Vehicle Assisted Data Delivery using Ant Colony Optimization

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***Abstract*—*Routing of data packets in vehicular adhoc network (VANET) is a challenge because of constant dynamic change in the network topology and dynamic nodes. Especially in case of sparse environments where there does not exist a continuous end-to-end connection from source to destination. Sparse environments like rural areas and hilly areas lack technological support in the form of infrastructure due to deployment difficulties or due to economic reasons. These areas usually do not have a high priority in governmental investments. In the following paper we define a protocol VADDACO which does not require infrastructure assistance and is an advancement in already existing protocol VADD. The comparison and results show that VADD-ACO perform better than VADD in terms of delay, throughput and delivery probability. The protocol hence formed is suitable for sparse networks as it will not incur extra cost and hence is cost efficient.*

***Index Terms*—** *Ant colony optimization, Delay tolerant network, Routing protocols, sparse environment, vehicle to vehicle communication.*

I. INTRODUCTION

Vehicular Ad hoc Networks (VANETs) as the name defines is a network of nodes (vehicles here) which communication with each other using wireless communication and signals. Vehicles share information via wireless which includes warning message, advertisements, weather report, internet etc. VANET systems are gaining much importance recently pertaining to its various applications like traffic safety, driver assistance, entertainment information services and internet access. VANETs are the key networking technologies for future vehicular communication even in Intelligent Transportation System (ITS) [1].

VANET aids in reducing the road mishaps and help in parting with the situation in case of an emergency. VANET routing can be done by two means: Inter-Vehicle Communication (IVC) and Roadside-Vehicle Communication (RVC). In IVC routing is shared by vehicles and no external aid is required in the form of RSUs (Road side Units) i.e communication is infrastructure free. RVC systems on the other hand uses external aid i.e from RSUs and hence form a communication which is between vehicle and road side unit. The cost of such system would be high but it is expected to be more reliable than the IVC system [2].

Various protocols have been defined for VANETS. They can be classified as topology based and position based which can be further classified into various categories. Position based further is divided into delay tolerant and non-delay tolerant protocols. Delay tolerant are the ones where a little bit delay in the network is bearable. They are usually used in case of areas where there is no end to end connectivity such as remote areas etc. where the number of vehicular nodes is very less. Routing in such an environment is a challenge. In case of VANETs there are a number of protocols present but we need a strong base in VANETs. We need strong basic protocols which will further help in future advancements. Specially in case of sparse network, a lot of work needs to be done [3].

Various DTN protocols include VADD [4], GPSR [5], epidemic routing [6], GeoOpps [7] etc. One of the protocols which was proposed for sparse network such as rural areas is VADD [4]. The proposed vehicle-assisted data delivery (VADD) is based on the idea of carry and forward, where nodes carry the packet when routes do not exist and forward the packet to the new receiver that moves into its vicinity. VADD works on delay i.e. the path with the shortest delay to the destination is chosen. But there are few problems in VADD. One such problem is that it does not always choose the optimal path and may choose a path which incurs longer time.

RUDTI [8] was proposed which uses the help of infrastructure and performs better than VADD. IBR [9] is another protocol which uses infrastructure assistance for better performance in terms of throughput, delay and delivery ratio.

It can be seen that all the protocols which have been proposed and result to perform better than VADD, most of these use infrastructure assistance. Any protocol which uses an extra help in the form of infrastructure will automatically perform better. But it is costly to take any extra help in the form of infrastructure. Moreover it may not be physically feasible to deploy roadside units or other infrastructure units in certain areas such as hills or certain remote areas.

Our research is based on defining a protocol which performs better than VADD and does not require any help in the form of infrastructure. The proposed protocol uses ant colony optimization.

II. VADD AND ITS DRAWBACKS

Vehicle assisted data delivery is a delay tolerant network protocol and hence it works on the idea of carry and forward. It carries the packet when there is no other vehicle to forward the packet. At an intersection it sends the packet to the vehicle on the way to the destination. It calculates the delay to reach the destination on each road when a vehicle reaches an intersection.

VADD delay model calculates the delay according to the following equation.

$$d_{ij} = (1 - e^{-R \cdot \rho ij}) * (l_{ij} * c)/R + e^{-R \cdot \rho}{}_{ij} * l_{ij} / v_{ij} \qquad (1)$$

l_{ij}: the Euclidean distance of r_{ij}

ρ_{ij}: the vehicle density on r_{ij}

v_{ij}: the average vehicle velocity on r_{ij}

d_{ij}: the expected packet-forwarding delay from I_i to I_j

R : the wireless transmission range

c the average one-hop packet transmission delay.

It basically calculates the delay to reach the destination on each road and sends the on the road with minimum delay. For example, consider the scenario in figure 1**.** Where node A is the source node and node D is the destination node. At the intersection node A has to decide between choosing node B or node C for forwarding the packet. Now VADD has been classified into two types: L-VADD (Location VADD) and D-VADD (Direction VADD). In case of L-VADD the vehicular node chooses the node closer to the destination in terms of distance. So in the following scenario L-VADD would choose node B. But node B is going away from the destination. Therefore L-VADD has few drawbacks. D-VADD was proposed to overcome the problems of L-VADD. D-VADD after considering the distance, checks the direction of the vehicle too. It sends the packet to the vehicle in the direction of the destination. So in the following scenario, D-VADD would send the packet to node C, which is in the direction of the destination node D.

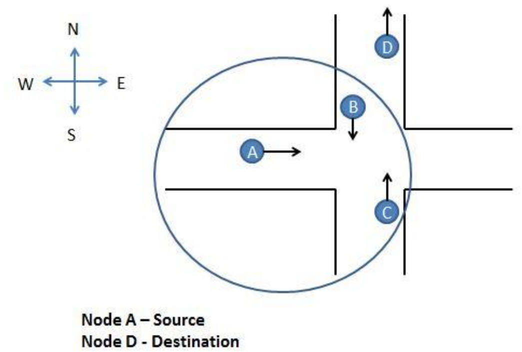

Figure 1. Node B is chosen by L-VADD and node C by D-VADD

Though D-VADD works well in most cases but it has few drawbacks as well. Consider the following scenario shown in figure 2, where source node S has to send data to destination node D. According to VADD the path chosen would be the dashed line path since it is closer to the destination. But the number of vehicles on this path is two and they may be slow too. If the data is sent through the solid line path as shown, the packets or the data will reach destination faster and hence the delay will be less.

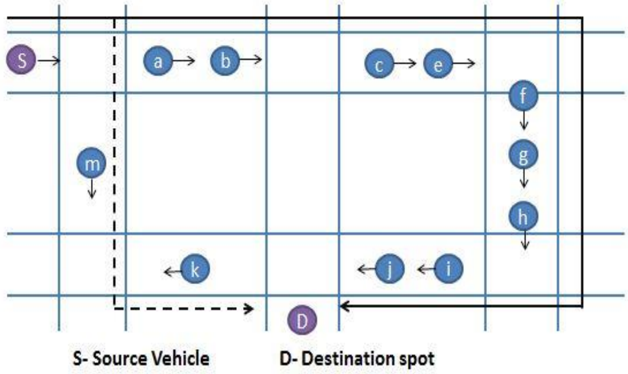

Figure 2. Choice of path by VADD

Ji-Han Jiang et al. propose RUDTI (Roadside Unit Deployment Based on Traffic Information) which uses roadside unit's help to overcome this problem of VADD. RUDTI performs better than VADD but uses extra help in the form of infrastructure. So the focus of our research is to find ways to overcome the problems of VADD without using infrastructural help, so that the protocol is feasible in cases where it is not possible to deploy infrastructure such as hilly areas, remote areas etc.

III. ANT COLONY OPTIMIZATION

Ant colony optimization was proposed by Dorigo et al [10] in early 1990s. Ant colony optimization (ACO) is a meta heuristic technique inspired from the behaviour of ants in real life. Ants make use of a chemical named pheromone, which they leave behind while the follow a path. The pheromone had a tendency to evaporate with time. Other ants can sense this pheromone and tend to follow the path with a fresh pheromone quantity. In this way ants define the shortest path i.e the path with higher pheromone value to the food from their nest. The path which is less travelled due to evaporation of pheromone is discarded. ACO is one of the artificial algorithms applied largely in networking domain to create self-organizing methods for routing related problems. ACO and other meta-heuristic techniques like bee colony optimization, swarm intelligence have gained huge popularity recently and are being widely used for various applications like scheduling problems, vehicular routing, image processing, Nano electronics etc.

In our research we are using ACO in VANETs to find the optimal path with minimum delay. The protocol VADD is modified and is worked with ant colony.

The delay calculated in VADD protocol is given as an input to the ant colony optimizer. ACO hence chooses the path with minimum delay in all cases.
Following sections include the methodology of the proposed protocol with simulation details and results. It is concluded from the results and analysis that the proposed protocol VADD-ACO performs better than VADD in terms of delay and delivery probability.

IV. VADD-ACO METHODOLOGY

VADD-ACO algorithm starts with the deployment of VADD protocol in the simulator (ONE simulator in our case). Then the various parameters required are extracted next, for example velocity, location, number of nodes, source and destination nodes etc. Then all these values are used to calculate the VADD delay using equation (1) as described in the previous section. This delay hence calculated is given as an input to the optimizer (ACO). ACO now checks and optimizes the delay value so calculated using pheromone updation and calculating the transient probability according to the algorithm VADD-ACo given below. Before that a flowchart has been described for the steps followed in VADD-ACO.

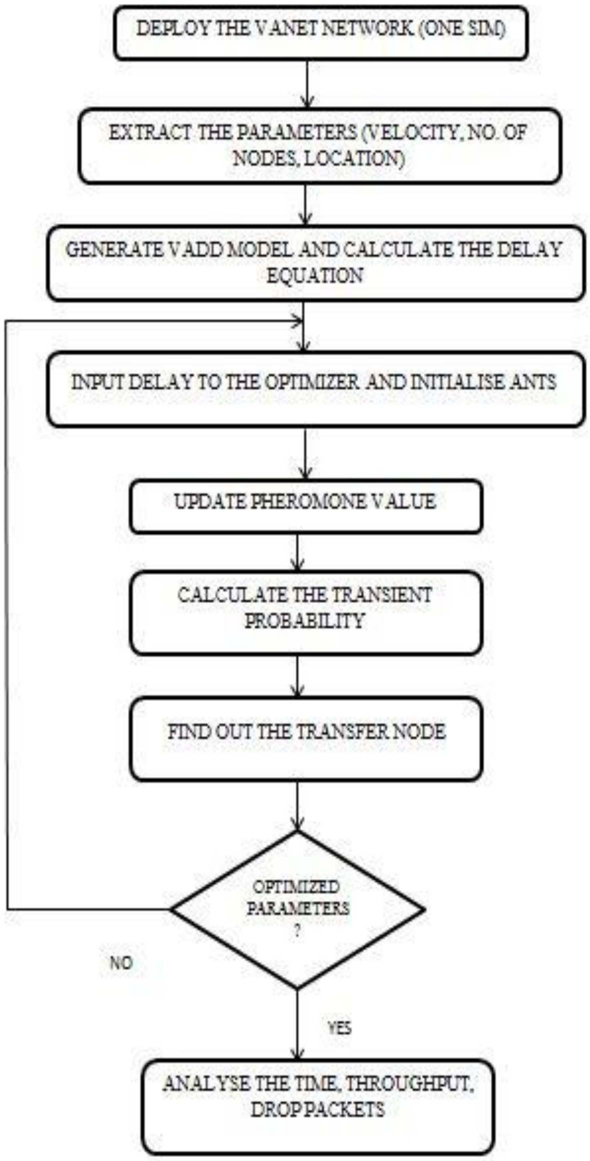

Figure 3. Flowchart for VADD-ACO Protocol

Algorithm VADD-ACO **INPUT:** VANET network. **OUTPUT:** Optimized or Converge parameters. **Step 1:** Apply delay model from equation (2) to the network.

$$d_{ij} = (1 - e^{-R \cdot \rho_{ij}}) * (l_{ij} * c)/R + e^{-R \cdot \rho_{ij}} * l_{ij} / v_{ij} \quad (2)$$

This defines the packet-delivery delay, with the following notations.

l_{ij}: the Euclidean distance of r_{ij}
ρ_{ij}: the vehicle density on r_{ij}
v_{ij}: the average vehicle velocity on r_{ij}
d_{ij}: the expected packet-forwarding delay from I_i to I_j
R is the wireless transmission range
c is the average one-hop packet transmission delay.

Step 2: Initialize the number of Ants and Default variables.

Step 3:

While (true)
t++ // Simulation Time
for every vehicle
if source = destination
return
else
change in pheromone value
for every path by equation (3)

$$T_{ij} = (1 - \rho)\, T_{ij} + \sum_k \Delta T_{ij} \quad (3)$$

T_{ij}- updated pheromone on the edge from node i to node j
k- iteration
ρ- density
ΔT_{ij} – amount of pheromone deposited

for every adjacent path calculate probability by equation (4)

$$P_{ij} = (T_{ij})^{\alpha} * (\eta_{ij})^{\beta} / \sum (T_{ij})^{\alpha} * (\eta_{ij})^{\beta} \quad (4)$$

η_{ij}- is the inverse of the distance between the two nodes
α -parameter to control the influence of T_{ij}
β-parameter to control the influence of η_{ij}

end loop
if (converge)
break;
else continue
end loop
end loop
end loop

V. SIMULATION SETUP

The simulation scenario is based on the map-based model of a part of the city of Helsinki presented in Figure 4. It assumes a fully cooperative opportunistic environment.

Table 1. SIMULATION SETUP

Parameter	**Value**
Simulation area	4500m x 3400m
Number of Vehicles	70- 150
Vehicle velocity	10-50 kmph
Transmit Range	300m
Scenario run time	10000 seconds

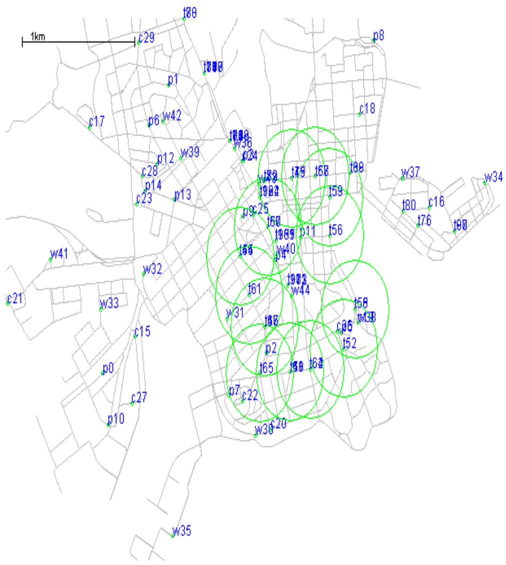

Figure 4. Simulation scenario: Helsinki downtown (area of 4500 x 3400 m)

Few of the simulation setup parameters and their values are given in table 1 above. In our simulation the setup is map based model based on city of Helsinki. The number of nodes are varied from as low as 70 to 150 or more. In our simulation 70 nodes network is considered as sparse and 150 nodes network is considered as dense. The simulator used for the setup is ONE simulator. It is a simulator specially designed to carry out routing in delay tolerant networks. The next section describes the analysis done on both VADD and VADD-ACO.

VI. SIMULATION RESULTS

The results are calculated on the following parameters:
1. Throughput: The number of packets sent per unit of time.
2. Delay: The overall average delay in seconds for the packet to reach destination.
3. Delivery probability: The probability that the packet is delivered over the total number of packets sent.
The following are the results shown in graphical form.

Figure 5. shows the results of delay in both protocols. It can be seen that the delay in VADD-ACO is quite less as compared to VADD. This was the main aim of the research i.e. to decrease the delay. The delay here is less in VADD-ACO because in VADD-ACO the number of retransmissions of the number of drop packets is decreased by following the optimized paths. Hence the time taken to reach destination is less and since the number of drop packets are decreases, delay time is further decreases.

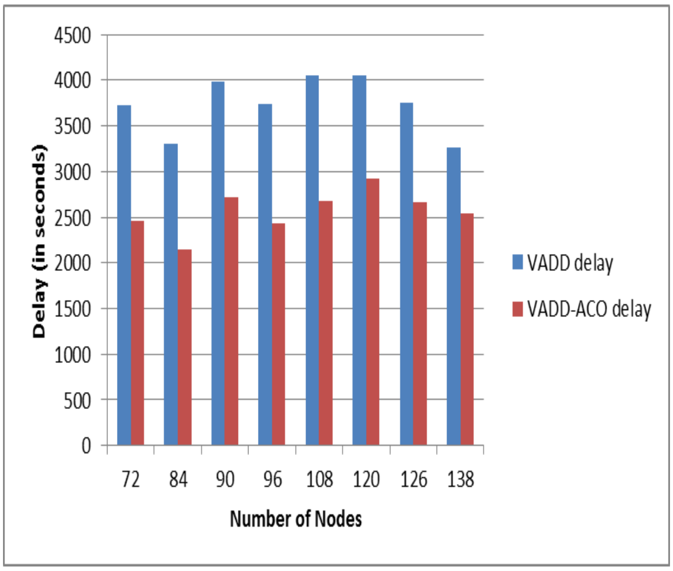

Figure 5. Delay analysis of both protocols

Figure 6. shows the analysis of throughput in both the protocols. Throughput here is almost the same in both the protocols. It is because though we have succeeded in decreasing the retransmission time but the actual time taken to reach the destination is almost same. It is because of the time taken for the path calculation in VADD-ACO.

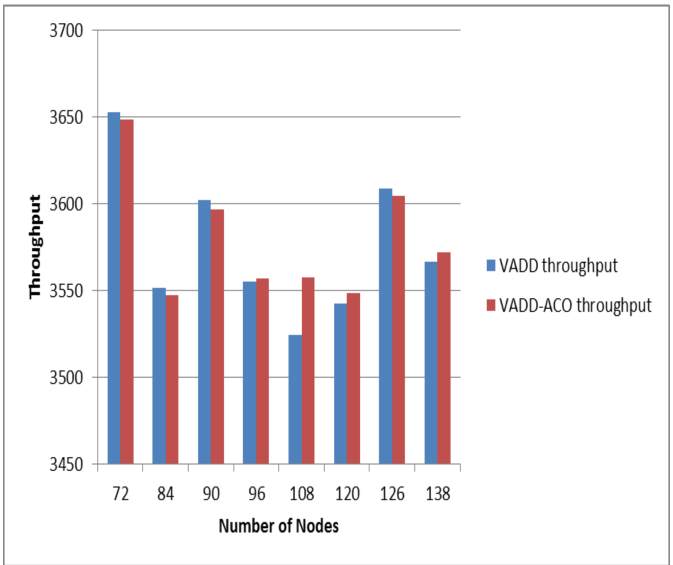

Figure 6. Throughput analysis of both protocols

Following figure 7. displays the analysis of delivery probability in both the protocols. It can be seen that the chances of a packet to reach destination is more in case of VADD-ACO for the same reason as delay i.e. the number of drop packets are less in case of VADD-ACO.

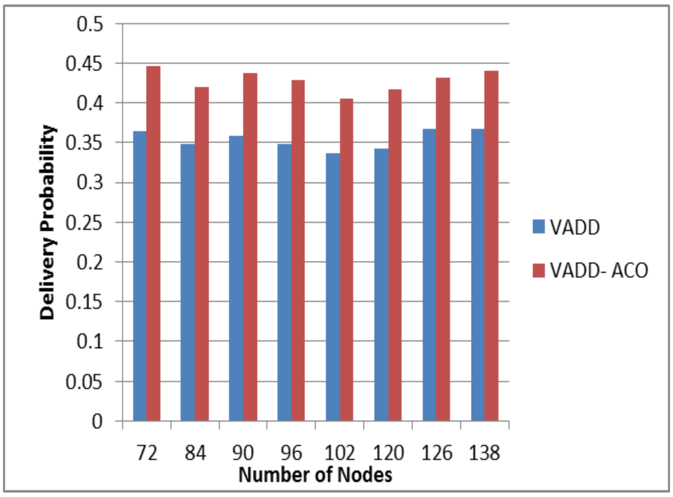

Figure 7. Delivery probability analysis of both protocols

So from the results we can see that VADD-ACO performs 8% -10 % better than VADD in terms of delay and delivery probability. But in throughput VADD-ACO performs 2% - 4 % better than VADD in few cases only. The throughput can be further taken as a challenge in future research. It can be increased and analyzed by using a hybrid approach of various meta-heuristic techniques.

VII. CONCLUSION AND FUTURE SCOPE

Many researchers believe that the cost exercised on deploying a VANET network should be justified. That means, for the factors the VANET network is deployed which are providing road safety and other commercial application should be effective enough. Most protocols work well for dense environment. But there is a challenge in sparse network where the end to end connectivity does not always exist. Most protocols solve this problem by deploying extra infrastructure which eventually further increases cost. Also, it may be the case that the extra infrastructure cannot be deployed in those areas. So in our research we developed a protocol to work for sparse network without using extra infrastructure. Results show that VADD-ACO works better than VADD in terms of delay and delivery probability. Therefore VADD-ACO can prove to be effective and efficient in case of delay tolerant networks. Though the change in throughput is very less, but it can be included in future scope for this protocol.

The protocol can be further advanced to increase the throughput and decrease the overhead using various other techniques. Also, other meta-heuristic techniques can be combined with VADD and results can be compared to check which one works the best for delay tolerant network.

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