An Efficient Routing Algorithm based on Ant Colony Optimisation for VANETs

Santanu Majumdar, Shivashankar, Rajendra Prasad P, Santosh Kumar S, Sunil Kumar K N

***Abstract*—The Vehicular Ad Hoc Networks (VANET), which are essentially the subset of Mobile Ad Hoc Networks (MANET) have been focused in the recent years mainly for the research and development of the Intelligent Transport Systems having the ability for both self-management and also self-organization, making them reliable as a highly mobile network system Also, the disconnection of such high mobile nodes will be a problem in VANET structure, where the loss of information will be critical because the vehicles/nodes in a VANET can move at a speed of 300 km/h or 186.41 miles/h. The protocols suggested earlier used a fixed topology for the mobile nodes in VANET. Even though the scientists had proposed different algorithms like beaconing, greedy or moving directional approach, the environmental changes were ignored which usually play an important criterion in regulation of information. In this paper, we propose a bio-inspired meta-heuristic and mathematically probabilistic technique of the Ant Colony Optimization (ACO) where efficient path establishment and information transfer can be achieved. Path availability and the delay time have been used for the evaluation of discovered paths. But, here the real time environmental changes were taken into account and the performance was measured in accordance with ACO. The technical software for VANET implementation using modifications in the ACO was implemented in the Matrix Laboratory (MATLAB)-2015b simulator along with the different randomized changes in environmental conditions.The random movements of the ants have displayed an efficient means for the delivery of packets to the maximum number of available nodes/vehicles in the network with verylow latency. So that even if accidental failure of any node occurs, the surrounding ant neighbors will carry the required information to the desired nodes resulting in improvement of the throughput. Thus, the results obtained through various environmental modifications indicated that the use of randomized ACO algorithmfor a highly mobile VANET system offers a much higher performance as compared to other earlier suggested on demand methods and can be realized commercially. Hence, this project tries to become a state of art technology for the benefit of society and the country.**

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I. INTRODUCTION

The Vehicular Ad Hoc Network (VANET) forms essential parts of the Intelligent transport System (ITS) and iscommercially important for inter-vehicular communication. The superset of VANET is the Mobile Ad Hoc Network (MANET) which is basically an infrastructure-less topological network following different routing protocols. The VANET topology is infrastructure-less because they do not have access points or any fixed structures like we normally have for GSM, WiFi and so on. This new technology allows the inter-vehicular communication for monitoring an environment remotely with necessary features for reduction of energy which though is a secondary factor for VANET topology, as the route establishment is the primary factor which needs to be focused for VANETs.

The VANET can be thus used for broad variations of applications such as the safety of vehicles on the road, the traffic management, completely automatic toll payment machines, enhanced location based services, military road tactics and many more of them. In case of the surplus consumption of power by the distributed nodes are the limitation factors for network expansion, whereas in the case of VANETs the energy is delivered from car battery having vast power storage in the form of car batteries, thus making them more efficient in case of power consumption. For inter-vehicular communication, mostly the multi-hop principle with either the broadcast or flooding is used for the data transfer to a group of receivers. Usually the broadcasting methods may have two types. The first type enables the nodes/vehicles to broadcast the required information periodically and can be at regular intervals. So that if any messages from the cars at the behind arrives, it can be ignored as the routing table would already have the message which was broadcasted earlier to the nodes from front to the back.

But the limitation of the above mentioned method is that the delivery times are increased, thus systems may experience stalls and other problems. But, in the case of another methodology, if the message received from the nodes at the back is same as that beaconed earlier, then the system stops sending the message periodically assuming that the nodes at the rear ends would have received the message and will have the responsibility of transmitting the information afterwards. Thus, all the aspects of VANETs are being researched and are experimented and are invested upon. The United States (US), Japan and the European Union are developing the VANET system under public safety program, for the reduction of road fatalities and for increasing the efficiency of traffic flows. The wireless infrastructure focused mainly on the Media Access Control (MAC) protocol with the standardization of IEEE 802.11p [1] and Dedicated Short Range Communications (DSRC), supporting the Internet Protocol version 6 (IPv6) protocols.

The forthcoming of these advanced protocols enabled the Vehicular technology for avoiding vehicular crashes. Thus, the algorithms suggested in this project would contribute for public safety and to prevent the driver from getting distracted in all environmental and physical conditions and to provide accelerated development in the field of VANET. The VANET system not only supports inter-vehicular or vehicle to vehicle communication but also vehicle to infrastructure and vehicle to broadband connections. In case of vehicle to vehicle communication the driver directly gets environmental conditions and weather updates, which can be at both local and global levels.

For more advanced conditions, the aim for reduction in fuel consumption, acceleration and other scenarios can be suggested to the driver in real time. Whereas, in vehicle to broadband communication, the vehicles achieve communication through the wireless mechanisms such as 3G/4G or 5G in future. More efficient information sharing mechanism can perform global operations.

Thus the VANET protocols, energy scenario and security protocols are always updating. Therefore, a fixed protocol for VANET application is difficult to implement. Also, the military of few countries are looking ahead for research in VANET applications because of their importance in the Unmanned Ground Vehicles (UGV), so that in low visibility conditions such as foggy weather or hurricanes, the vehicle mounted personnel or the UGV would be able to avoid collisions in their path and could destroy the target with lesser ammunition and fuel consumption. The VANET also imprints an idea of future unmanned vehicles, requiring no drives where the passenger can take rest without the accident of vehicle. In this project we suggest a technique based on Ant Colony Optimization, with few modifications is suggested, which tries to implement and improve the VANET protocol in a positive direction.

II. RELATED WORK

Vehicular Ad Hoc Network (VANET) has many protocols classified under proactive and reactive category. In case of proactive protocols, the information about the nodes encountered is kept in the form of a table. But with a limitation that the paths which are not used for transmitting is also kept in the memory thereby occupying a large portion of bandwidth. But in the case of reactive or on-demand protocols, the route discovery will be initiated when a node needs to communicate with another node in the network, thus reducing the traffic and the network bandwidth.

So, one of the reactive protocols is the Temporally Ordered Routing Protocol (TORA) [2], which is a highly adaptive and on demand distributed protocol, which has the basis of the link reversal methodology for work function. The authors tried to combine the same with the ACO. The intention of the author was on the Quality of Service (QoS) constraints such as energy, bandwidth and other parameters such as delay and the delivery rate.

They performed route discovery and route maintenance for the highly mobile nodes of VANET. They noted that their methodology is more suitable for the parameters concerning the energy constraints, with the increase of throughput. But the disadvantage of their scheme was that even though the protocol was performing good for dense networks, the network in itself was not scalable and also other protocols for example protocols like the Ad Hoc On-Demand Distance Vector Routing (AODV), which performs better than TORA for VANET applications.

The Moving Directions and Destination Location Based Routing Algorithm (MEDAL) [3] support the inter-vehicular communication by sending a Beacon message for the updating of the routing table information in the buffer heads. The movement and direction of the mobile nodes is considered when transmitting the data vehicle which would be closer to and is moving along in the same direction as that of the destination vehicle is selected for the transmission of the information. The MEDAL technique has shown its effectiveness in forwarding of data packets for an urban scenario. But with the limitation that it does not perform well for other scenarios and sometimes the destination vehicle may receive the data late due to packet latency.

Chuka Oham, *et al*. [4], suggested a congestion control mechanism for VANETs. Their suggested work was to increase the message delivery rate for increasing the driver awareness on road for prevention of the road accidents. With the help of Opportunistic Networking Environment (ONE) simulator, they implemented a new congestion aware algorithm for controlling the congestion and the associated confusion in a network.

And therefore, their protocol performed efficiently as the message drop rates were significantly reduced. Their protocol was working first on check phase where the buffer is checked for any sort of information. Then in the spray phase, the nodes except for the destination are send messages. In case of wait phase, the nodes transfer the data directly to the destination node.

Ozan Tonguz, et al. [5], first suggested the advantage of using the broadcasting method over other methodologies. They used local transmission or connectivity for transmission of information under three conditions, namely the dense traffic, the regular traffic and the sparse traffic. In the dense traffic scenario, excessive broadcast messages are shared by the cars. But, due to this the collisions between the data packets will occur. For reducing this, they suggested the use of probabilistic persistence scheme for this scenario, with the limitation that the total packets delay was seen to increase in this case. In case of sparse scenario, they suggested that by using DSRC methodology the vehicle could store the information and pass it to other nodes, but with the limitation that the consumption of bandwidth will be more for this case.

The mobility aware [6] based principle supports the use age of ACO technology for the VANET taking into account the position and speed of the respective vehicle. They proposed a method where the paths of the pheromone trial and evaporation rate are considered for path discovery. The scenario evaluated by them is the urban type, combine intelligently with Dynamic MANET on Demand (DYMO) protocol and was seen to perform better than pure DYMO for VANET applications, as the throughput and the packet delivery ratio was higher compared to earlier suggested protocols like AODV.

III. ANT COLONY OPTIMISATION

Ant colony optimization is critically and is proved to be a meta-heuristic algorithm and is probabilistic in nature. It is a bio-inspired algorithm and does not follow the commonly used centralized controlled mechanism for problem solving which is based on real ant colony structure and their moving mechanisms.

Meta-heuristic algorithm signifies that a user defined particular optimization technique or solution can be applied to any problem with slight modifications. A simple example could be addition of two numbers. Here the addition operation is the algorithm which remains the same, but the numbers or operands for the given operation can be changed. The ACO uses a large or small number of complex set of iterations using the natural behavior of real time ants for solving the problem. The ants normally travel along the path having the highest pheromone concentration, where pheromones are the hormones secreted by the ants when they are moving along a path and can be sensed by other ants, which may be the same colony, the ally colony or even the enemy colony.The ants in the system or colony move randomly from one node 'x' to another node 'y' with the probability [7],

$$P_{x,y} = \frac{(t_{x,y}^{a}) \cdot (c_{x,y}^{b})}{\sum (t_{x,y}^{a}) \cdot (c_{x,y}^{b})} \qquad (1)$$

Where,

'$t_{x,y}$' is the pheromone concentration which is being deposited at edge x,y.

'$c_{x,y}$' is the user defined parameter which defines the effective desirability for the path x,y.

'a' and 'b' are the user defined parameters for controlling the real time proportionate values for $t_{x,y}$and $c_{x,y}$respectively.

Thus, the pheromone trials can be updated after each iteration after the ants have successfully finished a proper solution or tour by the formula,

$$t_{x,y}(t) = [e \cdot t_{x,y}\ (t-1)] + \Delta t_{x,y} \qquad (2)$$

Where,

'$\Delta t_{x,y}$' is the sum of the moves orthe contribution of the artificial ants for constructing the entire solution.

'e' is the pheromone evaporation coefficient and is user defined whose values lie between 0 and 1.

Thus, from the above equation it is clear that after the iteration, part of the pheromone trail can get evaporated and the process will be further iterated. So, the global routing will be more effective in the ACO, as it will avoid the delay time by focusing search in the neighborhood for the best route to follow up the trail. Therefore, the artificial ants in ACO use the proportional rule, where the probability of an ant moving from node x to node y depends upon any random variable 'z' which would be uniformly distributed over [0, 1]. Thus, the inherent parallelism in ACO makes it favorable for obtaining faster feedbacks and thereby choosing optimal path for reaching destination, not only for VANETs but also for other problems. The last evaporation phase will be formed by updating of the pheromone from the initial construction phase.

Every time when the ants move from one path to the next one, the pheromone associated with that path will surely change. It should be seen that the updating mechanism should prevent the hazardous and undesirable situation of stagnation. It arises when the pheromone updating is discontinued due to some errors and the ants will repeatedly construct the same solutions without searching for other routes. Hence, the ACO algorithm could be applied for the vehicle routing issues where the main objective will be to find optimal paths for reduction of the overall delay of ACO system and other constraints that should be able to overcome with this algorithm for benefit of VANET systems.

IV. PROPOSED WORK

The advantages of the bio-inspired Ant Colony Optimization technique are utilized for that benefit of inter-vehicular communication.The presence of multiple protocols for vehicular networks make it complicated for selecting only a single protocol for the same. The earlier suggested works either focused on increasing throughput or saving the energy of the system. But here we focused on the reception of the information to the destination vehicle.

The commonly seen drawbacks of the previously suggested was either high latency or the data was unable to reach the destination because of very high mobility nature of the real time VANET system.

Thus, we suggested a bio-inspired technique of ACO, which employs the use of artificial ants and the artificial neighbors. The pheromone evaporation and re-deposition was given a high priority, so that no circular loop dependencies would affect the system and therefore avoid the same path they travelled earlier. This improves the discovery of new routes in the ACO algorithm.

The simulation is entirely performed on MATLAB-2015b simulator. The artificial ants and its neighbors are randomized such that even if a failure at any node occurs it will not result in a catastrophic failure. Instead the system will carry forward the information to the immediate neighbor with selection of a different path and from there the information will be received by the destination without any packet loss.

V. RESULTS

The results for the proposed efficient algorithm have been obtained from the MATLAB-2015b simulator.

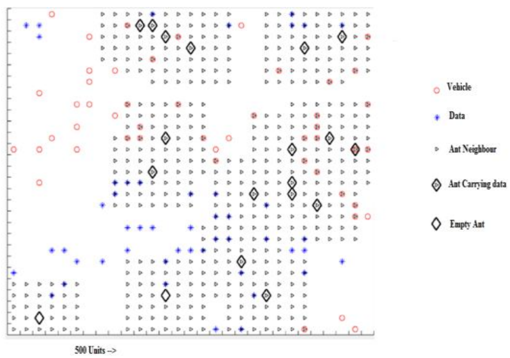

Fig.1: Ant colony implementation in MATLAB-2015b.

Figure-1 shows the distribution of packets in the VANET system which are carried forward by the artificial ants and their neighbors that are randomly distributed over the network. The vehicular movement and their speed have also been randomized so that the results will be accurate for both urban and rural scenarios.

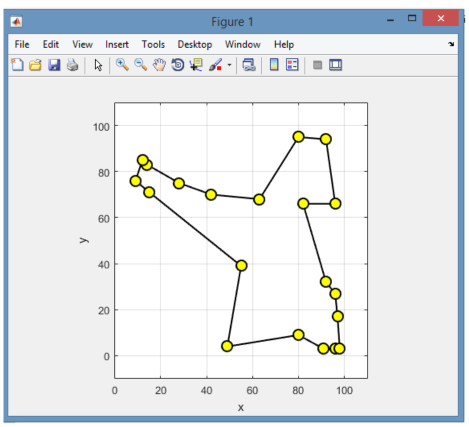

Fig.2: Routing in VANET system with prescribed ACO.

Figure-2 gives a description of the routing in VANET system using the proposed ACO algorithm. The routing is randomized and selects optimal paths without much loss of data packets enabling shortest path selection. It shows the optimal choice of nodes for transmission of data from a number of nodes.

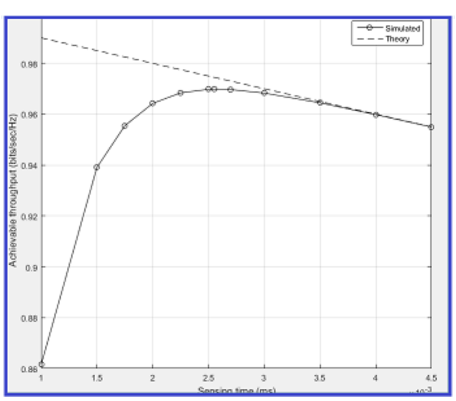

Fig.3:Throughput measurement in the defined route .

Figure-3 shows the throughput measurement in the above defined route for the prescribed algorithm for the simulated environment which is measured across time. The throughput varies differently for various algorithms. In this project the throughput achieved was higher than the previously suggested methods, suggesting that this algorithm is highly compatible with VANET systems.

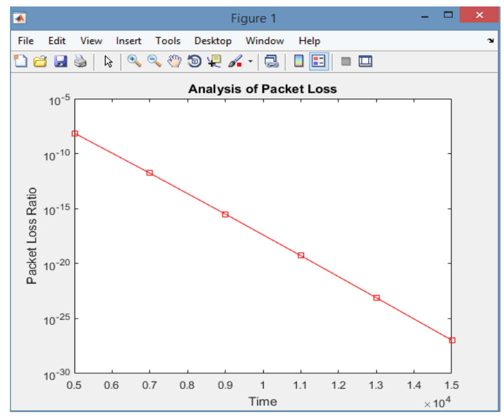

Fig.4: The Packet loss analysis for prescribed ACO model.

Figure-4 displays the graph for analysis of the packet loss obtained with simulation of the ACO algorithm, suggesting the high reduction in loss of packets with time. Initially the loss of packets is high which in turn reduces with time, thereby increasing the overall efficiency of the suggested ACO algorithm. This proves the conclusion that the reduction in the delay time with increase in efficiency is successfully achieved.

VI. CONCLUSION

In this paper, the advantages of the bio-inspired Ant Colony Optimization technique are utilized for that benefit of inter-vehicular communication. The suggested protocol has been seen to overcome the limitations of the previous protocol and increase the packet delivery ratio and reduce the overall latency, considering the real time environmental changes. Parameters used for discovering new paths are the pheromone concentration, its evaporation rate and along with the path availability and delay time. The simulation environment is the MATLAB-2015b simulator.

The randomization of the artificial ants increased the throughput for ACO algorithm and was seen to perform better than the previously suggested algorithms as the number of packets dropped or lost has been significantly reduced. Even if there is an accidental failure of any node or disconnection between them, the randomization of artificial ants clearly displayed that the information which needs to be reached at the destination will be carried forward, thus ensuring no loss of data. The results clearly concluded that the efficiency in finding the optimal route for reduction of the overall delay time in the network has been determined; with the reduction of the energy consumption even though it is the secondary factor of consideration in VANET has been realized successfully. Hence, this project tries to improve the future of the Intelligent Transport System and can be invested upon for the purpose of VANET routing.

For the future work on this project, we can try to improve the throughput and delivery ratio with high reduction in latency. More reduction in the network overhead can be further reduced with hybridization of ACO with newer algorithms, which would be compatible with VANET systems. The suggested algorithm hopes to become a universal communication method for all VANET applications. Also, if combined with Unmanned Ground Vehicle (UGV), it can produce significant benefit results for the military uses in counter terrorism without the use of actual defense personnel for combat situations.

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