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MANET ROUTING PROTOCOLS BASED ON A SOFT COMPUTING TECHNIQUE (SWARM INTELLIGENCE)

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Abstract: Mobile Ad Hoc Networks are communication networks built up of a collection of mobile devices which can communicate through wireless connections. Routing is the task of directing data packets from a source node to a given destination. This task is particularly hard in Mobile Ad Hoc Networks: due to the mobility of the network elements and the lack of central control, routing algorithms should be robust and adaptive and work in a decentralized and self-organizing way. In this paper, I will describe bees and ant based protocols which draws inspiration from Swarm Intelligence to obtain these characteristics. More specifically, borrow ideas from ant colonies and from the Ant Colony Optimization framework and bee nature .In an extensive set of research, I will compare bees and ants nature with a state-of-the-art algorithm, and show that it gets better performance over a wide range of different scenarios and for a number of different evaluation measures. In particular, I will explain that bees and ants based protocols scales better with the number of nodes in the network.
Keywords: MANET, Energy management, Routing, design issues.

I. INTRODUCTION

In communications network research, there is currently an increasing interest for the paradigm of autonomic computing [14]. The idea is that networks are becoming more and more complex and that it is desirable that they can self organize and self-configure, adapting to new situations in terms of traffic, services, network connectivity, etc.To support this new paradigm, future network algorithms should be robust, work in a distributed way, be able to observe changes in the network, and adapt to them. Nature's self-organizing systems like insect societies show precisely these desirable properties. Making use of a number of relatively simple biological agents (e.g., the ants) a variety of different organized behaviors are generated at the system-level from the local interactions among the agents and with the environment. The robustness and effectiveness of such collective behaviors with respect to variations of environment conditions are key-aspects of their biological Success. This kind of systems is often referred to with the term Swarm Intelligence. Swarm systems have recently become a source of inspiration for the design of distributed and adaptive algorithms, and in particular of routing algorithms. Routing is the task of directing data flows from sources to destinations maximizing network performance. It is at the core of all network activities. Several successful routing algorithms have been proposed taking inspiration from ant colony behavior and the related framework of Ant Colony Optimization (ACO) [8] and bee inspired protocols. Examples of ACO routing algorithms are AntNet [6] and ABC [19]. One type of networks where the need for autonomic control is intrinsically necessary are Mobile Ad Hoc Networks (MANETs) [17]. These are networks in which all nodes are mobile and communicate with each other via wireless connections. Nodes can join or leave at any time. There is no fixed infrastructure. All nodes are equal and there is no centralized control or overview. There are no designated routers: nodes serve as routers for each other, and data packets are forwarded from node to node in a multi-hop fashion.

The ACO routing algorithms mentioned before were developed for wired networks. They work in a distributed and localized way, and are able to observe and adapt to changes in traffic patterns. However, changes in MANETs are much more drastic: in addition to variations in traffic, both topology and number of nodes can change continuously. Further difficulties are posed by the limited practical bandwidth of the shared wireless channel: although the data rate of wireless communication can be quite high, algorithms used for medium access control, such as IEEE 802.11 DCF[12] (the most commonly used in MANETs), create a lot of overhead both in terms of control packets and delay, lowering the effectively available bandwidth. The challenges of autonomic control are therefore much bigger, and new designs are necessary to guarantee even the basic network functions. In the following, I describe AntHocNet, an ant inspired algorithm and bee inspired protocols for routing in MANETs. Building on ideas from previous work on ACO routing, in combination with techniques from dynamic programming, it is tailored to deal with the challenges posed by the extreme dynamics of MANET environments. I compare the algorithm with traditional approaches and show its superiority especially under those conditions where the difference with wired networks is more evident. We also present results indicating that the algorithm is remarkably scalable. The rest of this article is organized as follows. First i introduce some necessary background, next i describe the algorithm.

II. BEES IN NATURE

A very interesting swarm in nature is honey bee swarm that allocates the tasks dynamically and adapts itself in response to changes in the environment in a collective intelligent manner. The honey bees have photographic memories, space-age sensory and navigation systems, possibly even insight skills, group decision making process during selection of their new nest sites, and they perform tasks such as queen and brood tending, storing, retrieving and distributing honey and pollen, communication and foraging. These characteristics are incentive for researchers to model the intelligent behaviors of bees. Before presenting the algorithms described to use intelligent behaviors and their applications, behavior of the colony is explained below: Bees are social insects living as colonies. There are three kinds of bees in a colony: drones, queen and workers.

A. QUEEN BEE

Queen bee can live several years. She is the only egg-laying female who is the mother of all the members of the colony. The queen usually mates only once in her life and she fertilizes for two or more years by the sperms stored in the mating. After consuming the sperms, she produces unfertilized eggs and one of her daughters is selected as a queen in order to keep on egg-laying. A laid egg hatches into larva, pupate, adult bee, respectively. When the colony is lack of food sources, queen produces new eggs. If the colony becomes too crowded, the queen stops laying. A healthy queen bee can lay 2,000 eggs a day and 175,000–200,000 eggs per year depending on the conditions mentioned.

B. DRONES

Drones are the fathers of the colony, in other words drones are male bees. They are produced from unfertilized eggs, queens and workers produced from fertilized eggs which are fed differently as larvae. They never live more than 6 months. There are several hundred of drones in the colony in summer times. The primary task of a drone is to fertilize a new queen. Drones die after they mate with the queen.

C. ORKERS

They collect food, store it, remove debris and dead bees, ventilate the hive and guard the hive. Workers make the wax cells in which the queen lays eggs and feed the larvae, drones and queen by special substance or secretion of their salivary glands. The tasks of a worker bee are based on its age and the needs of the colony. In second half of her life, she works as a forager by initially leaving the hive for short flights in order to learn the location of the hive and the environment topology. They live for 6 weeks during summer times and 4–9 months during the winter times.

D. MATING-flight

The queen mates during her mating flights far from the nest. A mating flight starts after a dance performed by the queen bee. During the flight the drones follow the queen and mate with her in the air. A drone mates with a queen probabilistically according to queen’s speed and fitness of the queen and the drone. Sperm of the drones will be deposited and accumulated in the queen’s sperm theca to form the genetic pool of the potential broods to be produced by the queen.

E. FORAGING

Foraging is the most important task in the hive. Many studies have investigated the foraging behavior of each individual bee and what types of external information (such as odor, location information in the waggle. Dance, the presence of other bees at the source or between the hive and the source) and internal information (such as remembered source location or source odor) affect this foraging behavior. Foraging process starts with leaving the hive of a forager in order to search food source to gather nectar. After finding a flower for herself, the bee stores the nectar in her honey stomach. Based on the conditions such as richness of the flower and the distance of the flower to the hive, the bee fills her stomach in about 30–120min and honey making process begins with the secretion of an enzyme on the nectar in her stomach. After coming back to the hive, the bee unloads the nectar to empty honeycomb cells and some extra substances are added in order to avoid the fermentation and the bacterial attacks. Filled cells with the honey and enzymes are covered by wax.

F. DANCE

After unloading the nectar, the forager bee which has found a rich source performs special movements called “dance” on the area of the comb in order to share her information about the food source such as how plentiful it is, its direction and distance and recruits the other bees for exploiting that rich source. While dancing, other bees touch her with their antenna and learn the scent and the taste of the source she is exploiting. She dances on different areas of the comb in order to recruit more bees and goes on to collect nectar from her source. There are different dances performed by bees depending on the distance information of the source: round dance, waggle dance, and tremble dance. If the distance of the source to the hive is less than 100 meters, round dance is performed while the source is far away, waggle dance is performed. Round dance does not give direction information. In case of waggle dance, direction of the source according to the sun is transferred to other bees. Longer distances cause quicker dances The laboratory test rig consists of a water reservoir, an electrical pump with inlet valve, a Rota meter, a conical tank with outlet valve, a differential pressure transmitter, ADC/DAC, RS232, and a Personal Computer. Fig.1 shows the real time closed loop control setup of conical tank level system. The outlet valve, which controls the output flow, is set at a opening as the tank be empty with the lowest flow in (180LPH). The inflow to tank can be controlled by a SCR driven motor. The input voltage of the pump is controlled by the SCR circuit, which is supplied by a digital controller. The level output of the conical tank is measured by the pressure transmitter.

III. ANTHOCNET

AntHocNet is a hybrid multipath algorithm, designed along the principles of ACO routing. It consists of both reactive and proactive components. It does not maintain paths to all destinations at all times (like the ACO algorithms for wired networks), but sets up paths when they are needed at the start of a session. This is done in a reactive path setup phase, where ant agents called reactive forward ants are launched by the source in order to find multiple paths to the destination, and backward ants return to set up the paths. The paths are represented in pheromone tables indicating their respective quality. After path setup, data packets are routed stochastically as datagrams over the different paths using these pheromone tables. While a data session is going on, the paths are probed, maintained and improved proactively using different agents, called proactive forward ants. The algorithm reacts to link failures with either local path repair or by warning preceding nodes on the paths. An earlier version of the algorithm described here.

A. REACTIVE PATH SETUP

When a source node s starts a communication session with a destination node d, and it does not have routing information for d available, it broadcasts a reactive forward ant F^sd .Due to this initial broadcasting, each neighbor of s receives a replica of F^sd. We refer to the set of replicas which originated from the same original ant as an ant generation. The task of each ant of the generation is to find a path connecting s and d. At each node, an ant is either unicast or broadcast, according to whether or not the node has routing information for d. The routing information of a node i is represented in its pheromone table T^i. The entry T^i_{nd} € R of the table is the pheromone value indicating the estimated goodness of going from i over neighbor n to reach destination d. If pheromone information is available, the ant chooses its next hop n with probability Pnd:

$$P_{nd} = \frac{(\mathcal{T}^i_{nd})^\beta}{\sum_{j\in\mathcal{N}^i_d}(\mathcal{T}^i_{jd})^\beta}, \quad \beta \geqslant 1, \qquad (1)$$

Where N^i_d is the set of neighbors of i over which a path to d is known, and b is a parameter value which can control the exploratory behavior of the ants (although in current experiments b is kept to 1).

If no pheromone is available for d, the ant is broadcast. Due to this broadcasting, ants can proliferate quickly over the network, following different paths to the destination (although ants which have reached a maximum number of hops, related to the network diameter, are killed). When a node receives several ants of the same generation, it compares the path travelled by each ant to that of the previously received ants of this generation: only if its number of hops and travel time are both within an acceptance factor a1 of that of the best ant of the generation, it will forward the ant. Using this policy, overhead is limited by removing ants which follow bad paths. However, it does have as an effect that the ant which arrives first in a node is let through, while subsequent ants meet with selection criteria set by the best of the ants preceding them, so they have higher chances of being killed. Duplicate ants which result from a broadcast of the best ant just before it reaches the destination are close in performance to the best ant and have higher chances of being accepted. The result is a set of ‘kite-shaped’ paths, as shown by the solid line arrows in Figure 1. In order to obtain a mesh of sufficiently disjoint multiple paths, which provide much better protection in case of link failures, we also consider in the selection policy the first hop taken by the ant. If this first hop is different from those taken by previously accepted ants, we apply a higher (less restrictive) acceptance factor a2.

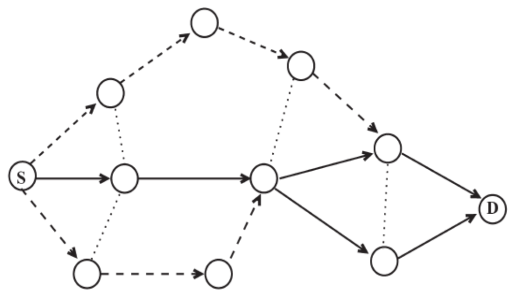

Fig. 1. Example of ‘Kite-Shaped’ and mehsed multiple paths.

A. STOCHASTIC DATA ROUTING

Nodes in AntHocNet forward data stochastically. When a node has multiple next hops for the destination d of the data, it randomly selects one of them with probability P_{nd}. P_{nd} is calculated in the same way as for reactive forward ants (Equation 1), but with a higher b exponent (set to 2), in order to be more greedy with respect to the better paths. According to this strategy, we do not have to choose a priori how many paths to use: their number is selected automatically in function of their quality.The probabilistic routing strategy leads to data load spreading according to the estimated quality of the paths. If the estimates are kept up-to-date (which is done using the proactive ants described in Subsection 3.3), this leads to automatic load balancing. When a path is clearly worse than others, it will be avoided, and its congestion will be relieved. Other paths will get more traffic, leading to higher congestion, which will make their end-to-end delay increase. By continuously adapting the data traffic, the nodes try to spread the data load evenly over the network.

B. PROACTIVE PATH PROBING, MAINTENANCE

Exploration While a data session is running, the source node sends out proactive forward ants according to the data sending rate (one ant every n data packets, where n was 5 in the experiments). They are normally unicast, choosing the next hopaccording to the pheromone values using the same formula as reactive forward ants (Equation 1), but also have a small probability at each node of being broadcast (this probability was set to 0.1 in the experiments). This way they serve two purposes. If a forward ant reaches the destination without a single broadcast it probes an existing path. It gathers up-to-date quality estimates of this path, and the backward ant updates the pheromone values of intermediate nodes, just like reactive backward ants do. If, on the other hand, the ant got broadcast at any point, it leaves the currently known paths and explores new ones. After a broadcast, the ant arrives in all neighbors of the broadcasting node. It is possible that in these neighbors it does not find pheromone for its destination, so that it needs to be broadcast again. The ant will then quickly proliferate and flood the network, like reactive forward ants do. To avoid this, we limit the number of broadcasts to nab (set to 2 in the tests). If the proactive ant does not find routing information within nab hops, it is killed. The effect of this is that the search for new paths is concentrated around the current paths, so that we are looking for path improvements and variations. To guide the forward ants better, we use hello messages. These are short messages (in our case containing just the sender's address) broadcast every 1/4 seconds by the nodes (e.g. ¼ 1 sec). If a node receives a hello from a new node n, it adds n in its routing table. After that it expects a hello from n every hello seconds. After missing a certain number of hello's (allowed-hello-loss ¼ 2 here), n is removed. Using these messages, nodes have pheromone information about their immediate neighbors in their routing table. So when an ant arrives in a neighbor of its destination, it can go straight to its goal. Looking back at the ant colony inspiration of our model, this can be seen as pheromone diffusion: pheromone deposited on the ground diffuses and can be detected also by ants further away. In future work we will extend this concept to give better guidance to the exploration by proactive ants. Hello messages also serve another purpose: they allow detecting broken links. This allows nodes to clean up stale entries from their routing tables.

C. LINK FAILURES

Each node tries to maintain an updated view of its immediate neighbors at any time, in order to detect link failures quickly, before they can lead to packet losses. The presence of a neighbor node can be confirmed when a hello message is received, or after any other successful interception or exchange of signals. The disappearance of a neighbor is assumed when such an event has not taken place for a certain amount of time, defined by hello _ allowed-hello-loss, or when a unicast transmission to this neighbor fails.When a neighbor is assumed to have disappeared, the node takes a number of actions. First, it removes the neighbor from its neighbor list and all associated entries from its routing table. Then it broadcasts a link failure notification message. This message contains a list of destinations to which the node lost its best path, and the new best estimated end-to-end delay and number of hops to this destination (if it still has entries for the destination). All its neighbors receive the notification and update their pheromone using the new estimates. If they in turn lost their best or their only path to a destination due to the failure, they also broadcast a notification, until all concerned nodes are notified. If the link failure was discovered due to the failed transmission of a data packet, and there is no other path available for this packet, the node tries to locally repair the path (and does not include this path in the link failure notification). The node broadcasts a path repair ant that travels to the involved destination like a reactive forward ant: it follows available pheromone when it can and is broadcast otherwise. One difference is that it has a maximum number of broadcasts (two in our tests) so that proliferation is limited. The node waits for some time (empirically set to five times the estimated delay of the lost path), and if no backward repair ant is received, it concludes that it was not possible to repair the path. Packets which were in the meantime buffered for this destination are discarded, and the node sends a link failure notification about the lost destination. Link failure notifications keep routing tables on paths up to- date about upstream link failures. However, they can sometimes get lost and leave dangling links. A data packet following such a link arrives in a node where no further pheromone is available. The node will then discard the data packet and unicast a warning back to the packet's previous hop, which can remove the wrong routing information.

IV. CONCLUSIONS AND FUTURE WORK

In this paper I have discussed about swarm intelligence in manets . Also discussed about the types of manet protocols based on swarm intelligence- bee in nature and anthoc net. AntHocNet is inspired by the stigmergy-driven shortest paths following behavior of ant colonies and the related bee optimization framework. Bee inspired protocols deliver the same/better performance as that of the state-of-the-art algorithms but at significantly smaller energy expenditure. In future there is a lot of scope and researches ans simulations have to be done on these protocols.

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