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Full Length Research Paper

Swarm intelligence based approach for routing in mobile Ad Hoc networks

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Mobile Ad Hoc Networks (MANETs) are built up of a collection of mobile nodes which have no fixed infrastructure. The nodes communicate through wireless network and there is no central control. Routing is the task of directing data packets from a source node to a given destination. This task is particularly complex due to the dynamic topology, limited process and storing capability, bandwidth constraints and lack of the central control. Ants routing resembles basic mechanisms from distributed Swarm Intelligence (SI) in biological systems and turns out to become an appealing solution when routing becomes a crucial problem in a complex network scenario, where traditional routing techniques either fail completely or at least face intractable complexity. Ants based routing is gaining more popularity because of its adaptive and dynamic nature. A number of Swarm Intelligence (SI) based, more specially Ant Colony Optimization (ACO) based routing algorithms are proposed by researchers. In this paper, we discuss the basic routing technique of biological insects like ants and present an overview of all the ACO based proposed routing algorithms.

Key words: Swarm intelligence (SI), mobile ad hoc network (MANET), ant colony optimization (ACO), autonomy.

INTRODUCTION

Swarm intelligence (SI) is “The emergent collective intelligence of groups of simple agents” (Bonabeau et al., 1999). It gives rise to complex and often intelligent behavior through simple, unsupervised (no centralized control) interactions between a sheer numbers of autonomous swarm members. This results in the emergence of very complex forms of social behavior which fulfills a number of optimization objectives and other tasks. Swarm is considered as biological insects like ants, bees, wasps, fish etc. In this paper we have considered biological insects’ ant for our study. Ants possess the following characteristics:

(1) Scalability: The ants can change their group size by local and distributed agent interactions. This is an important characteristic by which the group is scaled to the desired level.
(2) Fault tolerance: Each ant follows simple rule. They do not rely on a centralized control mechanism, graceful, scalable degradation.
(3) Adaptation: Ants always search for new path by roaming around their nest. Once they find the food their nest members follow the shortest path. While nest members follow shortest path, some of the members of the colony always search for other shortest path. To accomplish this they change, die or reproduce for the colony.
(4)Speed: In order to make other ants to know the food source, they move faster to their nest. Other ants find more pheromone on the path and follow the path to the food source. Thus changes are propagated very fast to communicate to other nest mates in order to follow the food source.
(5) Modularity: Ants follow simple rule of following the path which has higher level of pheromone concentration. They do not interact directly and act independently to accomplish the task.
(6) Autonomy: No centralized control and hence so no

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supervisor is needed. They work for the colony and always strive to search food source around their colony. (7) Parallelism: Ants work independently and the task of searching food source is carried out by each ant in parallelism. It is parallelism due to which they change their path, if a new food source is found near their colony. These characteristics of biological insects such as ants resemble the characteristics of Mobile Ad Hoc Networks. This helps us to apply the food searching characteristics of ants for routing packets in Mobile Ad Hoc Networks.

BASIC PRINCIPLE OF ANTS ROUTING

The biological insects like ants in the ant colony form a collective behavior. Their collective behavior is studied and applied to solve the complex engineering problems. Ants live in colony and they form the distributed biological systems and in spite of the simplicity of their components, they show highly structured social organization. Thus, ant colonies can accomplish astonishingly and computationally complex tasks, which could never be performed by a single ant. The principle of an ant routing algorithm is mainly the depositing of pheromone on the path followed by the ant. Pheromone is a chemical substance which is deposited on the ground, by ants when they roam around for search of food. Ants have ability to smell this chemical substance that is, pheromone. They follow simple rule of following the path which has higher concentration of pheromone. Pheromone decay is directly proportional to time. The pheromone concentrations on a path allow the other ants to find their way to the food source. Thereby more ants follow the same path and more and more pheromone is deposited on the path which is the shortest route to the food source. Then same pheromone trails can be used by other ants to find the location of the food sources discovered by their nest mates. It was found that the pheromone-trail-following behavior gives rise to the emergence of the shortest path which is followed by other ants of the colony. On the basis of Figure 1 (a), (b) and (c) in comparison with routing of packets in MANETs, we can define the Ant routing basic principle as: (1) Each network node sends a number of discovery packets that is, called forward ants (F-ANT) are sent towards the selected destination nodes of the network as shown in Figure 1(a). (2) The routing tables maintained at each node are replaced with stochastic tables, which select next hops according to weighted probabilities available. (3) Accordingly, the ants deposit pheromone on the crossed links, that is, in the nodes routing tables are changed for selection of the next node in the network. This is shown in resemblance with Figure 1(b). (4) When forward ant (F-ANT) reaches the destination node, it generates a backward ant (B-ANT) and then dies. Similarly in MANETs routing, the new packet created and sent back to the source will propagate through the same path selected by the forward ant (F-ANT). This is shown in Figure 1(c). (5) Now backward ant (B-ANT) deposits pheromone on the crossed links. It means that it updates the routing table of the nodes along the path followed by forward ant (F-ANT). (6) After arrival to the source node, the backward ant (B-ANT) dies.

THE PRINCIPLE OF SELF-ORGANIZING ABILITY

Biological insects have the ability to self-organize and it relies on four principles that is, Positive Feedback, Negative Feedback, Randomness and Multiple Interactions. A fifth principle, stigmergy, arises as a product of the other four (Bonabeau et al., 1999). Such self-organizing ability of biological insects is known as Swarm Intelligence.

A simple example of food foraging behavior of ants provides a strong analogy to the mechanisms of ants routing in particular and Swam Intelligence routing in general. We will consider a surface upon which ants and foods are distributed. The ants would like to search the food source and carry it to the nest that is; food should be collected in the nest. Each ant acts independently, of all other ants and move only on the basis of an observed local pheromone gradient. Pheromone is a chemical excreted by the insect which evaporates and disperses over time.

Ant is bound by the following rules: A biological insect like ant moves randomly, but is biased towards the locally observed pheromone gradient. If no pheromone exists, an ant moves randomly in all directions. An individual ant carries only one part of food at a time, but it is important to follow the path from food to nest. During their random roaming, if an ant is not carrying food and it encounters food, the ant will pick it up. When an ant is carrying food and it encounters other food source, the ant will put the food down. The ant will also put certain amount of pheromone near the food, so that other ants roaming around can smell the pheromone and hence they also come to know about food source. The following characteristics describe the principle of Swarm Intelligence which is followed by ants for searching a food source and shortest path to the food source from an ant colony that is, nest.

Positive feedback

An ant follows the path which has higher deposit of pheromone. A general guideline for particular behavior is formed on the basis of Positive feedback. When an ant finds a food source and returns to its colony, it lays more pheromone on that path. Thereby the pheromone level on that path is increased. Increase in pheromone level in a particular path is a positive feedback for other ants. An

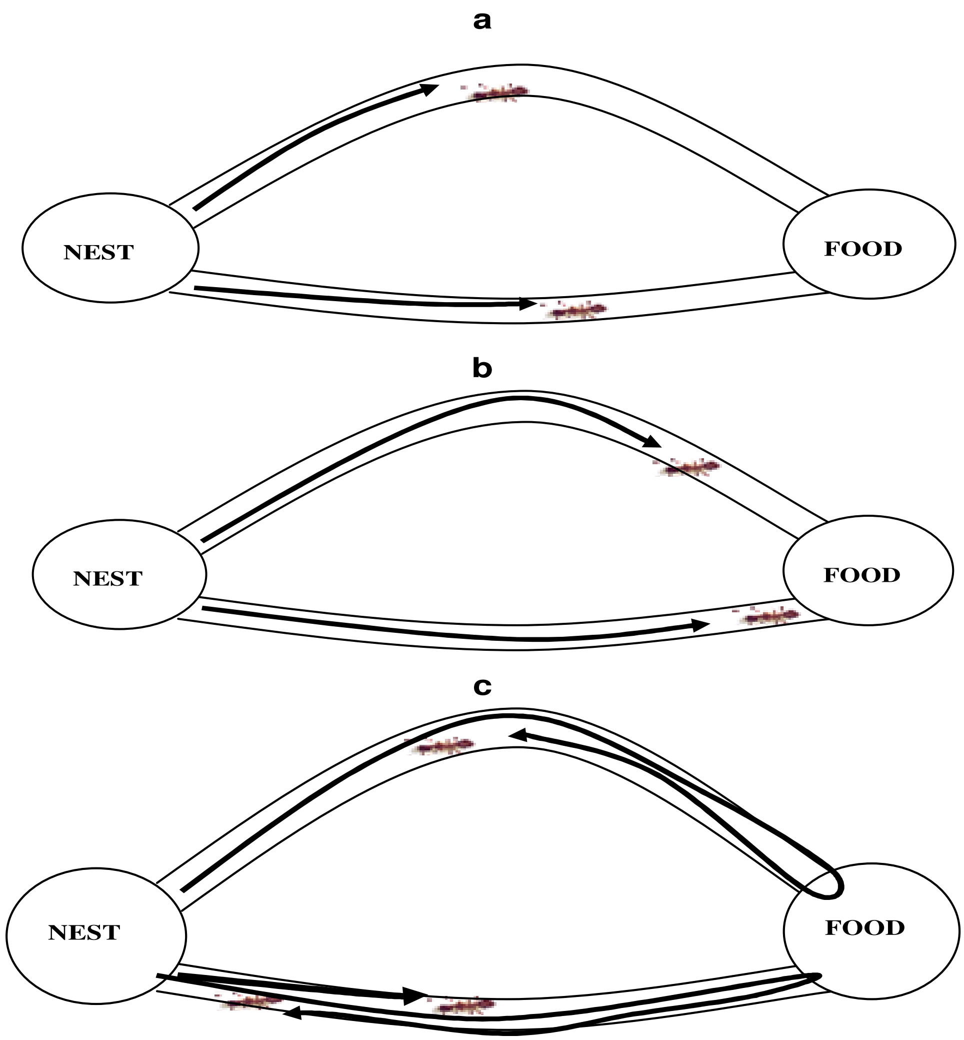

Figure 1. Basic ant routing principle. (a)Two ants from nest are moving out to food source through two different length path and depositing pheromone on path. (b) One ant following shortest path reaches food source early and returns to nest laying pheromone on path. (c) The ant following shortest path deposits more pheromone on shortest path and other nest mates follow the same shortest path.

ant is more biased to move towards a food source and lead to more collection of food by searching for higher deposit of pheromone on path. Whenever they find a decision point, they follow the path which has higher concentration of pheromone. When more ants follow the same path, pheromone deposit is more and hence is a positive feedback. This leads to greater follow up of ants on a particular path resulting in more deposit of pheromone.

Negative feedback

The chemical substance pheromone diffuses in the environment and evaporates over time. This evaporation consequently weakens the pheromone deposit, lessening the resulting gradient on the path. Thus a diminished gradient will attract fewer ants as they will be less likely to move in its direction. As a result, the path where food does not exist is not followed. This may seem detrimental to the task of collecting food, though it is an essential phenomenon. When the task of food search begins, several small food collections will emerge very quickly. The food sources that are able to attract more ants will grow faster than other food sources. As pheromone decays slowly, small food collections are more and ants will be less likely to visit these again, thus preventing them from growing to that food source. Thus negative feedback, in the form of pheromone decay, helps large collection of food to grow by preventing small collection of food sources from continuing to attract more ants. In general, negative feedback is used to remove poor solutions from the collective memory of the system. Hence it is important that the decay rate of pheromone be well tuned to the problem at hand to optimize the path. If pheromone decays too quickly, good solutions will lose their appeal before they can be exploited or found by other agents in the colony. On the contrary, if the pheromone decays too slowly, bad solutions will remain in the system as viable options and will not be able to find the best solutions.

Randomness

A very important characteristic of swarm intelligence is randomness. The ants in the colony are not supervised. They do not have central control. They roam around randomly; where collections start and how they end is entirely determined by chance. Very small fluctuations in the behavior of ants may have a very large influence in future events. It is exploited to allow for new solutions to arise or to direct current solutions as they evolve to fit the environment of the biological insect ants.

Multiple interactions

The entire colony tenant have the same goal of finding a food source near their colony and it is essential that many individuals work together to achieve this task. When not enough ants exist, the pheromone would decay before any more food could be added to large collection. Ants would continue their random walk, without forming any significant food source near their colony. They use multiple interactions to find the food source near their colony.

Stigmergy

This refers to indirect communications between individuals, generally through their environment. Ants are directed to the largest food source by the deposit level of pheromone. There is no need for ants to directly communicate with each other or even to know of each other's existence near their colony. For this reason, ants act independently of other individuals in their colony, which greatly simplifies the necessary rules for search of food source around their colony.

REVIEW OF ANT BASED ALGORITHMS FOR MANETs

Generally Swarm Intelligence and specially ant routing algorithms can be classified in different ways, according to the pheromone updating, calculation of route probabilities, how often and how many ants are sent per request and so on. However, we can use any of the characteristics of the biological insect ants in an application to find the shortest route in the network. There are number of ant based routing algorithms proposed by researchers and are appended as follows: Ant Based Control (ABC) is a proactive algorithm proposed by Schoonderwood et al. (1997). The algorithm was designed for load balancing in a circuit switched network. It is used for call controlling. This algorithm maintains only one routing table whose rows show destination, columns show neighbors. Routing table is maintained at each node containing probabilities of reaching next node. Forward Ant (FANT) updates routing table on each node. Pheromone value depends on age of agent. The next hop is chosen according to pheromone value. Antnet (Di Caro and Dorigo, 1998) is a simple and direct extension of simple ant colony optimization algorithm. It is a proactive approach that is, route is explored even if there is no data to send in hop to meet immediate need. It is used for wired datagram network. The algorithm uses two artificial homogenous ant agents. Forward ant agent is to find out minimum cost path joining its source and destination node. The next hop is chosen on the basis of Greedy-Stochastic policy. It depends on pheromone value, ant memory and local probabilistic information. Forward ant collects information about time, length, congestion status and node identifiers. While backward ant traverses back the path of forward ant and updates the routing table and an additional table containing statistics and probabilities of network traffic distribution. As backward ant reaches the source they are deleted by system. AntHocNet (Di Caro et al., 2004, 2005a, b,) is a hybrid algorithm, which combines reactive path setup with proactive path probing, maintenance and improvement.

Co-operative Asymmetric Forward (CAF) Routing is proposed by Heusse et al. (1998). It is designed of wired as well as wireless networks and is a reactive algorithm so finds path only on demand. Link cost in CAF is assumed asymmetrical. Here forward ants are released from source to destination. These forward ants collect information regarding various nodes in network as according to the routing table maintained at each node and also records the launch-time. The next hop is chosen on the basis of pheromone concentration when backward ant retraces the path of forward ant in opposite direction and deposits equal amount of pheromone on nodes.

Ant Colony Based Routing Algorithm (ARA) (Gunes et al., 2003) is reactive algorithm and reduces the overhead for routing. It is a highly efficient, adaptive and scalable routing protocol. It is a multi path routing scheme. It uses two ant agents- Forward ant (FANT) and Backward ant (BANT). Each agent has a unique sequence number so duplicate agents can be identified and destroyed. Sender transmits FANT to nearby neighbors. The Swarm Intelligence based routing algorithms Ant-AODV (Marwaha et al., 2002a, b) is designed for Mobile Ad Hoc

Networks which uses mobile agents like ants to carry on big scope to scan the networks, make use of ant agents to collect the information about routing. The Ant-AODV combines ACO proactive characteristics with AODV reactive characteristics, to improve the performance of routing search delay and to adapt the constantly change of network's topology. Probabilistic Emergent Routing Algorithm (PERA) is proactive algorithm proposed by Baras and Mehta (2003). The algorithm assumes that all nodes in network fully co-operate in process of data transfer and there are bidirectional links in network. There are uniform forward ant and regular forward ants that are unicasted to reinforce available paths in network. Termite is a distributed routing algorithm proposed by Roth and Wicker (2003). It provides scalability, adaptability and control overhead. Ant Routing Algorithm for Mobile Adhoc Networks (ARAMA) is proposed by Hossein and Saadawi (2003). It is a proactive algorithm. The algorithm is efficient and scalable because it reduces route discovery time and overhead maintenance cost and delay. Mobile Ant Based Routing (MABR) proposed by Heissen and Braun. This protocol is responsible for updating the routing tables of logical routers and determining logical paths for routing packets. Adaptive Swarm Based Distance Routing (ASDR) routing protocol features of high utilization, high scalability, destination of routing coops and oscillations (Kassabalidis et al., 2002). Antbased Distributed Routing Algorithm (ADRA) is a reactive Algorithm that finds a single path between source and destination. Like other algorithm, it also uses two types of ant agents FANT and BANT. FANT moves from node to node (Zheng et al., 2004). Ant Colony Based Multipath QoS aware Routing (AMQR) is a reactive algorithm to find out multipath between source and destination (Liu and Feng, 2005). Ad hoc Networking with Swarm Intelligence (ANSI) is a reactive algorithm which finds out path only when demanded that is, when node has data to send to other nodes it finds out the path (Rajagopalan and Shen, 2006). The Multicast for Ad hoc Network with Swarm Intelligence (MANSI) protocol provides multicast support for ad hoc networks. Within a multicast group, each member launches a forward ant in order to find an existing forwarding node where it can be used to establish connectivity to the group with lower cost (Roth and Wicker, 2005). The Multicast for Ad hoc Network with hybrid Swarm Intelligence (MANHSI) utilizes small control packets equivalent to ants in the physical world. These packets, traveling like biological ants, deposit control information at nodes they visit similar to the way ants laying pheromone trails on the path (Zeyad et al., 2007).

Hybrid Ant Colony Optimization Routing Algorithm for Mobile Ad hoc Network (HOPNET) is a hybrid multipath routing protocol and it combines concept of ZRP all DSR (Wanga and Osagiea, 2008). Ant Colony Optimization – Ants Hybrid Routing (ACO-AHR) Hybrid routing algorithm (Yu et al., 2008). It introduces the service agents to reduce expense of network. It uses two artificial ant agents that is, forward ant agent which travels from source to destination and find out information about quality of the path. Backward ant agent travels from destination to source and collect information about pheromone deposited. There are other types of agent that is called service agent (sagent). Improved Ant Colony Optimization algorithm for mobile ad hoc network (PACONET) is a reactive algorithm. It is a very dynamic algorithm which takes into account the mobility, route maintenance, Link Failure-Handling (Osagie et al., 2008). Position based on Ant colony routing algorithm for MANETS (POSANT) is reactive that is, route is established only when there are some data to send. It is position based routing means each node has information about its own position, position of its neighbors, position of destination node (Kamali and Opatrny, 2008). Probabilistic Ant Routing (PAR) is proposed for routing in MANET (Prasad et al., 2009). Each node maintains a list of neighbours according to HELLO MESSAGE received. Forward ant agents (FANT) are probabilistic and explore the network to collect network traffic information. They are routed on normal priority queue. If route to destination is available as present node, the FANT is unicast otherwise it is broadcasted. Also, ant Pheromone for Quality of Service (QoS) provisioning in Mobile Ad Hoc Networks is described in Singh et al. (2010).

SUMMARY OF ANT BASED ROUTING ALGORITHMS

A number of routing algorithm for routing in Mobile Ad Hoc Networks is proposed. All the ant based routing algorithms are enlisted in the Table 1.

DISCUSSION

The proposed ant routing algorithms are solutions, when routing becomes a crucial problem and / or to find a route across a dynamic but difficult topology, that cannot be solved with traditional routing techniques, at least not without facing intractable complexity. Apart from Swarm Intelligence as mentioned earlier, there are other techniques like Genetic Algorithms which provide an adaptive optimization technique based on the natural process of evolution. A population of individuals representing possible solutions for a given problem is submitted to the Darwinian principle of "survival of the fittest" over consecutive generations. Since the agents are created at the beginning with random characteristics it is possible that they are not adapted to a specific environment and it could take too much time for a good result to emerge or they could even not find a solution. Swarm is considered as biological insects like Ants, bees, wasps, Fish etc. In this paper we have considered

Table 1. Year-wise list of proposed ant based routing algorithms for MANET.

Algorithm	Year	Proposed by	Type	Path
Ant based colony	1997	Ruud Schoonderwood	Proactive	Single
Ant net	1997	Gianni Di Caro	Proactive	Single
CAF	1998	M.Huesse, P.Kuntz, D.Snyers and S.Guerin	Position based	Single
RBA	1998	T. White, B. Pagurek, and F. Oppacher	Proactive	Single
ASGA	1998	Tony White	Hybrid	Single
AARA	2001	H. Matsuo and K Mori	Proactive	Multipath
ASDR	2002	Kasabalias and Sharkawli	Zonal	Single
ANT-AODV	2002	Shrivanajay Marwala, Chen kong Tham, Dipti Shrinavasan	Hybrid	Single
ARH	2002	Fujta	Reactive	Single
ARA	2002	Mesut Gunes, Udo Sorges and I.Bouazizi	Reactive	Multipath
MABR	2003	Heissen and Braun	Proactive	Single
PERA	2003	John S Baras, Harsh Mehta	Proactive	Single
EARA	2003	Zhenyu Liu and Kwialkowska Costas Constantinou	Reactive	Multipath
TERMITE	2003	Martin Roth and Stephen Wicker	Proactive	Multipath
ADRA	2004	Xiangquan Zheng,Wei Guo and Renting Liu	Reactive	Single
Anthoc net	2004	Gianni Di Caro, Frederick Ducatelle LM Gambardella	Hybrid	Single
ANSI	2005	Rajgopalan and Shen	Reactive	Single
AMQR	2005	Liang gui Liu, Guang Zeng Feng	Reactive	Multipath
MANSI	2005	Martin and Wicker	Reactive	Multipath
GPSAL	2006	D. Camara and A.A.F. Loureiro	Proactive	Single
MANHSI	2007	Zeyad M Alfawar	Hybrid	Multicast connectivity
POSANT	2008	Shabab Kamali and Jaroslav Optarny	Reactive	Multipath
HOPNET	2008	Jianping Wanga, Eseosa Osagiea, Parimala Thulasiramam and Ruppa K Thulasiramam	Hybrid	Multipath
ACO-AHR	2008	Wan-Jun Yu, Guo-Ming Zuo and Qianq-Qian Li	Hybrid	Multipath
PACONET	2008	Eseosa Osagie, Parimala Thulasiramam and Rupple Thulasiramam	Reactive	Single
PSO-ODMRP	2008	E. Babura, and V. Vasudevas	Reactive	Single
PAR	2009	S P Prasad, Y P Singh, C S Rai	Hybrid	Multipath

biological insects' ant for our study. The basic principle is to use ants like packets and let ant routing operate to gather routing information. We find that a number of ant based routing algorithms are proposed for routing in Mobile Ad Hoc Networks. Some of them are proactive that is, they keep on searching the best path from the source and destination even if no data packet is available for sending from source to destination. Some of the algorithms are reactive and nodes come into action only when a packet is received for transmission from source to destination. These proactive and reactive algorithms are having their own limitations and are not found suitable for routing in Mobile Ad Hoc Network mainly when real time applications QoS is to be ensured. Hybrid routing algorithms are proposed which contain advantages of proactive and reactive algorithms. These algorithms are simulated using different simulation environment that is, NS-2, QualNet. In these simulations some of the real scenario / environment constraints are not considered. There is need to consider environmental factors affecting real time applications. It can be concluded that Swarm Intelligence based approach offers to be a powerful means to solve routing problems in Mobile Ad Hoc Networks. Further, it is required to consider real scenario/constraints/environmental conditions and need to tune and simulate to get an efficient and effective routing protocol for Mobile Ad Hoc Networks.

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