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ANT COLONY OPTIMIZATION BASED ROUTING ALGORITHM FOR MOBILE AD HOC NETWORK : A SURVEY

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ABSTRACT: Mobile ad-hoc networks are infrastructure-less networks consisting of wireless, mobile nodes are ordered in peer-to-peer and self-governing fashion. "The highly active topology, limited bandwidth availability and energy constraints make the routing problem a challenging one. Recently a new family of algorithms emerged inspired by Swarm Intelligence, which provides a novel approach to distributed optimization problems. Initial studies have unveiled a great deal of matching properties between the routing requirements of ad-hoc networks and certain features of SI, such as the ability of ant colony to find a nearly optimal route between elements. Several algorithms which are based on ant colony optimization were introduced in recent years to solve the routing problem in ad-hoc networks. In this paper we offer a survey of ant-based routing algorithms for MANETs. We categorize algorithms and summarize their operation.
Keywords: Ant Colony Optimization, Mobile Ad hoc Network

I. INTRODUCTION

Mobile ad hoc network is a collection of mobile devices which form a communication network with no pre-existing wiring or infrastructure. Routing in MANETs is challenging since there is no central coordinator that manage routing decisions. Multiple routing protocols have been developed for MANETs. In proactive protocols, every node maintains the network topology information in the form of routing tables by periodically exchanging routing information. Routing information is generally flooded in the whole network. Whenever a node requires a path to a destination, it runs an appropriate path finding algorithm on the topology information it maintains. The destination sequenced distance vector routing (DSDV) protocol, and wireless routing protocol (WRP) are some examples for the proactive protocols. Reactive protocols do not maintain the network topology information. They obtain the necessary path when it is required, by using a connection establishment process. Hence these protocols do not exchange routing information periodically. The dynamic source routing (DSR), Ad-hoc on-demand distance vector routing (AODV), and temporally ordered routing (TORA) algorithm are some examples for the protocols that belong to this category. Recently, a new family of algorithms emerged inspired by swarm-intelligence, which provides a novel approach to distributed optimization problems. The expression "Swarm Intelligence" defines any attempts to design algorithms inspired by the collective behaviour of social insect colonies and other animal societies. Several algorithms which are based on ant colony were introduced in recent years to solve the routing problem in ad-hoc networks. These algorithms show that the biologically inspired concepts can provide a significant performance gain over traditional approaches. Ant based routing algorithms in ad-hoc networks, categorized to flat and hierarchical routing algorithms. The reminder of this paper is structured as follows. In section 2 we present the basics and the background of ant colony optimization meta-heuristic. In section 3 and 4 we present flat and hierarchical ant routing algorithms respectively. Section 5 present conclusions.

II. BASICS AND BACKGROUND

Basic ant algorithm

The basic idea of the ant colony optimization meta heuristic is taken from the food searching behavior of real ants. When ants are on they way to search for food, they start from their nest and walk toward the food. When an ant reaches an intersection, it has to decide which branch to take next. While walking, ants deposit pheromone, which marks the route taken. The concentration of pheromone on a certain path is an indication of its usage. With time the concentration of pheromone decreases due to diffusion effects. This property is important because it is integrating dynamic into the path searching process. Figure 1 shows a scenario with two routes from the nest to the food place. At the intersection, the first ants randomly select the next branch. Since the below route is shorter than the upper one, the ants which take this path will reach the food place first. On their way back to the nest, the ants again have to select a path. After a short time the pheromone concentration on the shorter path will be higher than on the longer path, because the ants using the shorter path will increase the pheromone concentration faster. The shorter path will thus be identified and eventually all ants will only use this one.

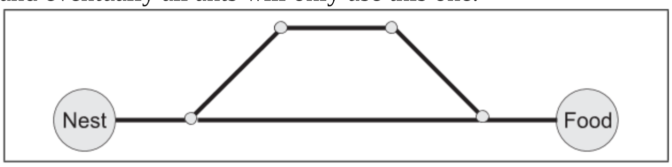

Figure1: All ants take the shortest path after an initial searching time.

This behavior of the ant can be used to find the out a path that satisfies multiple constraints in ad-hoc networks. Especially, the dynamic component of this method allow a high adaptation to changes in mobile ad-hoc network topology, since in these networks the existence of links are not guaranteed and link changes occur very often.

Simple Ant Colony Optimization Metaheuristic Algorithm

Let G=(V,E) be a connected graph with n=|V| nodes. The simple ant colony optimization meta heuristic can be used to find the shortest path between a source and destination node on the graph G. the path length is given by the number of nodes on the path. Each edge of the graph has a variable ϕ i, j (artificial pheromone), which is modified by the ants when they visit the node. The pheromone concentration is an indication of the usage of this edge. An ant located in node vi uses pheromone of node v j ∈ Ni to compute the probability of node vj as next-hop.

$$p_{i,j} = \left\{ \frac{\emptyset_{i,j}}{\sum_{j \in N_i} \emptyset_{i,j}} \quad if\ j \in N_i \right\} \quad (1)$$

$$p_{i,j} = \left\{ 0\ \ if\ j \notin N_i \right\} \quad (1)$$

Where *Ni* is set of one-step neighbors of node *vi* . During the route finding process, ants deposit pheromone on the edges. In the simple ant colony optimization meta-heuristic algorithm, the ants deposit a constant amount of pheromone on the edge *e*(*vi* , *v j*) when moving from node *vi* to node *v j* as follows:

$$\emptyset_{i,j} = \emptyset_{i,j} + \Delta\emptyset \qquad (2)$$

Like real pheromone the artificial pheromone concentration decreases with time to inhibit a fast convergence of pheromone on the edges. In the simple ant colony optimization meta-heuristic, this happens exponentially:

$$\emptyset_{i,j} = (1-q)\emptyset_{i,j}\ ,\ \ q \in (0,1] \qquad (3)$$

Why ant colony optimization meta heuristic suits to ad-hoc networks?

The simple ant colony optimization meta-heuristic shown in the previous section illustrates different reasons why this kind of algorithms could perform well in mobile multi-hop ad-hoc networks. We will discuss various reasons by considering important properties of mobile ad-hoc networks.

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.

Local work: in contrast to other routing approaches, the ant colony optimization meta-heuristic is based only on local information.

Link quality: it is possible to integrate the connection or 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.

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 multi-path routing.

III. FLAT ROUTING ALGORITHMS

In the flat networks, nodes are harmonious and their functionality is same. But in hierarchical networks, network divided into clusters. Clustered nodes only communicate directly with other nodes in their cluster, and any packets for outside nodes are sent to a designated cluster head node. The nodes therefore form a layered or hierarchical network structure. In this section we describe flat routing protocols.

Geus *et. al* [1] presents a simple ant routing algorithm (ARA) using distance vector routing, which is very similar constructed as many other routing approaches and consist of three phases. 1)Route Discovery Phase, 2)Route Maintenance and 3)Route Failure Handling. The main goal in the design of the protocol was to reduce the overhead for routing. In the route discovery phase new routes are created. The creation of new routes requires the use of a *forward ant* (FANT) and a *backward ant* (BANT). The FANT is similar to RREQ packets in AODV. A FANT is broadcasted by the sender. A node receiving a FANT for the first time, creates a record in its routing table. Then the node relays the FANT to its neighbors. When the FANT reaches the destination, this node extracts the information of the FANT and destroys it.

Subsequently, it creates a BANT–similar to RREP in AODV-and sends it to the source node. When the sender receives the BANT from the destination node, the path is established and data packets can be sent. Note that, for prevents loops, ARA implements the packet sequencing mechanism. Once the ants have established the pheromone tracks for the source and destination nodes, subsequent data packets are used to maintain the path. While walking ants in network, the pheromone concentration of links increase by Δϕ , this parameter is a function of the length of the route. The evaporation process of the real pheromone is simulated by regular decreasing of the pheromone values, which is performed according to equation 3. In the case of a route failure, the intermediate node attempts to send the packet over an alternative link. If no alternative link is found, the packet is returned to the previous up-stream node which also tries to send the packet over an alternative link. If the packet is returned in this way to the source node, a new route discovery sequence is initiated. This mechanism is generally referred to as *backtracking*. The algorithm is compared to AODV, DSDV and DSR, and the results indicate that, ARA and DSR perform comparatively in terms of *delivery rate*, with DSDV and AODV lagging behind. ARA and AODV perform comparatively in terms of *overhead ratio*, with DSDV and DSR lagging behind.

Probabilistic Emergent Routing Algorithm

In this approach, initialization and neighbor discovery is done by single-hop, broadcast HELLO messages that are transmitted periodically. The creation of the first forward ant at a node for the source-destination pair causes the routing table entries to be initialized with probabilities 1/ N for each neighbor as the next-hop for the respective destination, where N is the number of neighbors of the node where the routing table is being established. In addition to routing table, each node also maintains a table of statistics for each destination to which a forward ant has been previously sent;

the mean and the variance for the routes between source node s and destination node d .

In addition to routing table, each node also maintains a table of statistics for each destination to which a forward ant has been previously sent; the mean and the variance for the routes between source node s and destination node d .

When a node does not have a route to a certain destination, it creates a forward ant and broadcast it to all its neighbors. If forward ant reaches a repetitive node, is destroyed. It is important to note that the forward ants travel on the same queues as data packets. Hence, experience the same delay and congestion as the data packets. When a forward ant reaches the destination, the node extracts its information and creates a backward ant. Backward ant uses the information contained in the forward ant on the reverse path to change the probability distribution at each node and update the routing tables to reflect the current status of the network more accurately. This agent travels in unicast fashion back to the source node and forwarded on high priority queues.

Note that in this algorithm, pheromone reinforcement factor is defined as a function of some metric or a combination of metrics. The algorithm is compared to AODV, and the results indicate that, in low mobility, the overall goodput for both algorithms is high, but in high mobility, the PERA's goodput is lower than that of AODV. At the lower speed, the throughput is the same for both algorithms, however at the higher speed, the throughput is slightly less for PERA in some cases. Both algorithms show a large initial delay, which is required for routes to be set up. Subsequently, AODV shows large delays again in situations with high mobility. PERA on the other hand, shows low delays in all cases.

AntHocNet

Di Caro, Ducatelle and Gambardella [4] present a hybrid multi-path algorithm that uses source routing principles combined with ACO.

If a source node does not have valid routing information to a destination, sends out reactive forward ants to discover routes to destination. If the current node visited by the forward ant has a route to

destination, the packet is unicast using that route, Otherwise packet is broadcast. Nodes will compare both the travel time and hop count of any subsequent forward ant, and will only rebroadcast the forward ant if both these criteria are within a certain factor of the best forward ant in that generation. What is not mentioned in the work is that this features may cause loops, and that it relies on the source route in the header of the forward ant to ensure routes are loop free.

When forward ants reach destination node, become backward ants which trace their route back to node s . The pheromone deposited by backward ants is calculated as the average of the inverse of the cost, in terms of estimated delay and number of hops. Since the amount of pheromone by backward ants takes the packet delay into account, the AntHocNet algorithm features automatic load balancing. Once routes are created and a data session is running, source node sends one proactive forward ant toward destination node on every nth data packet. These proactive forward ants monitor the quality of the routes in use. Additionally, at each node a proactive forward ant has a small probability of being broadcast so that it can explore new routes. This algorithm also uses hello messages to improve local connectivity of nodes. If the failure occurs on a route with does not have alternatives, the nodes attempts to locally repair the route by broadcasting a route repair ant that travels to the destination in a similar way to a reactive forward ant. If no reply is received within a specified time, the entry is removed from the routing table and a notification is broadcast to all neighbor nodes. Di Caro et al does not mention whether a data packet on the failed route will be dropped at the node where the link failed or backtracked to an upstream node. Authors tested the protocol in an environment with a realistic MAC layer and compared it to the AODV. In all reported experiments, AntHocNet produces superior delivery ratio over AODV. In simpler scenario (with less node mobility or fewer nodes) AODV produces lower packet delay than AntHocNet, but AntHocNet produce better packet delay in more complex scenarios.

IV. CONCLUSION

Mobile multi-hop ad-hoc networks are flexible networks, which do not require pre-installed infrastructure. With upcoming wireless transmission technologies and highly sophisticated devices their application will increase. However the main challenge in mobile multi-hop ad-hoc networks is still the routing problem, which is aggravated by the node mobility. Various approaches were introduced in the recent years which try to handle the problems in this kind of networks, but no one fits best for all applications. In this paper we focused on ant-based routing algorithms, and summarize their operations. Note that although these routing algorithms show promising results, but should be implemented very carefully. Some parameters such as number of ants, evaporation rate, etc are influence in the simulation results. If these parameters select carefully, these algorithms are very well substituting for traditional routing protocols.

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