Due to change in topology of adhoc network, existing routes may fail or new paths may be generated. In order to adapt for the change in topology, route refreshing is done periodically.

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