A Reactive Inter-Domain Routing Protocol for MANETs

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***Abstract*—Mobile Ad hoc Networks (MANETs) were developed to support communication in an environment and places where the permanent availability of fixed infrastructure who maintains communication between different nodes cannot be assured. The first interest in mobile ad hoc networks was the simple routing between similar nodes. That's why researchers focused more on how to make routing efficient within a single domain. In last decade, the heterogeneity of mobile nodes increased dramatically and the need of the interconnection between MANETs in many situations, such as in battlefields or disaster recovery is more important because of diversity of "intra-domain" routing protocols in each domain. For this purpose, an inter-domain routing protocol was developed to support communication across different MANETs. In many researches, the mobile agent paradigm was used to perform routing in MANET. In this paper, a highlight of the use of mobile agents in ad hoc networks, and the application of them with bees' communication to design a reactive inter-domain routing protocol for MANETs. Our bees' communication-based proposal will helps to enhance the efficiency of the routing protocol and to reduce the battery use of the node.**

Keywords-mobile ad hoc networks; inter-domain routing; mobile agents; bees communication.

I. INTRODUCTION

In the twentieth century, the wireless ad hoc networks take an emerging aspect. Any fixed infrastructure or central administration needs to deploy this kind of networks. Most of researches concerning routing in ad hoc networks focused on routing in a single domain.

A research has been performed in the beginning of the 2007^{th} for routing between heterogeneous domains (different routing protocol and different technology of transmission can be employed in each domain). The protocol instances issued from this research [1][2] run in routers in a distributed manner. There are gateways in each domain used for routing packets from one domain to another until the destination is reached.

Nowadays, many protocols in the field of inter-domain routing in mobile ad hoc networks focused on the semi-proactive and proactive routing, but did not consider the reactive side. In this paper, we introduce a new reactive inter-domain routing protocol for ad hoc networks using bees' communication. The natural inspired metaheuristic algorithms take advantages on the design of the intra-ad hoc routing.

We present, in this paper, an overview of using mobile agents in inter-MANETs, then, their application in the context of bees' communication to design a reactive inter-domain routing protocol for MANETs. Bees' communication was introduced and developed for routing in a single MANET. Bees' communication will be a first use in the inter-domain routing for ad hoc networks. We use it to enhance the efficiency of the inter-domain routing and for reducing the battery use. The method used is inspired by the bee dance foraging principle to find food.

The rest of the paper is organized as follows. In Section 2, an overview of the related works that use swarm intelligence is presented. In Section 3, a description of the basic inter-domain routing protocol for MANETs. Section 4 outlines method bees employ to share food among them using dance language. Sections 5 and 6 provide details on our approach.

II. RELATED WORKS

The enhancement of routing in MANETs was based on swarm intelligence many times. The first routing algorithm related to the use of Ants' communication was the Ant-Colony based Routing Algorithm (ARA) [3]. The core of the algorithm is described in the ant-based routing algorithms (AntNet) [4] and (ABC) [5], two swarm intelligence routing protocols for fixed networks. Another routing algorithm designed for MANETs and based on AntNet (AntHocNet) [6], it is a hybrid routing protocol using both a reactive mode of operation (on-demand route discovery) and a proactive mode of operation (periodic route discovery). However, the routing overhead of AntHocNet is a disadvantageous factor [7]. The swarm intelligence method based on Ant Colony Optimization was also used in the inter-domain routing for MANETs. Dressler and Gerla [8] proposed to enhance inter-domain routing in MANETs, based on virtual cord for routing between a set of MANETs, by applying the ACO mechanism of the AntHocNet protocol to handle topology change. The result of their work showed that the proposed combination is efficient and had marginal overhead by applying ACO mechanism.

Bees' communication was first studied by Karl Von Frish in 1911 [9]. He spent his professional life studying the comportment of bees and won a Nobel Prize for his research. The application of bees' communication in routing data packets so far has only been introduced and developed for routing in a single MANET. Farooq et al. developed a

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protocol called BeeHive for fixed networks [10]. They claimed that the study of honey bees has revealed a remarkable sophistication of the communication capabilities as compared to ants. Their work on BeeHive demonstrated that it can be more energy-efficient than AntNet and deliver the same or better performance. BeeAdHoc [11] is an application of the principle of bees' communication to route packets within a single MANETs and it was proposed by the same researchers. BeeAdHoc uses fewer control packets as compared to AntNet and AntHocNet, which decreases the routing overhead, and distributes traffic to different paths proportional to their quality and capacity, which makes it an energy-efficient routing protocol. Based on early results, BeeAdHoc shows also that packet delay is lower.

As the use of Bees' communication shows more interesting results than the use of ants' communication for intra-domain routing in ad hoc networks, we will use bees' communication to perform an efficient and reactive inter-domain routing protocol for MANETs and compare it with the existing inter-domain routing protocol for MANETs [8] based on ants' colony optimization.

III. BASIC SCHEME INTERCONNECTING SEVERAL MANETS

The interconnection between groups of MANETs is maintained by gateways belonging to each MANET. When a node "a_1" from a certain MANET "A" want to reach a node "d_2" from an another MANET "D", firstly, it routes packets to a reachable internal gateway within MANET "A", using the underlying routing protocol; after that, packets are routed to an external gateway within external MANET using inter-domain routing protocol, and so, until the packets reach destination in domain "D".

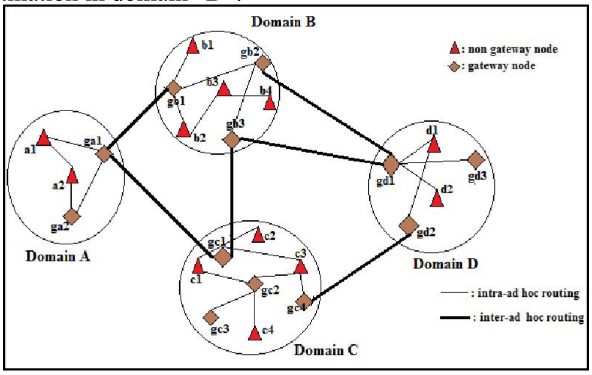

Figure 1. Interconnection of several MANETs.

The inter-domain routing protocol is proactive; thus, the external routing table of each gateway to different domains is known by at least all gateways.

IV. HOW BEES SHARE FOOD LOCATION

Bees are very organized and communicate in a very complicated manner through dances. When a food source is found by a bee, the other bees reach this location after some time; this is done by sharing the way to source using dance language done by the first discoverer bee. All information that other bees need to find food source are: its distance from the hive, its direction, and productivity. The dancing process is performed into two dances; see Figures 2 and 3.

A. Waggle Dance

This type of dance is performed when food is located at a long distance from the hive. At this state and taking as reference the direction if the sun, the movement of this dance resembles to the number "eight". In a typical dance, the bee moves in a straight line, for a short distance, moving its body from side to side approximately 13 to 15 times a second and return after to the beginning point from which it starts the dance tracing a half-circle.

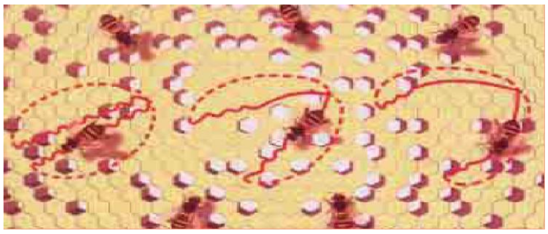

Figure 2. Waggle Dance [12].

By varying the angle between the waggling run and an imaginary line running straight up and down, the bee conveys the direction of the food source. If a line is drawn which connects the food source and the hive, and another line which connects the hive and the spot on the horizon immediately below the sun, then the angle formed by the two is observed to be the same as that of the angle in the waggle dance.

B. Round Dance

The round dance is a round movement of the discoverer bee, it turns around itself in a quick rhythm of eight to ten tour/second then make a half round in the opposite sense.

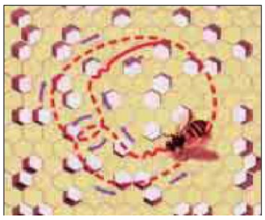

Figure 3. Round Dance [12].

The other bees, while observing this dance, know that source of nectar is near close to a radius of 50 meters.

V. EXTENDED APPLCATION OF BEES' COMMUNICATION TO THE INTER-DOMAIN ROUTING FOR MANETS

Our proposal is to design a reactive inter-domain routing protocol for mobile ad hoc networks. As mentioned earlier in the beginning of this paper, our idea is based on bees foraging principle. For instance, a discoverer bee starts searching food place, and when it finds it, it tells other bees the location of the food. It launches discovery process and when it discover the place, it tells the information about this place to the other bees; (for distance, we use PacketDelay, for direction, we use RouteLifeTime (because only nodes having a sufficient energy participate in the packets routing) and for productivity, we use AvailableBandwidth (the quantity of the food transported, is equal to the number of packets routed).

In our case, we use waggle dance since it will be applied for large scale interconnected MANETs.

We will use mobile agents to discover routes to a destination, and to transmit back results to the source node relying on three metrics, Packet Delay, RouteLifeTime, and AvailableBandwidth.

A. PacketDelay

It is the end-to-end packet delay for a discovered route between source and destination.

B. RouteLifeTime

It is the average remained battery of nodes composing a route between source and destination

C. PacketDelay

The bandwidth is the maximum data transfer rate of a network connection. It specifies how much data can be sent over a specific connection during amount of time. The available bandwidth then is the unused capacity of a network connection during a time interval. The available bandwidth along a path is the minimum available bandwidth of all traversed network connections.

VI. ALGORITHM DEFINITION

As mentioned in Section 3, a packet from a source S, traverses a path of intra-connected and inter-connected gateways until reach destination D. We will use three types of mobile agents, MA_D, MA_RL, and MA_AB.

MA_D: is the mobile agent responsible of packet delay computation. MA_RL: is the mobile agent responsible of RouteLifeTime computation. MA_AB: is the mobile agent responsible of available bandwidth computation.

A. PacketDelay Computation

From an intra-domain, a node requesting a high quality route to another intra-domain node does:

1) If the domain the source node belongs to uses proactive routing protocol then:

- The source node creates MA_D mobile agent for each gateway having connection to external domain.
- The mobile agents store the departure time from source node and are sent to the corresponding gateways.
- When arrival at the gateways nodes, they calculate difference between departure time and arrival time and store results in variable delay.
- After that, at each gateway the mobile agent is cloned and broadcasts to another connected gateway until the destination is reached.

2) If the domain the source node belongs to uses reactive protocol

- The source node launches a discovery process using underlying routing protocol. The discovery process is ordered to gateways having connection to the external domains.
- After the source node obtains the list of gateways having connection to the external domains, it uses the same procedure detailed above to perform computation of delay.

B. RouteLifeTime Computation

As done for packets delay, a source node creates mobile agent for each gateway having connection to the external domains and submit them to these gateways.

When mobile agents arrive to these gateways, they store the value of the remained battery energy in a structure containing (gatewayID, remainedbattery).

After that, a mobile agent is broadcasted to an external domain. It compares the stored remained battery energy to the remained battery energy of the current node.

- If the current node energy is less than a certain threshold (speed of average consumed energy per a degree of amount traffic) then, it returns to the source node with **routequalityfailed** message.
- Else, if the current energy is better than the stored one, then, the result is stored in the struct.

When mobile agent arrives to the destination, it calculates the average remained battery of the traversed path, and the result is send back to the source node.

C. AvailableBandwidth Computation

The available bandwidth can be calculated as: the total bandwidth of a network connection – consumed bandwidth

The consumed bandwidth (goodput): average data rate of successful data transfer per a slot of time, and can be taken by mobile agents from statics of the network device.

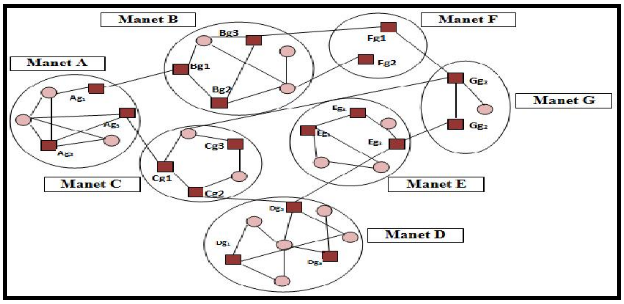

Figure 4. Proposed scenario to apply bees' communication.

When applying **routequality** request from node "a" in domain A, to node "e" in domain E (see Figure 4), node "a" will have routequality of all routes leading to node "e" so that it can choose the best one based on "minimum delay, maximum bandwidth, and maximum lifetime"

VII. CONCLUSION AND FUTURE WORK

With the proposed solution, mobile agents can contribute to minimise the energy of nodes and when the route quality to reach a node will be known, the overhead will be minimized. Future work will be to build the proposed solution for a large scale interconnected Mobile AdHoc Networks. We will use the network simulator ns-2.32 [13] with the integration of the mobile agent framework to perform the computation made by each gateway and to evaluate the performance and overhead of the given scheme.

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