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A TIME-BASED APPROACH FOR SOLVING THE DYNAMIC PATH PROBLEM IN VANETS – AN EXTENSION OF ANT COLONY OPTIMIZATION

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Abstract

Over a decade, Vehicular Adhoc Networks (VANETS) has been evolved and the field of vehicular communication has become a promising area for potential research. The challenges vary from a vehicle to vehicle communication, an indication during the event of a collision, and to enhance the drive and passenger safety. This paper aims at improving the performance of VANETs in terms of capacity, size, topological changes and maintaining the shortest routes. A new scheme termed as Ant Queue Optimization Scheme (AQO) has been introduced by extending the traditional Ant Colony Optimization (ACO). The proposed Ant Queue Optimization Scheme combines both proactive and reactive mechanisms. Unlike the ACO, the AQO dynamically makes decision in choosing shortest best route in highly congested areas. Route selection is dynamic at each intersection irrespective of the size of the traffic. Encouraging results have been achieved in using the Ant Queue Optimization even at high vehicular density scenarios.

Keywords: Ant colony optimization (ACO), VANET, Traffic congestion, Swarm Intelligence, Dynamic path problem (DPP)

1. Introduction and Motivation

VANETS are a special type of wireless network where the vehicles act as nodes and they form a network among themselves. In a Vehicular Adhoc Network, the node exhibits dynamic nature with respect to mobility. Most of the VANETS uses Dedicated Short-Range Communication (DSRC) [1]. The model of a regular VANET consists of set of nodes and few Road side units (RSU). These RSU's are fixed at road side and they act as a communication medium between nodes. This kind of configuration is possible only in the cities where mobility of the vehicles is less and more number of RSU’s. This configuration becomes difficult if the mobility of the vehicles is high and less number of RSU’s. Hence if there are more vehicles in a network, the information passing would be difficult and in case of high congestion, the vehicles must take decision to change its route in an optimal way. Several real-time solutions have been raised to overcome this problem. These real-time solutions have been introduced in order to increase the fluency of the traffic [1].

In many situations the drivers and the passengers do not know the status of the route ahead of them. This leads to the problem of finding an optimal path to reach the destination [2]. Hence it will be helpful for the driver if traffic information is available to him for a desired destination beforehand. Services like Google Maps, Waze have found success in achieving them. They track the number of android mobile on the road which has its location enabled to identify the real-time traffic. This solution will work in places where there is more number of people who have an android device. The solution will not be suitable in rural areas of many developing countries. Hence it would be more beneficial to form a communication with the vehicles on the road and to send out information among a particular group of vehicles [2].

The Ant Colony Optimization (ACO) has been employed as a solution for the dynamic problem path as mentioned in [2-4]. According to ACO, the ants send information packets to its neighbouring ants in the form of pheromone packets. The upcoming ants receive this pheromone information to decide its next best route. To obtain the traffic condition of entire area, accurate traffic evaluations of each and every road segment has to be considered. A novel data dissemination technique called Ant Queue Optimization (AQO) based on the Ant Colony Optimization is discussed to solve the problem of dynamic path problem. The contribution of this paper is to provide an efficient optimization scheme which is a time efficient method for solving the dynamic path problem in VANETs. The rest of the article is organized as follows; Section 2 Related Work, Section 3 Ant Queue Optimization for Dynamic Path Problem (DPP), Section 4 Results and Discussion Section 5 Conclusion and Future Direction.

2. Related Work

In recent times technology and science has become more specific and there are so many solutions for optimization problems in which heuristic solutions are one among them [5]. Recently many researchers have started to use Ant Colony Optimization for solving many optimization problems such as finding the shortest path, routing protocols, scheduling, etc. [5]. Although there are many algorithms to solve optimization problems but not many algorithms perform well for solving large scale realistic optimization problems. Probably, only few were able to derive the theoretical values. The heuristic optimization methods could not always give a global optimum solution but it could give us a better or good solution which may be a local optimum and also heuristic solutions usually take less computational resources [5]. The Meta heuristic approach has many set of optimization schemes of which Ant Colony Optimization (ACO) algorithms is one among them. The Ant colony optimization scheme deals with the natural behaviour of ants. ACO is been used in many combinatorial optimization problems and it is also used to outperform other heuristics problems such as genetic algorithms. Therefore, there is a lot of scope for ACO algorithms in this particular field.

In the year 1995, Gambardella and Dorigo [6] first conducted a research on Travelling salesman problem (TSP) which is one of the applications of Ant Colony Optimization (ACO) meta heuristics. Gambardella and Dorigo have founded a similarity between TSP and the way the real ants try to make their efficient route in the process of finding their own food resources. So, it is first domain where ACO Meta heuristics was implemented. According to the theory of TSP, the objective is to find out the most optimal best route so that each and every node in a connected graph is visited at least once. The node visiting helps in making efficient route plan for both physical traffic and electronic traffic. The implementation of ACO is tested and compared with many other efficient algorithms such as Self Organising map (SOM), Simulated Annealing and Elastic Net. All the tests were performed on the same hardware configuration having a set of 40 nodes each. Experimental results as shown in [6] suggest that Ant Colony Optimization algorithm is a better approach when compared to all other heuristic approach. The ACO in its early stage of research has been proved to be an efficient method for all heuristic problems.

Farhanchi et al. [7] discussed the problem of identifying the shortest path in stochastic networks. The article also goes on to provide a new local heuristic approach considering the probabilistic nodes for the NP hard problem of finding the shortest path in the network. An arc length and arc length distribution functions are employed in many example scenarios. The approach considers independent random variables having various distributions. It also assumes the presence of each node to be probabilistic, which may not be the case in all scenarios. Luo et al. [8] introduced an improved ant colony optimization for the Travelling salesman problem. The approach uses three major components which are introducing random factor, elitist ants as well as a weakened strategy. Results have been portrayed with less convergence time and a satisfactory complexity.

Meta heuristics has many problems and several solutions have been found, out of which Racing algorithm is one of the techniques. This technique is applied for Meta heuristics. This method gives out the optimal solution or efficient solution with respect to time constraint. It is done by selecting the most possible efficient solution from a finite set of solutions. Most of the problems under Meta heuristic are best suited for repetitive problems. For example, consider travelling salesman problem where the best route is found out efficiently even though there is a repetition. In the previous work, each and every node in the network is visited at least once so that the best route is found out between source and destination. But visiting the nodes is not an important issue as it does not give the optimal solution. Instead the node which is visited more often is considered as an optimal solution.

The experimental results based on the ACO problem, two of the racing algorithms were compared out of which one is not suitable for multiple executions of t_n race and the other is suitable for t_b race and the results shows that F race gives the better optimum results. Working under multiple instances is a good step for any algorithm where time constraint is considered. Testing an instance would definitely lead to wastage of execution time and does not allow an algorithm to produce an optimal solution [9].

Tests were made on different samples in which three different algorithms were executed. The objective of the racing algorithms is to find out an optimal solution or a nearby optimal solution with respect to time constraint so that the results could be taken as the no. of possible instances left out in the solution space once the time period gets expired. The experimental results show that the F race has 7.9 optimal solutions, t_n race has 31.1 solutions and t_b race has 253.8 solutions which are left out after a period of time. The rest of the solutions were tested to find out which one to be removed next and F race were tested several times, i.e., 77.9 times which is more than the other algorithms. It is use to select an efficient algorithm that could discard the solutions much faster. The F race, an efficient ant colony optimization approach has reduced the solution space and hence it is proved that the F race approach is most efficient algorithm when compared to remaining two approaches. All the approaches have used the same hardware configuration. F race is considered as the bravest algorithm compared to the other two algorithms as it discards most of the solutions within a period of time [9].

3. Problem Formulation

The Objective of the articles is to improve the performance of the VANET using Ant Queue Optimization scheme (AQO). The article also compares the performance of Ant Colony Optimization (ACO) and Ant Queue Optimization (AQO) in terms of time. AQO is a route Optimization scheme which dynamically selects its next best shortest route. The working of the Ant Queue scheme would be similar to that of Ant Colony Optimization. In ACO, the forward ants send some information about the traffic route in the form of pheromone packet. The natural ant's exhibits the behaviour of releasing the pheromone which is a chemical substance and it gets evaporated after sometime. In technical terms the ants are nothing but the vehicles and these vehicles send their pheromone packet information to their later nodes in the same network. Based on the experience of the forward ants, the later ants would take decision at its next intersection of the road.

In case of high congestion, the ants may change its path and chooses the best optimal path. AQO also works in the same way but in addition to ACO, the AQO exhibits some efficient features. The main drawback in ACO is, only the later ants are getting benefited using the pheromone information sent by their previous ants. The forward ants though they know the information, they cannot use it because they have already crossed the road. So they lay their pheromones to notify their later ants. The drawback has been identified and rectified using AQO scheme.

Using Ant queue optimization (AQO) scheme all the ants are processed in the same way dynamically. The main advantage of AQO is that each and every ant in the network would get processed with the updated information about all of its neighbours. Unlike in ACO, not the later ants get updated information but also the previous ants would be able to communicate and get processed as fast as possible. This scheme decreases the time complexity for highly congested traffic roads.

The vehicular network is assumed to be a connected graph G as shown in Fig. 1 such that

$$G = (V, E) \tag{1}$$

where $V = (V_1, V_2, V_3, V_4, V_5, \ldots\ldots, V_n)$ is the set of vehicles/nodes on the road. E depicts the directed edges. The objective of the approach is to reduce the time for vehicles to reach from a particular source to destination. The approach takes into consideration the heavy traffic conditions in the particular route. The edge is represented with respect to the distance x_{ij} and traffic T_{ij}. Each route in the network is given as

$$R = a_{ij} \tag{2}$$

$$a_{ij} = \begin{cases} 1 \; if\ node\ i\ is\ visited\ first\ followed\ by\ node\ j \\ 0 \qquad\qquad\qquad\qquad\qquad\qquad otherwise \end{cases} \tag{3}$$

By considering the time taken, traffic and the distance the Total transit time of a particular route $T_r(R)$ for a route R can be calculated using Eq. (4)

$$T_r(R) = \sum_{i=1}^{K} \sum_{j=1}^{K} a_{ij} x_{ij} T_{ij} \tag{4}$$

where K denotes the road intersection. $T_r(R)$ constitutes the fitness function. The primary focus of the approach is to identify a route from source to destination with minimum transit time. For every iteration the fitness function is used to calculate a score or the available routes in the network as shown in Eq. (5)

$$Fitness\ Score \ = Min\big(T_r(R)\big) \tag{5}$$

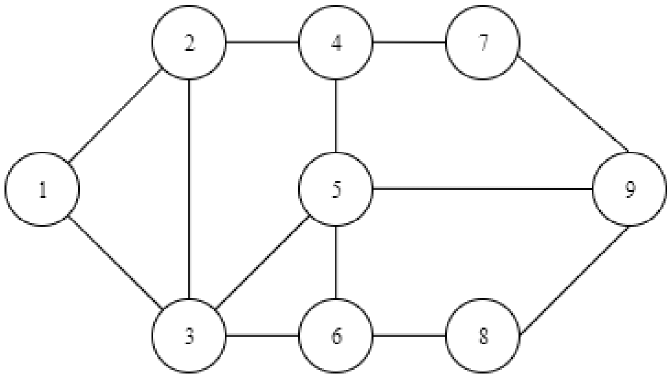

Fig 1. A sample connected graph.

4. Ant Queue Optimization for Dynamic Path Problem (DPP)

VANET is a network where vehicles transfer its route information to all its neighbouring nodes. In a large network, the most challenging part of the VANET is route discovery and information processing. The existing system uses Ant

Colony Optimization scheme for finding the best shortest route. Though the scheme was easy to implement and was a success, it too has many challenges in route discovery and information processing. In the process of searching food, the biological ant lays a pheromone packet. The following ants would understand whether there is food or not at that particular place and then they alter their path accordingly. Incorporating the same concept into VANETs, each vehicle is treated as an ant broadcasting some information very similar to how ants lay pheromone. In Ant Colony Optimization the ants lay pheromone packets which consist of route information, location information of the ants. Using that pheromone packet information the ants following gets updated but not the previous ones. This has become the main drawback of the ACO scheme. So in order to improve the performance of the VANET we opted for a better scheme than ACO called the Ant Queue Optimization (AQO).

First, an initial quantity of AQO which is a pheromone is laid on various edges and each and every ant performs its initial heuristics h_s to all its set of solutions s. Secondly, each and every ant s chooses its next heuristic h_s and then a cycle is defined. After sometime a pheromone is released by ants and the information is locally updated. At third step, all the ants have traversed throughout the graph and the shortest best routes are globally updated with the help of pheromone. These solutions are evaluated using a fitness function. This fitness function is used to compute the delayed reinforcement reward which refers to the additional quantity of pheromone laid only on the paths that have provided the best solutions. Finally, in the last step, if the end condition is not satisfied, the algorithm continues with other cycles.

Algorithm 1 Ant Queue Optimization for Dynamic Path Problem (DPP)

Initialization: For each edge (*i*,*j*) initialize pheromone for each ant *s*

Initialize the Destination

While Vehicle reaches destination **do**

Calculate the Fitness function using Eq. (4)

Update the Fitness Score based on Eq. (5)

End While

Compute the Transit Time T_r (*R*)

Identify the Minimum Fitness Score of all *R* in the network

5. Results and Discussion

The performance of Ant Queue Optimization scheme (AQO) is investigated and compared with Ant Colony Optimization (ACO). The experimental setup is done using ns2. The simulation scenario consists of 10 – 200 mobile nodes or vehicles and more details are given in the Table 1.

Figures 2 and 3 portray the result comparison between ACO and AQO in terms of the total number of vehicles in the network and the Time taken for the approach to identify a shortest path. When the number of vehicles is 10 in both the schemes the time taken to process all the vehicles using ACO is 4sec and AQO is also 4sec. But once the number of vehicles increases, the complexity in the network also increases. If the number of vehicles is 30, 50,70,100, 200 the time taken by ACO is 3,6,8,7,6 seconds and AQO took 3,4,4,3,4 seconds as shown in Table 2.

Table 1 Simulation parameters.

Parameters	**Specification**
Model Simulator	Ns2
Total number of Vehicles	100, 150, 200
Road Topology	8x8
Average Speed	30 km/h
Terminating Criteria	All cars to reach the destination

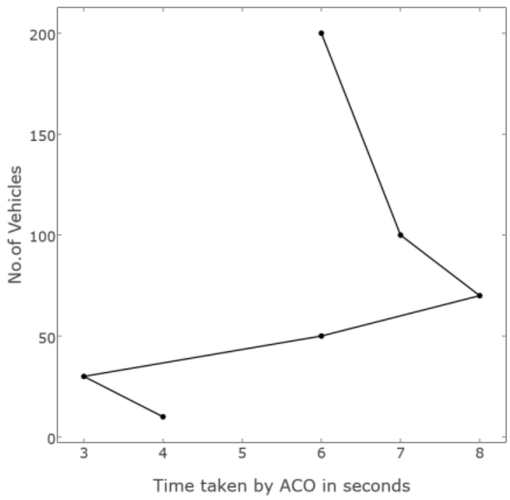

Fig. 2. Time taken by ACO.

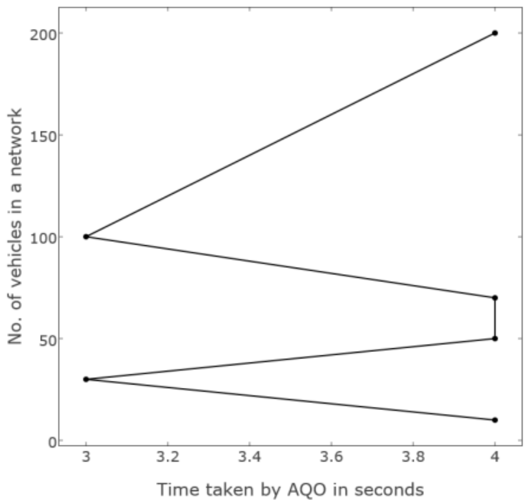

Fig. 3. Time taken by AQO.

On an average the time taken by ACO is 5.666 seconds and AQO is 3.666 seconds. Therefore, the experimental results show that the performance of AQO with respect to time is better than ACO.

Table 2. ACO and AQO result comparison.

No. of Vehicles in a Network	Time Taken by ACO in seconds	Time taken by AQO in seconds
10	4	4
30	3	3
50	6	4
70	8	4
100	7	3
200	6	4

6. Conclusions and Future Work

In this paper, a novel algorithm called Ant Queue Optimization (AQO) which is an extension of Ant colony optimization algorithm is proposed. ACO is a Meta heuristic approach which is based on natural behaviour of the real ants. The real ants in search of food lay a pheromone packet which is an indication of path to rest of the ants. But the drawback in this approach is only the later ants get to know about the path information correctly whereas the previous ants don't get it. This problem is rectified by AQO which acts dynamically in choosing the best optimal paths. The AQO could process each and every ant or vehicle within the network. Several experiments have been carried out to compare ACO and AQO with several set of vehicles, i.e., 10, 30, 50, 70, 100,200. Time taken to process all these set of vehicles has been recorded. The experimental results show that the AQO has taken less time to process all the vehicles within a given network when compared to ACO. In this paper, the experiments are carried out within the same cluster but in future work, there is a lot of scope for AQO in working with the different clusters.

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