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Adaptive ARA Algorithm (AARA): Proposed Modifications and Experimental Results

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Since ARA is a reactive protocol, that is why it is used in such situations where mobility of nodes are higher. In this section, we have proposed the modifications to the algorithm by which the potential of ARA will increase in high mobility scenarios. Pheromone updates play a critical role in the performance of the ant algorithm. In ARA algorithm, initial pheromone value is computed by number hops during the route discovery. This method may not be suitable when nodes are mobile. Pheromone equations are classified in different categories. Two of them are the Classic pheromone filter, where route quality is not taken into consideration, for example the original ARA pheromone equation and the Gamma pheromone filter, which takes time and route quality into consideration.

I. Pheromone tables

Routing information is organized in pheromone tables. Each node i maintains one pheromone table Ti, which is a two-dimensional matrix. An entry of this matrix contains information about the route from node i to destination d over neighbor j. This information includes the pheromone value , which is a value indicating the relative goodness of going over neighbor j when traveling from node i to destination d, as well as statistics information about the route, and possibly virtual pheromone. This latter value is derived from the normal pheromone, which we will from now on refer to as regular pheromone, and is used to support proactive route maintenance an improvements. Apart from a pheromone table, each node also maintains a neighbor table, in which it keeps track of which nodes it has a wireless link to.

7.2 The Time Metric

Taking path quality into consideration we developed a type of Gamma Pheromone filter for ARA to update pheromone values as Gamma Pheromone filters show a better performance over the classic pheromone filters [84]. The modified pheromone update equation sets the initial value of the pheromone as:

(7.1)

Where denotes the pheromone concentration over link (i, j) for a destination d and t denotes the time interval between the sending of a forward ant and the receipt of the backward ant, and hops is the total number of hops made by the ant. The pheromone update is done as per Equations (7.1).

(7.2)

The inclusion of time in the equation creates a pheromone gradient from source to the destination point depending on the time it takes for the backward ant to reach the node that forwarded it. In the case of only FANT hops being taken into consideration, many paths with a similar gradient are formed; however the time metric creates a marked difference in the path gradient and thus the packet would be randomly forwarded over the path with the greatest pheromone gradient. This metric is thus expected to produce better results than if only number of hops is considered.

7.3 Pheromone decay process

We have proposed that the pheromone decay should be discrete process rather than a continuous one. As the pheromone decreases asynchronously after a particular time interval, so the discrete process shall allow more pheromone to be available on the routes so that routes live longer.

(7.3)

(7.4)

Where $(1-\lambda)$ is called the pheromone decrease constant and $\lambda \in (0,1]$.

7.4 Route Selection Exponent

In original ARA algorithm, the route selection exponent is k = 1. We have proposed that the route selection exponent for the modified algorithm should be k = 4. This increases the sensitivity of the algorithm to changes in pheromone values, making it more adaptive in nature.
The selection of path is based on equation (7.4)

Where is the heuristic cost function of travelling path (i, j) which could be $1/d_{ij}$, where d_{ij} is the distance between the nodes i and j. is available bandwidth at each node i.

7.5 Routing mechanisms

In original ARA algorithm, flooding technique was used. But we have simulated the proposed algorithm using forwarding technique. So, if a route exists from a node to the destination, the FANT is forwarded over that route instead of flooding. This will reduces the overhead during the route discovery process. Maximum number of hops is increased. The maximum number of hops is set through experiential observation of a reasonable amount of time it takes for the FANT to reach the destination from the source. Due to this delay may increase but performance tested to be increased.

7.6 Simulation Parameters

Algorithm is implemented on Qualnet version 4.0 [85] and simulations for each "choice" are run on the Qualnet simulator. Qualnet is specifically optimized to simulate large-scale MANETs, and comes with correct implementations of the most important protocols for all the network layers and for routing in particular.We have compared the performance of AntHocNet, ARA and Adaptive ARA (AARA) with Ad Hoc On-Demand Distance Vector (AODV) Single-path routes are established on-demand and on the basis on a minimum-hop metric. Only the nodes along the path used by the application maintain routing information toward the destination, such that in practice a virtual-circuit is established and end-to-end signaling is used tear up and down the path, as well as to rebuild the path in case of broken links.

The simulations are conducted on an area of 1000m x 1000m. Node mobility is restricted to a maximum speed of 10 m/s and according to the random waypoint mobility model. 802.11b is used as the underlying MAC layer protocol with a propagation limit of -111dB. Tcp-lite is used as the application layer protocol. Simulation time for each instance of an experiment is 300s. For each experiment the sample size is 5. Constant bit rate connections, configured between the nodes are 18. The random seed for the simulation is initially set to 300. Through each experiment various performance metrics of the algorithm are measured in terms of Packet Delivery Ratio, End-to-End delay, Jitter, and Throughput at receiver node. Through experiential observations the maximum hops for the FANT is set to 10. Other parameters include a pheromone decrease constant of 0.4, a pheromone increase constant of 0.6, a decrease interval of 5s, and a route select exponent of 3. Measurements are taken by varying pause time, which is indicative of the mobility of the network. Pause times are taken to be 0s, 30s, 60s, 90s, 120s, and 150s. Lower pause times indicate a greater mobility of the nodes in the network.

7.7 Experimental settings

We first describe technical details about the setup of the study, and then investigate some general properties of the wireless network under the urban scenario as compared to an equivalent open space scenario, in order to give the reader a better understanding of the conditions in which these experiments are run. After that, we discuss a number of tests in which we compare AntHocNet, ARA and AARA to the AODV routing algorithm.

In this scenario 50 nodes are randomly placed in a rectangular area of $2000 \times 2000\ m^2$. Within this area, the nodes move according to the random waypoint model: each node randomly chooses a destination point and a speed, and moves to this point with the chosen speed.Under the RWP model, nodes choose a random destination and speed, move in a straight line to the chosen destination at the chosen speed, and then pause for a certain time before picking a new destination and speed. After that it stops for a certain pause time and then randomly chooses a new destination and speed. The maximum node speed in the scenario is 20 meters/sec and the pause time is 30 seconds. The total length of the simulation is 800 seconds. Data traffic is generated by 20 constant bit rate (CBR) sources sending one 64-byte packet per second. Each source starts sending at a random time between 0 and 180 seconds after the start of the simulation, and keeps sending until the end. At the physical layer we use a two-ray signal propagation model. The transmission range is around 300 meters, and the data rate is 2 Mbit/sec. At the MAC layer we use the popular 802.11 DCF protocol.Finally, at the transport layer, we use the UDP protocol.

In our settings of RWP, the nodes do not move along a straight line to their destination, but instead follow the shortest path through the available paths. In order to define node destinations and movements, we derived a graph representing the paths of the structure. Destinations were chosen from among all points that are located on an edge or in a vertex of the graph, and shortest paths were calculated in the graph using Dijkstra's algorithm. Finally, we keep 20% of the nodes static, to represent immobile network users. These can for example be wireless access points.

In this scenario nodes are densely packed, such that from one side there is a high probability of radio collisions but from the other side it is always possible to easily find a short route to a destination. The average path length is about two hops and the average number of neighbors of a node is about ten (due to the dimensions of the node area vs. the radio range and the fact that random waypoint movements tend to concentrate nodes in the central zone of the area). This is clearly a scenario that well match the characteristics of a purely reactive algorithm like AODV since it is relatively easy and fast to build or re-build a path while at the same time is important to keep low the routing overhead in order to reduce the risk of radio collisions. Moreover, since it is quite hard to find multiple (and good) radio-disjoint paths for the same destination given the high node density, the AODV's single-path strategy minimizing the hop number appears as the most suitable one. On the other hand, AntHocNet, ARA and AARA are a hybrid, reactive- proactive, algorithm for multi-path routing using both end-to-end delay and hop metrics to define the paths.

AODV is an important reference in the field of MANET routing: it is the most studied algorithm around, and is one of the candidates for standardization by the MANET working group of the IETF. We do tests with varying node density, node speed and the pause time. Finally, we also investigate in more detail whether it is possible to support voice communications with these routing algorithms in the given urban scenario.

II. Results and Analysis

In order to study the behavior of the two algorithms under this reference scenario but also under possibly more interesting and challenging conditions involving longer path lengths and less dense networks, we have performed extensive simulations changing the node density, node speed and the pause time. For each scenario delivery ratio, and end-to-end delay, throughput and jitter are compared for AODV, AntHocNet, ARA and AARA.

Average Throughput: Throughput is a measure of how much traffic is successfully received at the intended destination in a unit interval of time. A routing protocol should try to maximize this value.
Message Deliver Ratio: It is defined as the number of successful transfers which successfully arrive at all the receivers over the total number of messages which are expected to be received.
End to End Delay: It is defined as the average of the end to end message delivery latencies for each algorithm. A good algorithm should be able to deliver packets with minimum delay.

7.8.1 Node Density

In these tests we increase the number of nodes from 50 to 300 with incrementsof 50. Since the network area size is fixed, increasingthe number of nodes resultsto increasing the node density. Scenarios withhigher node density normally have better connectivity and shorter paths, butalso more radio interference between nodes.

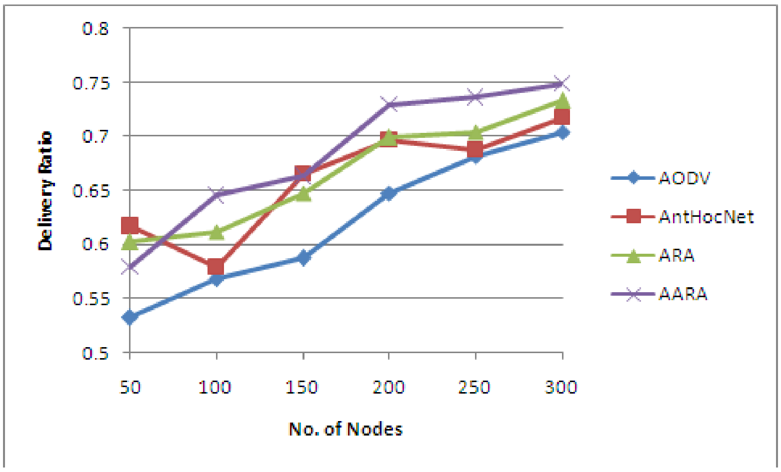

Figure 7.1: Delivery ratio Vs node density

From figure 7.1 it is clear that delivery ratio is better for proposed AARA when numbers of nodes are increased upto 200, but when node density is increased much, the radio interference increases much due to which delivery ratio nearly stabilizes.

As for as delay is concerned AARA is better than AntHocNet and ARA, but AODV has better delay than AARA when node density is increased. Throughput is also increasing upto a certain limit of node density, but decreases after that particular limit.

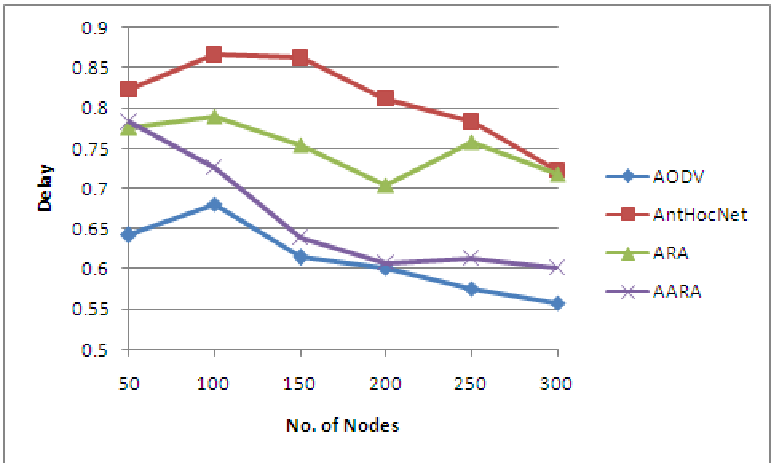

Figure 7.2: End-to-End Delay Vs node density

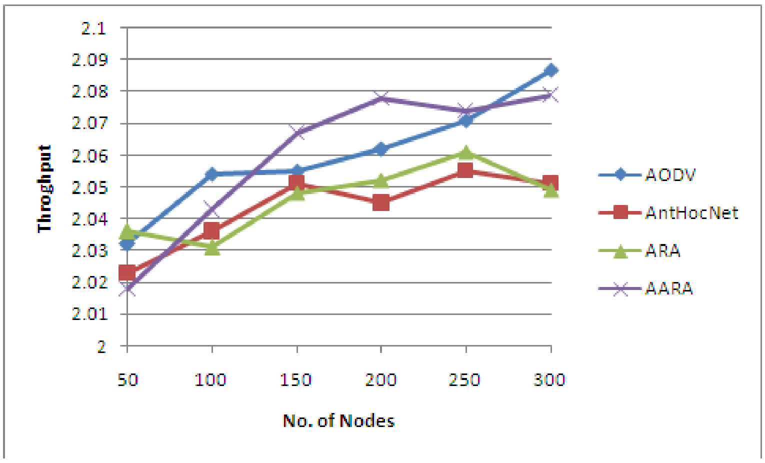

Figure 7.3: Throughput Vs node density

7.8.2 Pause Time

We have changed the level of mobility of the nodes, varying the pause time between 50 seconds (all nodes move constantly) to300 seconds (all nodes with slow speed). Figure 7.4 shows a trend similar to that of the previous experiment.

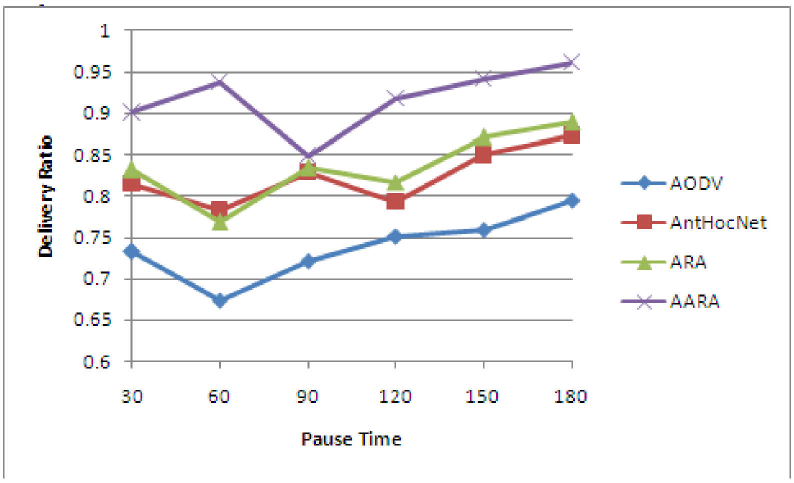

Figure 7.4: Delivery ratio Vs Pause time.

For easy situations (long pause times, hardly any mobility), AARA has a higher delivery ratio, while AODV has lower delay than AntHocNet and ARA. As the environment becomes more difficult (higher mobility), the difference in delivery becomes bigger, while the average delay of AARA becomes better than that of AODV.

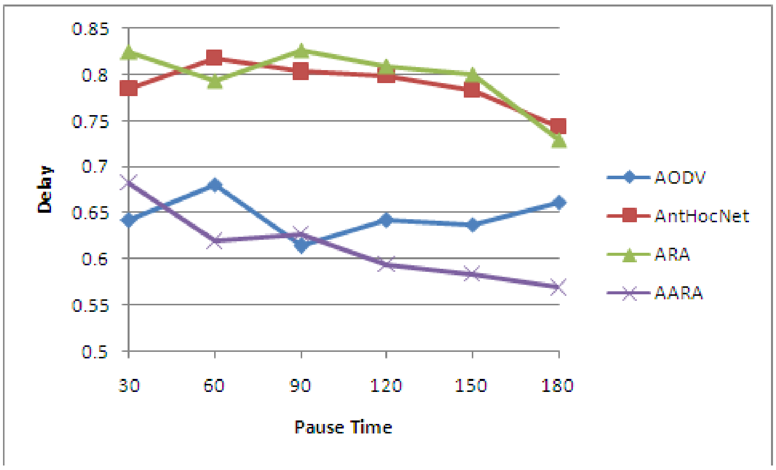

Figure 7.5: End-to-End Delay Vs Pause time.

On reducing the mobility or increasing the pause time we have seen by the experiments that throughput is better than other algorithms.

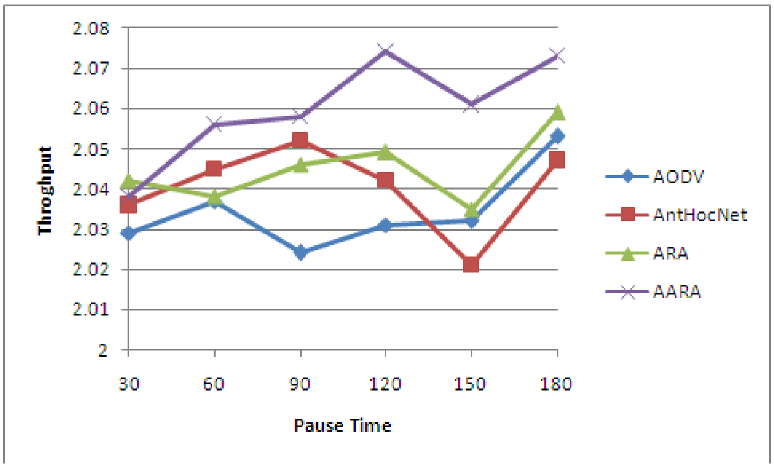

Figure 7.6: Throughput Vs Pause time.

7.8.3 Node Speed

In these experiments we vary the maximum node speed: we increase it fromthe 20 m/s, which correspond to a slow cycling speed, up to 30 m/s, which is areasonable higher speed with the increment of 2 m/s. We keep using 10 bidirectional data sessionsand again do tests with constant data load.

From figure 7.7 we see that, delivery ratios godown with increasing node speeds under all data send rates for all the algorithms and AARA proved to be better. Figure 7.8 and figure 7.9 it is clear that delivery ratio and throughput is better where as delay is best for AODV among all other algorithms. In terms of delay, we get a similar picture.Delay is increased on increasing the nodes speeds.

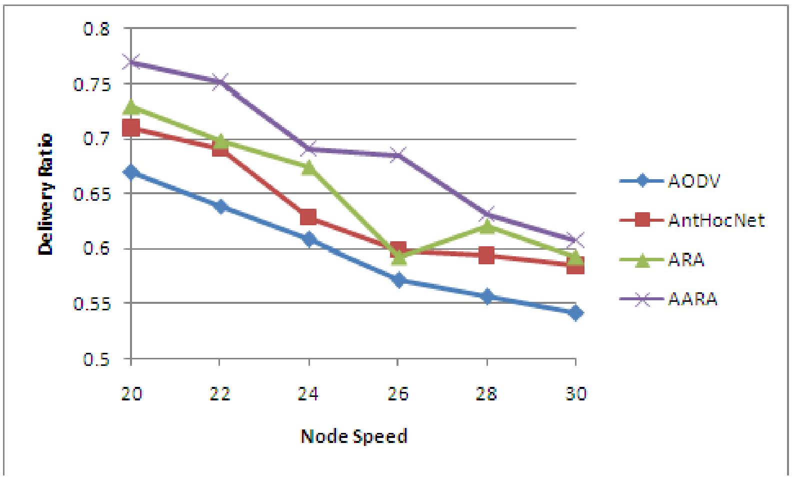

Figure 7.7: Delivery Ratio Vs Node Speed.

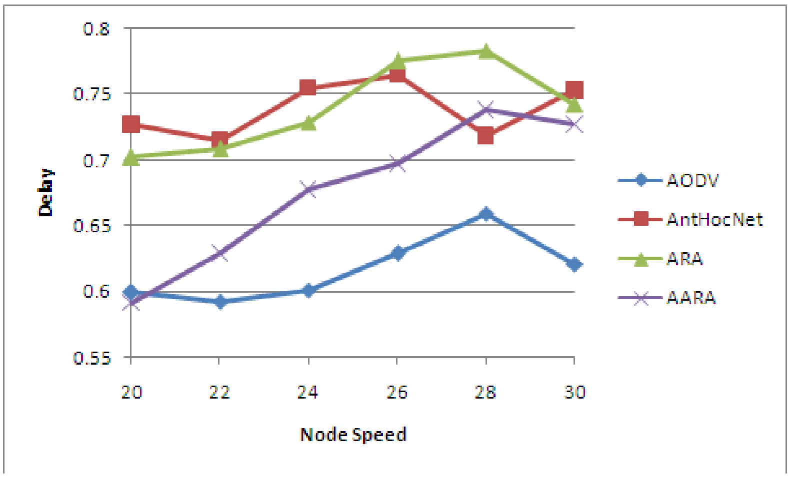

Figure 7.8: End-to-End Delay Vs Node Speed.

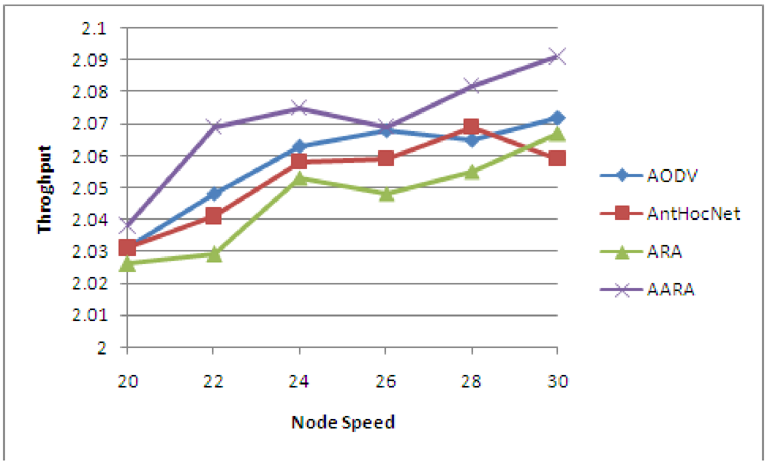

Figure 7.9: Throughput Vs Node Speed.

III. Summary

In this chapter we have reported an extensive set of experimental results based on simulation about the performance of AODV, ARA, and AntHocNet. A modified version of the ARA algorithm is proposed based on the findingsof the analyses carried out on the components of routing. It is observed howmodified ARA performs in comparison to a state of art algorithm of MANETrouting, namely, AODV,AntHocNet and ARA. The routing algorithms were analyzed through varioussimulation based experiments and it was seen that modified ARA performed betterin comparison to the other two algorithms in some metrics in terms of varyingmobility. The modifications to ARA were drawn from not only this analysis butalso inspired by the functioning of other ant colony routing algorithms.Ant Colony algorithms show a lot of promise, and have been shown to be very adaptive to changing environments. They show comparable performance toexisting state of the art MANET routing algorithms. However, their performancemust be improved further and they must be able to solve the problems ofheterogeneous networks before being recognized as state of the art solutions tothe MANET routing problem.

The performance of proposed AARA is compared with AODV, AntHocNet and ARA.The comparison is on the basis of some of the parameters like: Throughput, End-to-end delay and Delivery ratio. We investigated the behavior of the algorithms for a range of different situations in terms of node density, node speed and pause time. After rigorous experimental results we have found that delivery ratio and throughput is improved in all the possible combinations but the delay is not much improved in the proposed method.

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