Department of Computer Science and Engineering

Report on

ARA – The Ant-Colony Based Routing Algorithm for MANETs

Mesut G¨unes, Udo Sorges, Imed Bouazizi

Report Writers:
Shantanu Sarkar
(0416052041)
Mahmud Ahmed
(0416052027)
Md. Mostafizur Rahman
(0416052032)

Supervisor:
Dr. Ashikur Rahman

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Abstract

Wireless adhoc network consists of set of nodes, having a fixed transmission range, which communicate among themselves through wireless medium in multi-hop manner. They nodes are practically hugely mobile which makes the process of route finding followed by data transmission more difficult in real life applications. Several algorithms have been proposed till now with their respective pros and cons over several performance aspects of wireless networks such as the transmission redundancy, reliability, overheads, delivery rates, etc. In this report, we introduced a new method, called Ant Colony Based Routing Algorithm, which is built upon the skillful problem solving capability of ants, inspired from swarm intelligence. This reports also includes elaborate simulations result which compare the performance of this newly introduced algorithm with existing other well-known algorithms names AODV, DSDV and DSR which shows this new algorithm more effective, scalable and efficient in various real life networks.

1 Introduction

A mobile ad-hoc network (MANET) is a flexible, infrastructure less set of mobile nodes communicating over radio in wireless medium. Each node has a fixed limited transmission range which causes the communication traffic to be relayed over several intermediate nodes lying in its transmission range. Hence, the name, "Mobile Multi-hop Ad-hoc Networks", has been evolved from its nature of transmission. The primary goal or the prime obstacle in MANET is finding of a route between the communicating end-points. This problem becomes much severe when the mobility of the nodes is enhanced or increased.

In Figure 1, we present a sample of a wireless adhoc network consisting 8 nodes marked AS *A,B,C,D,E,F,G,H.* An edge is inserted between two nodes lying in each other transmission range. For example, node B is situated in the transmission range of A, so A and B are connected and this follows for the rest of nodes also.

This report sheds light on a new approach of path setting for communication between points in wireless mobile networks based on swarm intelligence. Swarm intelligence (SI), introduced by Gerardo Beni and Jing Wang in 1989, employed in work on artificial intelligence, is built on collective behavior of distributed systems, natural or artificial. Examples in natural systems of

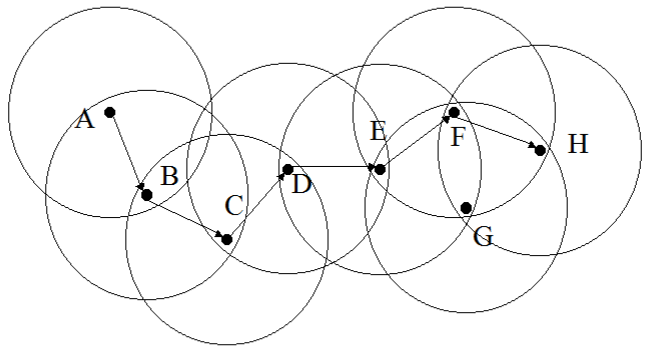

Figure 1: Wireless Adhoc Network

SI include ant colonies, bird flocking, animal herding, bacterial growth, fish schooling and microbial intelligence.

We will be using Ant Colony Algorithm, a sub-set from Swarm Intelligence, and use the ability of simple ants to solve complex problems by cooperation without any direct communication, rather by stigmergy, to devise optimized routing algorithm in the scenario of mobile wireless adhoc networks. The essence of finding complete routing algorithm in the wireless adhoc network emergence from the importance of these kinds of networks. These type of networks are very much fragile which makes it highly adaptable in disaster and military applications, vehicular networks, Ubiquitous computing, Sensor Networks, etc. The newly presented on-demand routing algorithm based on ant colony based meta heuristics is highly adaptive, efficient and scalable because the performance remains almost the same irrespective of dense or sparse network, irrespective low or high mobility, etc.

2 Background studies

The Ant-Colony-Based Routing Algorithm(ARA) used in this paper is a particular class of ant algorithms which is based on swarm intelligence. It is a multi-agent systems algorithm which consists of agents with the behavior of individual ants. It is found that in routing algorithms a lot of swarm intelligence based routing algorithm performs really well. The basic algorithms for ARA is really simple which is described in the later section.

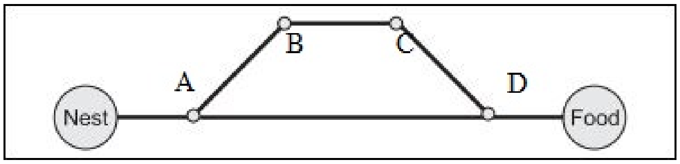

Figure 2: Ant Colony Algorithm

3 Methodology

3.1 Basic Ant Algorithm

The basic ant algorithm is simulated on the food searching behavior of ants. Leaving from their home, ant searches for food tracing the smell or some other indicator of foods. Coming upon a diversion or an obstacle, it randomly chooses a path and starts going along that path. But interestingly, they leave some pheromone while they move on a specific path. So the amount of pheromone is used as an measure of number of ants going in a specific path. Obviously the shortest path from the nest up to the food location gradually has the higher amount of pheromone which helps the ants coming later on that diversion to choose the path. The ants choose the path which has the higher pheromone concentration in a distributive fashion throughout the entire path. With time being elapsed, the concentration of pheromone is diffused and thus decreased which makes the path searching process dynamic.

In figure 2, the above scenario is described. Coming to an intersection point A, a few ant goes through path AB and randomly some other ants follows the path AD towards the food. But the ants that going through the path AD will reach the food quite fast and thus the number of ants following this path will increase which in turns increases the amount of pheromone along this path. As a result, in the long run, when other ants will come to this intersection point, it will assess the amount of pheromone and find its concentration higher in the path AD and thus the shortest path will be converged.

3.2 Ant Colony Optimization Algorithm for Routing

So, in accordance with such behavior of ant, when a data packet comes to a node, it chooses an outgoing edge from that node with a specific probability, calculated by dividing the amount of pheromone of that edge by the total

$$P_{ij} = \begin{cases} \dfrac{\varphi_{ij}}{\sum_{j \in N_j} \varphi_{ij}} & \text{if } j \in N_i \\ 0 & \text{if } j \notin N_i \end{cases} \qquad \text{..................(1)}$$

- $\sum_{j \in N_i} p_{ij} = 1 \qquad i \in [1, N] \qquad \text{...............(2)}$
- $\varphi_{ij} := \varphi_{ij} + \Delta\varphi \qquad \text{...............(3)}$
- $\varphi_{ij} := (1 - q)\varphi_{ij} \qquad q \in (0,1] \qquad \text{...............(4)}$

Figure 3: Equations for ACO

amount of pheromone of all the outgoing edge from that node. When an edge has been chosen for data transmission, the amount of pheromone of that edge is increased by a fixed amount to mark that the edge is being used highly for data passing. The amount of pheromone is also decreased with time by a fixed amount to engage dynamicity. The equations are listed in figure 3. The probabilty of picking an edge ij is the amount of pheromone of edge ij divided by the total pheromone value of all j edges outgoing from i, as described in *equation 1.* Obviuously, the sum of the probabilty of choosing all the edges be 1, as we see in *equation 2.* While an edge been chosen, it's concentration of pheormone is increased by $\delta\phi$ and with time, its concentration of pheromone is reduced by a certain amount, q, as listed in *equation 3 and 4*

3.3 The Routing Algorithm

3.3.1 Route Finding

This phase is done using two type of data packets: FANTs used to track pheromone to source node and BANTs used to track pheromone to destination node. Being broad casted by the sender, A node receiving a FANT creates a record consisting destination address, next hop and pheromone value in its routing table.. Thus being relayed upto he destination node, it extracts the information of the FANT, destroys it and releases BANT in similar manner as of the FANTs to the source which sets up the path for data transmission.

In figure 4, we showed the process of route finding, starting from node S and as destination upto node D. The intermediate nodes are used to recieve

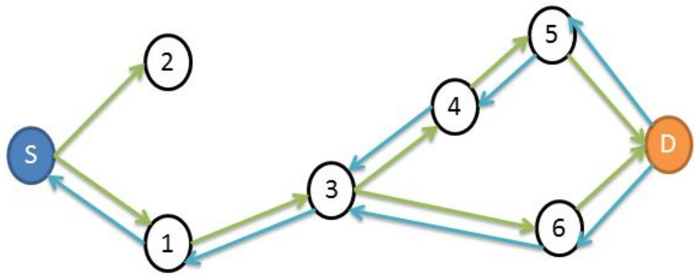

Figure 4: Route Finding Process

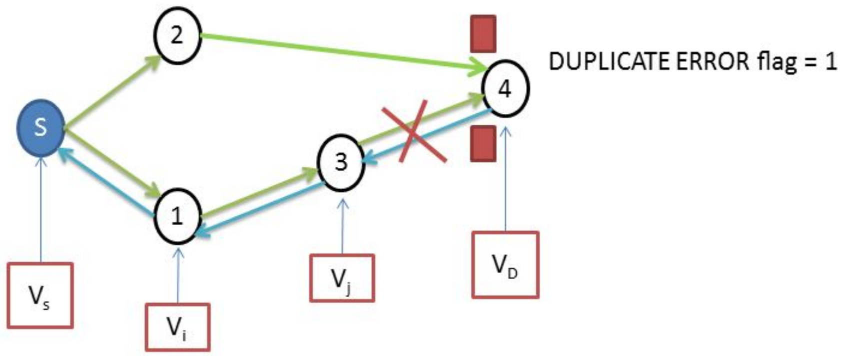

Figure 5: Route Maintenance Process

the FANT packets and transmit to the destination and also to recieve the BANT packets and tranmit it to other direction. The green direction is the flow of FANT packets and the Orange one for the BANT packets.

3.3.2 Route Maintenance

The data packets are used to maintain the path by increasing the amount of pheromones of that edges through which they travel. Duplicate packets are identified through the unique sequence number and detecting the duplicates, the DUPLICATE ERROR flag and the packet is sent back to the previous node followed by the deactivation of that link. In figure 5, we show this process, where a same packet came from node 2 and 3. So setting DUPLICATE ERROR flag = 1, the path node 3 to 4 has been deactivated.

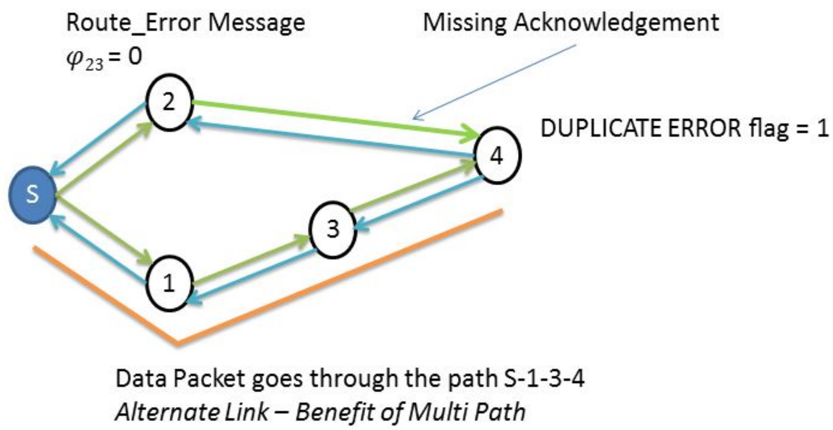

Figure 6: Route Error Process

3.3.3 Route Error

Recognizing a route failure through a missing acknowledgement, a node, receiving ROUTE Error Messge, deactivates a link setting pheromone value of that link as 0. The it searches for an alternate link. If it finds then it sends the packet through that path, otherwise, it informs its neighbors. If the packet does not reach the destination, the source initiates a new route discovery phase.

This scenario has been depicted in figure 6. Here, acknowledgement has been missing in the link of *34*. So, setting the pheromone of this edge as 0, the packet goes in aother alternate path as shown in the figure. If this path was not there and the packet backtracked to the root, it would have to initiate another rout finding process.

3.4 Worthiness of ARA

With a view to measuring the worthiness of presented algorithm, the authors jotted down the characteristics of their presented algorithm, calculated the overhead this algorithm and also confirmed their calculations by measuring the performance metrics like throughput, delivery rate, overheads in terms of packets and data bit, etc.

3.4.1 Characteristics of ARA

The authors picked the following reasons to prove the diligence of this algorithm. This reasons basically illustrates different aspects why this kind of algorithms could perform well in mobile multi-hop ad-hoc networks.

- Supports Dynamic topology
- being distributed algorithm
- Support for multi-path
- Chance for measuring link quality
- Prevents loop in the topology.
- Provides Demand-based operation
- Provides sleep mode operations.

3.4.2 Overheads of ARA

The authors measured the overhead of this algorithm which is very small, because of no interchange of routing tables between the nodes. Unlike other routing algorithms like DSDV or DSR, it doesn't exchange routing table information, which restricts ARA's overhead to minimal stage. Just a unique sequence number is transmitted in the routing packets to prevent the duplicated packets. Even no extra packets are needed for route maintenance, the data packets only carries the IP header, for which there is no extra burden of overhead.

Remark. The authors also confirmed the worthiness of their solution by calculating the throughput, delivery rate of the packets and the overhead in terms of packets and data bits.

4 Evaluation Metrics

According to the Authors, the main feature of ARA is its low routing overhead and easy maintainability of routes between nodes in the topology. So, The evaluation metrics considered to measure the performance of ARA are:

- Delivery rate

- Routing overhead in terms of bits
- Routing overhead in terms of packets

5 Evaluation Process

The performance of ARA was evaluated using simulation in terms of evaluation metrics mentioned earlier. The simulation was implemented in ns-2. Some important parameters of the simulation environment are:

- Simulation area 1500m×300m
- Maximum velocity of nodes 10 m/s using Random waypoint model.
- Simulation time 900 seconds
- 10 Constant bit rate(CBR) connections
- 7 different pause times[1] 0,30, 60, 120, 300, 600 and 900 seconds

6 Evaluation Results

Multiple simulations were run and the results were collected for evaluation.

6.1 Comparison with existing routing protocols in delivery rate

The best way to evaluate the performance of a new algorithm is to compare the performance with the existing algorithms. So, the performance of ARA was compared with AODV,DSR and DSDV in terms of delivery rate. The observed results are shown in Figure 7. With high mobility both DSR and ARA has more than 95% delivery rate. Throughout the simulations ARA performed better than DSDV and AODV in this criteria. Figure 8 shows the delivery rate of ARA within the confidence interval of 95%. As we can see All results are above 85% and most results are within the range 90% and 100% throughout the 10 simulation runs.

[1] pause time indicates the mobility of the nodes

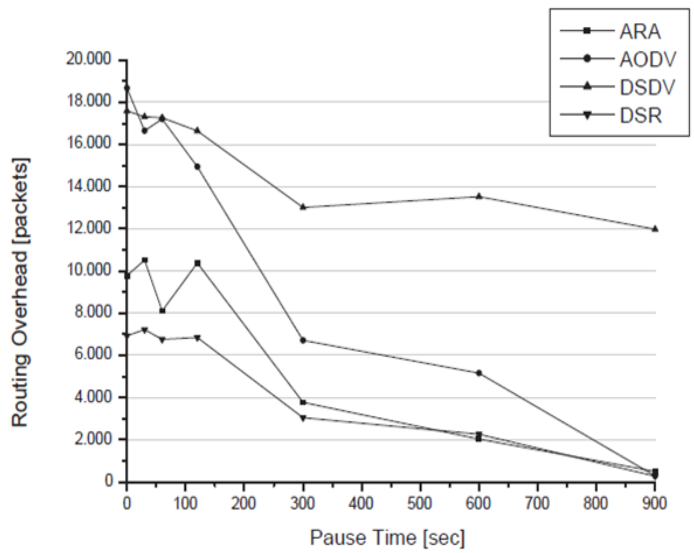

Figure 7: Successful delivered packets as a function of pause time.

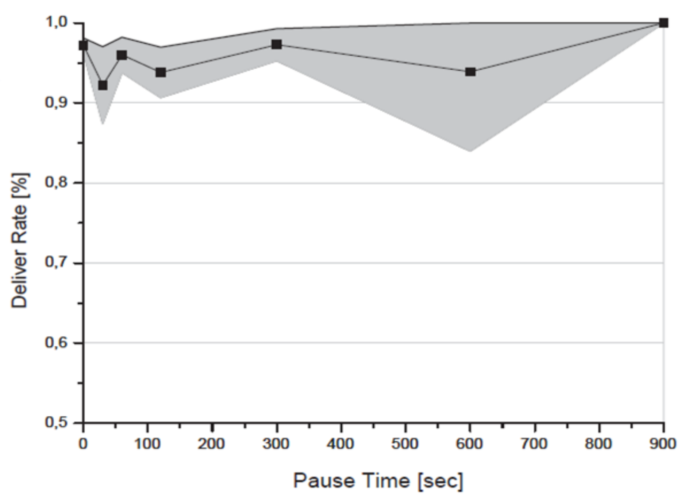

Figure 8: Delivery rate of ARA. Confidence interval of 95%

6.2 Routing Overhead Comparison

As different protocols generate the overhead in very different ways, the routing overhead of different algorithms were observed both in terms of fraction of routing packets needed to deliver a data packet and fraction of databits

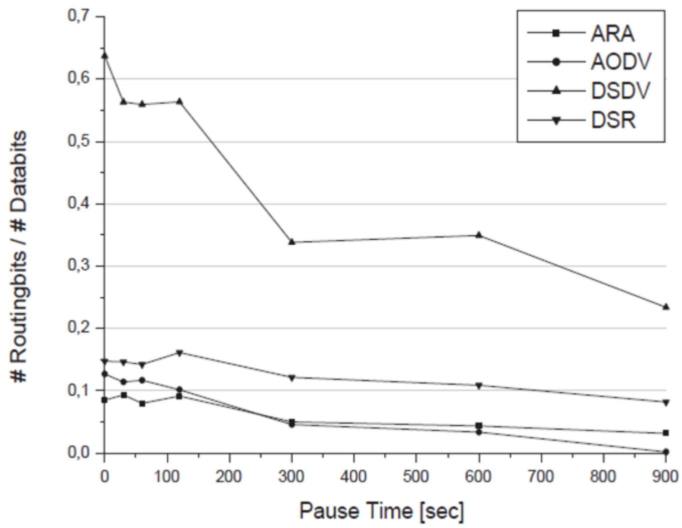

Figure 9: Pause time vs Fraction of successfully send bits and the needed bits

needed for routing.

6.2.1 Routing Overhead in terms of databits

Figure 9 shows the routing overhead of routing algorithms in term of routing bit as a fraction of total databits. In this case ARA give the best results throughout the simulations. Figure 10 show the overhead of ARA in 95% confidence interval.

6.2.2 Routing Overhead in terms of packets

Figure 11 shows the routing overhead of routing algorithms in term of packets. In this case ARA give second best results following DSR.This is due to the needed flooding of the approach in the route finding phase. With high node mobility route failure occur more often, thus requires the performing of the route failure handling part of the algorithm,which in worst case has to backtrack the path until the sender. Figure 12 show the overhead of ARA in 95% confidence interval.

Remarks: The authors used standard simulation processes to collect data under the simulation environment in Section 5. So, the collected data are

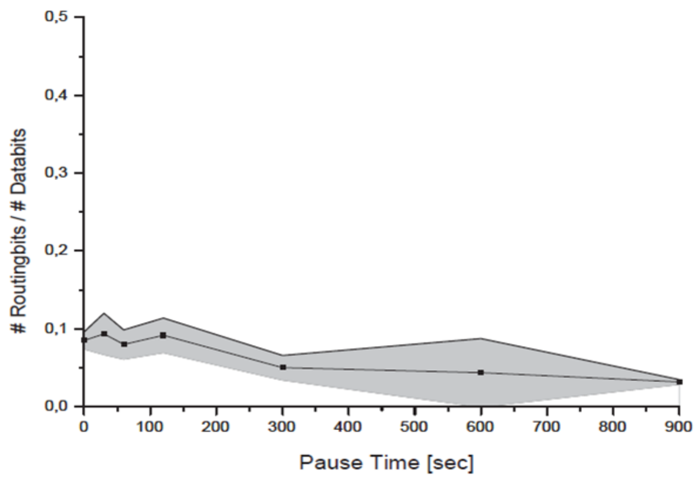

Figure 10: Overhead of ARA in bits. Confidence interval of 95%

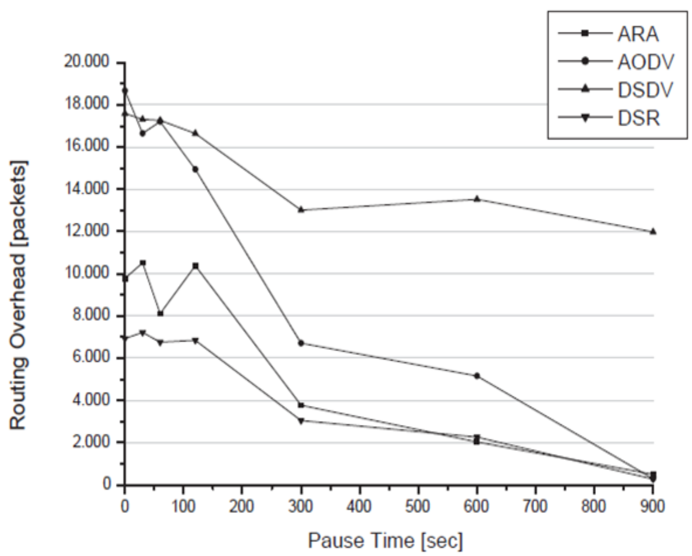

Figure 11: Pause time vs Fraction of successfully send bits and the needed bits

reliable and trustworthy. ARA is a good choice for mobile networks in terms of data delivery,routing overhead. But a better conclusion can be derived if individual performances of DSR,DSDV,AODV were presented in 95% confidence interval like Figure 8, Figure 10, Figure 12. In that case we would

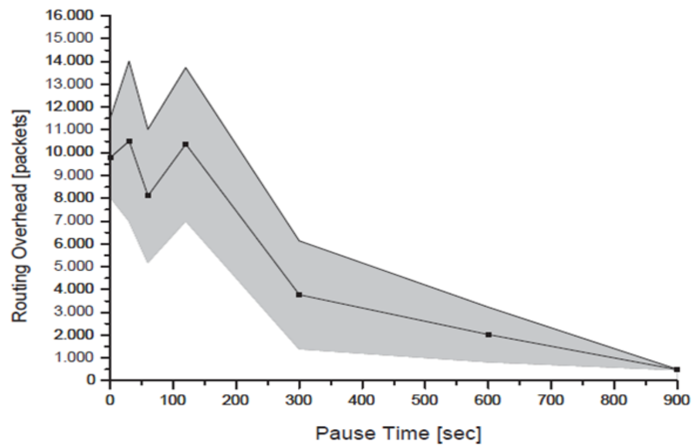

Figure 12: Overhead of ARA in packets. Confidence interval of 95%

be able to observe the fluctuations of performance over different mobility. Nevertheless, we consider ARA as a robust and highly maintainable routing protocols in mobile adhoc networks.

7 Limitations of ARA

In this paper the routing algorithm implemented for mobile multi-hop wireless ad-hoc networks for a dynamic topology works closer to DSR but with a lesser overhead. But routing problem still remains the main challenge for mobile multi-hop wireless ad-hoc networks. In this algorithm there are other aspects that could be evaluated. For instance we could introduce a difference topology for a different kind of dynamic environment. In more dynamic environment this algorithm performs worse than DSR. In those kinds of environment we could calculate the pheromone in a different way that might give us better result by trial and error. Though this algotithm works better but it does not fit best for all kinds of application. High network load and multimedia data are the fields that are still needed to be evaluated. Maintenance of pheromone is also a crucial part for this algorithm which can be improved to give better perrformance.

8 Future Works

- Maintenance of pheromone concentration is the most crucial part of this algorithm. Pheromone concentration can be calculated differently for different kinds of dynamic environment which may give better performance for certain scenerio. High network load and multimedia data are fields that can be extended for this algorithm. Since node mobility is the main factor for mobile multi-hop wireless ad-hoc networks if we could predict the mobilty for a certain environment and set the pheromone concentration accordingly of a node that might result in a improved performance.

- This algorithm was designed for mobile multi-hop wireless ad-hoc networks. So we can actually apply it to VANET by tweaking it to work with highly mobile network. Though it may have worse performance since this algorithm is designed particularly for MANET. If we we consider the mobility of a vehicle and if the mobility is not very high than this algorithm might give an average output.

9 Conclusion

The proposed ARA-Ant colony based rouging algorithm provides some great insights in mobile ad hoc networks.The approach is based on swarm intelligence and especially on the ant colony optimization meta-heuristic. The easy maintainability and low routing overhead of ARA gives better utilization of resources in the networks than other algorithms. Although there are some drawbacks of ARA and there are many scopes of improvements, we believe ARA is a good candidate for mobile ad hoc networks.

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