A Simplified Receiver Assisted Routing Enhancement (RARE) in MANET

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ABSTRACT
This paper shows a novel technique for routing protocol in ad hoc network, namely simplified receiver assisted routing enhancement (RARE). Simplified mathematical model has been explained to analyze the performance of RARE algorithm. In this algorithm, we use the principle of the biologically inspired ant routing technique to evolutionally maintain the routing information. The similarities and differences of RARE and the traditional ant technique have been highlighted. The RARE concept is implemented to increase the probability to find the destination and decrease the connection set up time between the source and the destination. The performance of the proposed RARE is simulated and compared to the traditional ant [1]-[2] in radio network model (random graph model). The simulation result shows the potential of RARE to achieve higher probabilities to find the destination. More, the RARE can be used as an add-on module to many ad hoc routing protocols.

Keywords
Ad hoc, ant colony algorithm, ant colony optimization, ant destination trails, routing protocol, mobile ad hoc network.

1. INTRODUCTION
The need for infrastructure less networks such as mobile ad hoc networks (MANETs) has been dramatically increasing in the recent years. A MANET is an autonomous collection of mobile or/and fixed nodes that can communicate together over relatively bandwidth constrained wireless links. Since some of the nodes are mobile, the network topology may change rapidly and unpredictably over time.

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MANET does not have centralized infrastructure similar to cellular system or other centralized radio systems. All the network routing activities including discovering the topology and delivering messages must be executed by the nodes themselves. The MANET needs high quality of service (QoS) requirement consisting of a fast communication establishment and a minimum signaling overhead.
To solve the MANET routing problem, the best route should be found between the source and the destination while taking into account the special network characteristics such as (i.e. mobility, limited energy, large networks, and high bit error rate). Such scenarios are referred to as ad hoc networks with critical connectivity. In such scenarios traditional MANETs routing protocol (such as AODV, OLSR DSR, …)could not work effectively due to the above constrains especially in the large networks, since the route discovery component intrinsically depends on finding the destination node within short time before the network topology changes .

The above challenges and possible applications of MANETs have made it very popular research area, and many routing algorithms have been proposed. The classical routing classification can be categorized into three main branches; proactive, reactive, and hybrid algorithms. Proactive routing protocols [3] maintain tables that store at all times routes to all nodes in the network. This means that any change in the network topology will be propagated across the whole topology, which can become difficult when the network size becomes large or the nodes are mobile. In reactive routing protocols such as AODV [4] and DSR [5], creating paths between the nodes are invoked only on demand: when a data needs to be sent to a new destination, or when a route which is in use fails. However this technique does not need constant broadcasts, but on the other hand causes delays since the routes are not already available in the routing tables. Additionally, the flooding of the network may lead to supplementary routing control traffic which is wasting the limited bandwidth. In order to combine the advantages of both proactive and reactive, the hybrid protocols such as zone protocol (ZRP) [6], can be used to find a balance between the proactive and reactive protocols. The basic idea behind hybrid routing protocols is to divide the network into zones and seek to employ proactive routing technique in some areas of the network at certain times and reactive routing for the rest of the network based on the weakness and strength of these routing protocols. The proactive operations are restricted to a small domain in order to limit the control overheads and delays. The reactive routing protocols are used for locating nodes outside this domain, as this is more bandwidth-efficient in a constantly changing network. The disadvantage of hybrid protocol such as ZRP is that if the zone radius is too large the protocol can behave like proactive technique, while for small zone radius it behaves like reactive technique. In addition to the overlapping between the zones will increase the node redundancy; one node may behave as proactive and reactive technique in the same situation.

The aim of the present paper is to introduce a new simplified analytical and simulation general model namely, simplified receiver assisted routing enhancement (RARE) that can easily be added as a separate component on the top of any ad hoc routing protocol. We examine RARE here with ant colony algorithm described in [1]. The remainder of this paper is organized as follows. In Section 2, brief description of the previous ant work. Section 3 introduces a mathematical model and a basic description of the RARE algorithm and its flowchart. Section 4 is devoted for the simulation results in comparison with traditional ant algorithm. Section 5 is maintained for the conclusion and the future work.

2. BACKGROUND ON ANT ROUTING

The basic principle behind the ant colony optimization (ACO) algorithms for MANETs routing is the acquisition of routing information through probabilistic selecting paths using small size of control packets, called ants [1] and [7]-[9] . As the real ants look for food in their environment, the artificial ants search for the solution space. The artificial ants are generated concurrently and independently by the nodes, with the task to explore new paths and re-explore the old visited paths to the destination. When a data needs to be sent from the source *S* to the destination *D*, the Source node *S* checks weather it has up-to-date routing information for *D*. If not, an ant will be generated and going from the *S* to *D* gathering information about the quality of the path (number of hops, available bandwidth, end to end delays, etc.). Once the ant reaches the destination, the destination *D* will generate another ant going back to the source taking into consideration the parameters of the path quality. Every node in the network can function as source node, destination node, and intermediate node. Routing table for each node is constructed. The routing table contains for each destination a vector of real valued entries, one for known each neighbor node. These entries can represent a term called pheromone which is always updated based on the path quality information. Therefore multiple paths will be available from the source *S* to the destination *D*. These paths are graded and selected based on the amount pheromone once the best path is failed. In turn, the following new ants will use the routing tables to determine which path to the destination. In other words the pheromone information is used for routing the control packets (ants), more or less in the same method as for the routing of data packets. A lot of research has been conducted to address the ACO algorithms [1] and [7]-[9] according to different criteria, and trying to answer questions such as how often and how many ants are sent by the source [7], what kind of information can be gathered by the ants [8], how the pheromone will be deposited and evaporated [9].

In [1], a resource management application of a probabilistic based ant routing algorithm for mobile ad hoc networks (ARAMA) have been proposed and examined. ARAMA is a dynamic, self configured, self built routing algorithm with controlled ants routing packets. ARAMA combines many advantage of the on demand based and table based routing algorithm. In ARAMA, each node will select the next hop based on weighted probabilities, calculated on the foundation of the pheromone trails left by the previous ant packets. When a node receives data packet with destination *D*, if a record for the destination *D* is available at the routing table, the data will be forwarded to the next neighbor randomly depended on the probabilities generated by the previous ant packets. Otherwise, the data packet will be buffered at the node and a sufficient number of ants will be traveled from the node searching for the destination node *D*. the network size or the mobility of the nodes increase, the number of discovery ant packet will dramatically increase. In turn, the routing overhead will increase and affecting the limited bandwidth.

3. THE PROPOSAL PROTOCOL

The main approach in most of ant routing algorithm is based on the concept that the source has the responsibility to find the destination. This may lead to large connection set up time or/and difficulty in finding the path in case of high mobility or large networks. To tackle the this problem and the above issues, all the possible routes between the source and the destination should be found quickly before the topology changes while taking into consideration the special network characteristics (i.e., mobility, limited energy, limited bandwidth, limited processing power, and high bit-error rate). In addition, as every node may forward other nodes' data, the network resources usage (limited energy, limited bandwidth, limited processing power, etc) should be fairly distributed across the networks nodes to avoid the high consumption of the resources in some network nodes and low consumption in other nodes. The routing algorithm should deal with the rapid changes in the network and it should have the ability to optimize more than one network parameters during the routing process.

We are proposing here a generic algorithm which can assist any ad hoc routing protocol to enhance its performance and to overcome the previous ad hoc routing protocols drawbacks. In this paper RARE will be applied to assist traditional ant technique to enhance its connection setup time. Figure 1. depicts the flow chart of the RARE technique. In a general view, the destination will participate in the routing process and assist the source in finding the destination. A new type of packet called destination trail pointer will be sent from the receiver to declare its locations. A destination node generates destination trail pointer packet concurrently, independently, and randomly with relatively low rate to insure low routing overhead. The destination trail pointer will move randomly in the network modifying and updating the routing tables to favor specific path than others leading to the destination. When any intermediate node *i* receives destination trail pointer packet, the packet will be forwarded to randomly selected neighbor of intermediate node *i*. The destination trail pointer packet does not search for the source; however its purpose is to announce to other nodes the destination location. This information could be used by any source in the network. While the destination node sends the destination trail pointer, the source node sends out the regular ant. The ant will follow the same rule as the destination trail pointer when it reaches intermediate node *i*. When the ant and the destination trail pointer intersect at same intermediate node *i*, these two paths from the intermediate node to the source node and from the intermediate node to the destination will be selected to form only one direct path from the source to the destination through the intermediate node *i*. Multiple paths will be available from the source to the destination through many intermediate nodes. Depending on the maximum probability one path will be selected and the other paths will be reserved for backup when the original path fails. In addition, these trails are very good pointer to the new location of the destination as it moves. This technique reduces the time needed for connection setup and insures the delivery of data. The main features of the proposed algorithm are:

1. Increase the probability to find the destination.
2. Reduce routes establishment time so that the routes can be used to transmit data before topology changes.
3. Decrease the routing network overhead in case of large network size.
4. Robustness to react quickly to the topology changes when the nodes mobility increases.
5. The concept of the receiver assisted can be added to any of the existing routing protocols

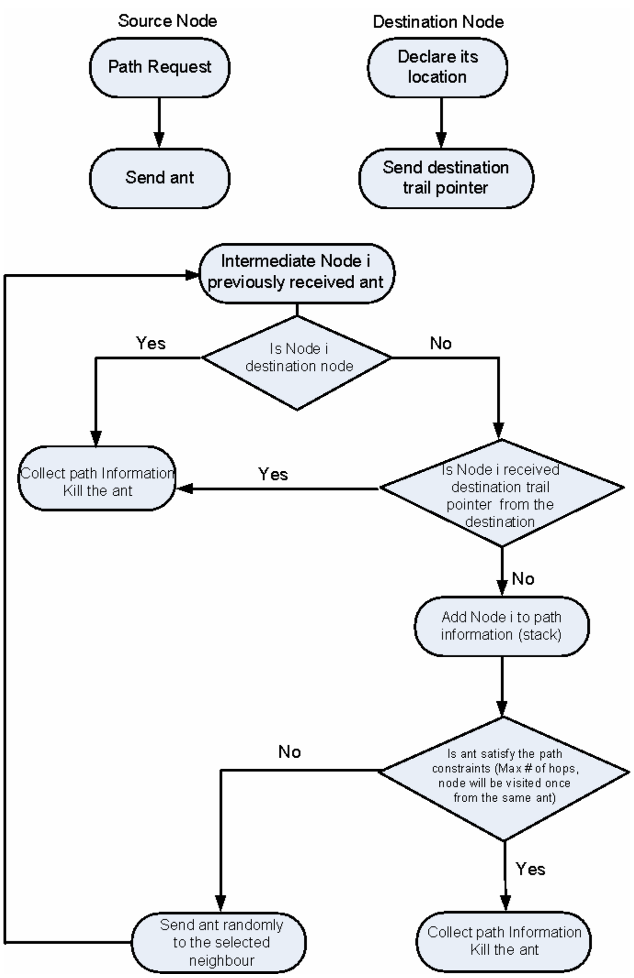

Figure 1. High level flow chart describing the RARE algorithm.

In Figure 2. we consider a wireless network made of N nodes. The links are distributed according to random wireless graph. In other words a link exists between two nodes if the distance between them is less than the wireless transmitting range.

The RARE algorithm is built in two steps simultaneously: the first step is the generation of destination trail pointer from the destination to declare for its location. For example, in Figure 2. the destination node X generates 3 destination trails pointer packets; the packets are traversing in the network randomly exploring the new network topology. The second step is the generation of the ant packet from the source (e.g. one packet is generated by the source in Figure 1). Some nodes in the network may work as intersection point between the destinations trails pointer packet and the ant packet; these nodes will the availability to set up a connection between the source and the destination (e.g. nodes K, P, M in Figure 1.). The paths from the source to the specific intermediate node and from the destination to the same intermediate node are not overlapped.

Our mathematical model is based on probability analysis approach. The following assumptions are taken into account:

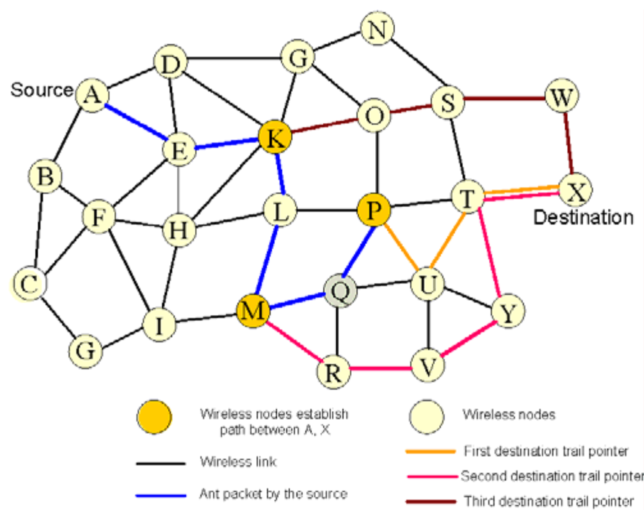

Figure 2. Example of RARE technique using the destination trail pointer by the destination node X and ant by the source node A.

1. The analysis will calculate the probability of finding an intermediate node i with a valid path between the source node S and the destination node D.
2. All possible intermediate nodes will be selected for analysis, this will be affected by the life time of both ant and destination trail pointer packets.
3. For each intermediate node i the following will be calculated:

a. The probability P_1 that a ant is sent from the source and reached an intermediate node i

$$P_1 = \Pr obability\ \ for\ \ ant\ will\ \ reach\ node\, i = \sum_{j=1}^{n}\prod_{k_j=1}^{\ell} prob_j(k_j)$$

Where n represents the numbers of all possible routes from the source S to the intermediate node i.

$prob_j(k_j)$ is the probability of selecting the k_j link in route j between the source node S and the intermediate node D. The number of links in route j is ℓ.

b. The probability P_2 that a destination trail pointer is sent from the destination and reached an intermediate node i.

$$P_2 = \Pr obability\ \ for\ destination\ trails\ will\ reach\ \ node\ i = \sum_{j=1}^{m} \prod_{k_j=1}^{q} prob_j(k_j)$$

Where m represents the numbers of all possible routes from the destination node D to the intermediate node i.

$prob_j(k_j)$ is the probability of selecting the k_j link in route j between the destination node D and the intermediate node i. The number of links in route j is q.

c. The probability P that intermediate node i will be reached by a single ant and single destination trail pointer.

$$P\ = \Pr obability\ \ for\ source\ to\ reach\ node\ i\ with\ one\ ant\ and$$
$$\Pr obability\ \ for\ destination\ to\ reach\ node\ i\ with\ one\ ant\ \ = P_1 \times P_2$$

4. SIMULATION RESULT

In this section, we present the simulation results to compare between the RARE technique and the traditional ant technique. As mentioned in section III the main goal of our algorithm is to increase the probability to find the destination and leading to reduction in the connection setup time between the source and the destination. The results are plotted in Figures 3-6.

Figure 3. shows the first network topology that used in our simulation. We have used 15 fixed network nodes. The nodes are randomly distributed over a terrain of size $1000 \times 1000\ m$. Each node was equipped with transceiver which was capable of transmitting signal up to $300\ m$. Since RARE does not depend on any routing protocol, we implement RARE on the top of simplified ant-based routing algorithm; we used the algorithm in [1] as an example.

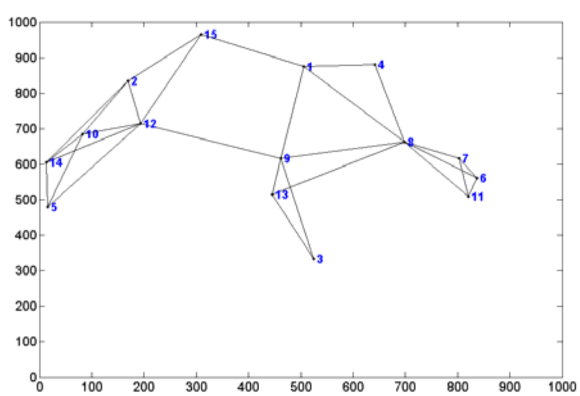

Figure 3. Network topology.

Figure 4. depicts the relationship between the probabilities that the source (node 14) finds destination (node 11) versus the life time of ant packet (number of hops) generated by the source for different destination trails pointer life time. General and expected graph can be noticed. Indeed, the probability that the source finds the destination increases as the life time of the destination trails pointer increases and as the life time of the ant generated by the source increases. In addition, it can be deduced that RARE technique gives much more improvement than the traditional ant technique. To make the comparison between the RARE technique and traditional ant somewhat fair, we proceed as follows. For example if the ant life time is 8 hops and destination trail pointer life time is 2 hops, the probability to find the destination using the RARE is 0.85. When comparing to simplified ant based algorithm with ant life time 10 hops (8+2), the probability to find the destination using the traditional ant technique is 0.3.

To better understand the problem we simulate RARE and the traditional ant technique at relatively large network topology. Figure 5 shows the second network topology, it consists of 25 fixed wireless nodes.

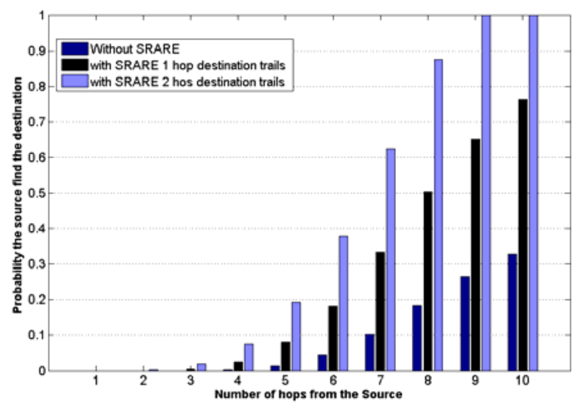

Figure 4. The probability that the source find the destination versus the length of the ant packet (number of hops) given 15 nodes.

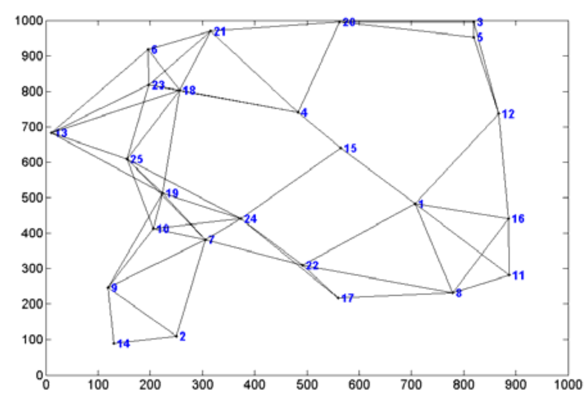

Figure 5. Network topology.

In Figure 6 the probabilities that source (node 13) finds the destination (node 11) has been plotted versus the ant life with different destination trails pointer life time size. It should be noticed that similar results are obtained in Figure 4. The results clearly indicate that the RARE algorithm significantly increases the probability to find the destination and decreases the connection set up between the source node and the destination node 11. For example: the source node S can find the destination node D with probability 0.7 from the first trail (ant life time 8 hops life time, and destination trail pointer 3 hops). It should also be noted that the price to be paid to obtain the high probabilities using RARE by increasing the control overhead routing packets and intelligent intermediate nodes that can detect and update the routing table with respect to the destination trails pointer and ant packets.

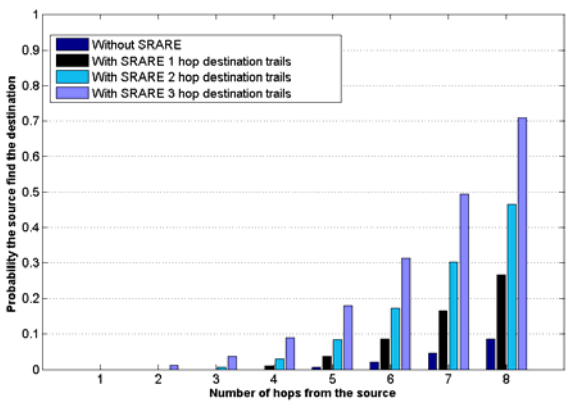

Figure 6. The probability that the source find the destination versus the length of the ant packet (number of hops) given 25 nodes.

5. CONCLUSION

This paper presents a technique that provides a technique for selecting and routing data in an ad-hoc mobile wireless network namely RARE technique. The method includes sending a forward control packet from a source (traditional ant packet) to the destination via at least one intermediate node at intervals of time, where the intermediate node is randomly selected. Each of the intermediate nodes store weights of the neighbor nodes. Each of the intermediate nodes receives the destination trail pointer packet from the destination node. Finally, a group of routes to the destination is selected based on the modified weights of the neighbor nodes and data packets are send from the source to the destination via the intermediate nodes upon selection of the group.

The proposed algorithm is a generic component that can reside above any ad hoc routing protocol. Simulations have shown that the RARE has higher probability to find the destination with still relatively low routing overhead.

6. REFERENCES

[1] Osama H. Hussein, Tarek N. Saadawi, and Myung J. Lee. Probability routing algorithm for mobile ad hoc networks resources management. IEEE Journal on Selected Areas in Communications, IEEE JSAC. 23, 12 (Dec. 2005), 2248-2259.

[2] O. Hussein, T. Saadawi. Ant Routing Algorithm for Mobile Ad-hoc Networks. The International Performance Computing, and Communications Conference (IPCCC), April (2003), Phoenix, Arizona.

[3] Pan-long Yang, Chang Tian, Yong Yu. Analysis on optimizing model for proactive ad hoc routing protocol. MILCOM, 5, 17-20 Oct. 2005, 2960 - 2966

[4] C. E. Perkins, E. M. Royer, S. R. Das. Ad hoc on demand distance vector (AODV) routing. IEEE workshop on mobile computing systems and applications, (1999), 90–100.

[5] D. B. Johnson and D. A. Maltz. Dynamic source routing in ad hoc wireless networks. Mobile computing, (1996), 153-181.

[6] P. Samar, M. R. Pearlman, Z. J. Haas. Independent zone outing: an adaptive hybrid routing framework for ad hoc wireless networks. Networking IEEE/ACM Trans. 12, 4 , (Aug. 2004), 595 - 608.

[7] R. Schoonderwoerd, O. Holland, and J. Bruten. Ant like agents for load balancing in telecommunications networks. In international conference of autonomous agents. 5, 2, (1997), 209-216.

[8] T. White, B. Pagurek, and F. Oppacher. Connection management by ants: an application of mobile agents in network management. PDPTA'98, (1998).

[9] G. Di Caro and M. Doriago. Antnet: distributed stigmergetic control for communication networks. Journal of theoretical biology. 159, (1998), 317-365.

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