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Auro: Adaptive Unicast Routing Framework for Vehicular Ad Hoc Network

Thandapany Sivakumar
Department of Computer Science,
School of Engineering and Technology,
Pondicherry University,
Pondicherry, India
e-mail: tsivakumar@yahoo.com

***Abstract*—** A special type of Mobile Ad hoc network (MANET) is Vehicular Ad hoc Network (VANET) and it provides exchange of messages between vehicles. VANET encourages researchers to create safety and comfort applications that will lead to Intelligent Transport Systems (ITS). Link failure in the routing path occurs due to frequent change in the network topology of VANET. To handle this situation, the routing protocol has to initiate either a local repair of route or find a route by broadcasting control overhead packets. This increases the network bandwidth utilization of the VANET. When the number of vehicles increase in VANET, broadcasting of redundant route repair packets increases the collisions in the medium leading to broadcasting storm problem. This paper proposes an Adaptive Unicast ROuting (AURO) framework to address frequent disconnections and broadcast storm problems in VANET. This framework selects suitable protocol from the three unicast routing protocols namely On-demand Proactive with Route Maintenance Protocol (ORPM), Efficient Reactive routing Protocol (ERP) and Stable Routing Protocol (SRP) from the network context and the user requirements. The proposed AURO framework is implemented using NS2 and SUMO simulators. The performance of these protocols were thoroughly analyzed and compared with existing popular protocols.
Keywords- *Minimum Connected Dominating Set of Vehicles, Vehicular Ad hoc Network, Unicast Routing and Framework.*

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I. Introduction

Vehicular Ad hoc NETwork (VANET) [1] enables communication among vehicles and Road Side Units (RSUs) [2] through wireless technology. Vehicles in VANET communicate using single hop or multi-hop communication [3]. In single hop communication, the source and destination vehicles communicate directly whereas in multi-hop communication, vehicles communicate using intermediate vehicles. VANET has lots of applications viz., safety, traffic efficiency, infotainment, etc. [4]. VANET is one of the important network options for Intelligent Transportation System (ITS) to avoid accidents and to manage the traffic of vehicles in an efficient manner. Figure 1 depicts a sample scenario of VANET.

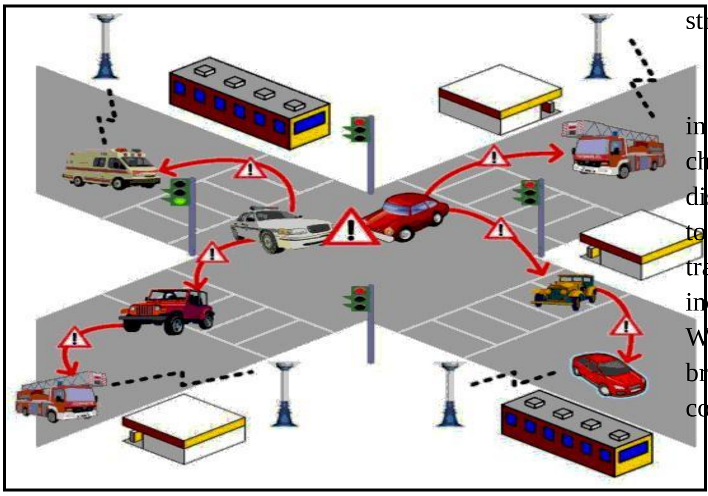

Figure 1. A sample VANET scenario.

VANET has distinct characteristics that differentiates it from MANET like high mobility [5], dynamic network topology [6], restricted mobility (road layout) [2], unlimited transmission power and higher computational capability. However, seamless connectivity, reliable routing, scalability and security [7,8] are the main challenges and these challenges need to be addressed for effective communication in VANET. Among these challenges, dynamic change of network topology of VANET makes routing of packets as a most challenging job. The main aim of routing protocol is to establish and maintain an optimal path between source and destination with less control packets [9]. Numerous unicast routing mechanism had been developed for VANET and they are categorized into many categories based on various parameters namely, techniques used, routing information, characteristics, network structures, routing algorithms, Quality of Services, etc., [10].

Most of the VANET protocols face frequent disconnection in routing path due to speed of the vehicles and dynamically changing topology, which leads to link failure and network disconnection. To handle this situation, the routing protocol has to initiate either a local repair of route or find another route by transmitting route request and route reply packets [11, 12]. This increases the network bandwidth utilization of the VANETs. When the number of the vehicles increase in VANET, broadcasting of redundant route repair packets increases the collisions in the medium lead to broadcasting storm problem.

This paper explores the possibility of enhancing the unicast routing protocols to address frequent disconnections and broadcast storm problems in VANET. This paper proposes an adaptive unicast routing framework for VANET to select a suitable protocol based on the network context and the user requirements. The proposed protocols were implemented using NS2 and SUMO simulators. The performance of these protocols were thoroughly analyzed and compared with existing popular protocols.

The remaining part of the paper is structured as explained below: Section 2 describes about the survey of related works in routing of VANETs. Section 3 explains about the proposed framework Adaptive Unicast ROuting (AURO) framework for vehicular ad hoc network. Section 4 explains about the new unicast routing protocol On-demand Proactive with Route Maintenance (OPRM). Section 5 describes about a new unicast routing algorithm called Efficient Reactive routing Protocol (ERP) for routing the packets. Section 6 explains about the Stable Routing Protocol (SRP). Section 7 explains about the mathematical model of AURO and section 8 concludes and proposing suggestion in the proposed framework as future enhancements.

II. Related Work

This section describes various unicast routing protocols for VANET existing in the literature. The unicast routing protocols in VANET are broadly classified into two categories viz., a) topology based unicast routing protocols and b) position (or) location based unicast routing protocols [13].

A. Topology Based Routing Protocols

Topology based routing protocols utilize link information to find the route between the source and destination vehicles to forward the packets. These protocols have two phases viz., a) route discovery phase and b) route recovery phase [14]. In route discovery phase, route request and route reply packets are utilized to find the routing path. In route recovery phase, route error packet is used to notify link error to the source or upstream vehicle and initiate finding an alternate route. Further, topology based unicast routing protocols are categorized into three categories viz., a) Proactive, b) Reactive and c) Hybrid routing protocols [14].

Proactive Routing Protocols

Proactive routing protocols are also known as table driven routing protocols in which the entire route information are stored in the table. Most of the proactive routing protocols are depending on the shortest path routing algorithm to find the routing paths. The routing information of a vehicle is communicated to the neighbors and the neighbor vehicles update the routing information in their table when there is a network topology change. The popular routing protocols of these types are Destination Sequenced Distance Vector (DSDV), Fish-eye State Routing (FSR), Optimized Link State Routing (OLSR) etc. The brief descriptions of these protocols are explained below.

In DSDV protocol [15], each vehicle broadcasts Hello messages periodically to its neighbor vehicles in order to maintain the latest routes in the routing table. In this protocol, distance vector strategy is implemented and Bellman Ford shortest path algorithm has been used to find the route. The limitation of this protocol is the wastage of bandwidth due to finding of unsolicited routes.

FSR routing protocol [16, 17] updates periodically its routing table information from its neighbor vehicles. FSR routing protocol uses Link State (LS) routing method to route the packets. LS keeps a map of topology in each vehicle. LS packets are created and broadcasted when there is an alteration in the topology. In FSR, vehicles keep a LS table constructed on the recent information obtained from neighbor vehicles and regularly exchange them with their neighbors. FSR efficiently scales for larger networks as the control packets are restricted in this protocol.

OLSR protocol [17] maintains a routing table by applying link state procedure. In OLSR, Multi-Point Relays (MPR) nodes transmit the packers and they are chosen by all the nodes. Since, MPRs only retransmits the packets the volume of retransmission is minimized. However, OLSR protocol frequently sends control packets to the neighbor vehicles which lead to network congestion.

Reactive Routing Protocols

Reactive routing protocols are also known as on demand routing protocols [18] as they find the route as and when required. Unlike the proactive routing protocol, the initial route discovery phase increases the end-to-end delay to find the route between source and destination as the routing table does not have entire route information. The popular reactive routing protocols are Dynamic Source Routing (DSR), Ad hoc On-demand Distance Vector (AODV), Ad hoc On-demand Multipath Distance Vector (AOMDV) etc. The brief descriptions of these protocols are detailed below.

DSR protocol [19] uses source routing method to route the packets. It reacts quickly to frequent changing network topology. In route discovery phase, it sends a route request packets to the neighbors to find the route. All the neighbor vehicles accept the route request and rebroadcast it again to find the route until it reaches the destination. Then destination vehicle sends route reply packets to the source vehicle after receiving the route request packet. Then the source vehicle receives reply message from the destination vehicle and stores in the routing table of the source vehicle. DSR uses source routing rather than relying on transitional node routing table. The drawback of DSR is the routing overhead increases while the network size increases when degrades the network performance.

AODV routing protocol [20] is an on-demand unicast routing protocol. AODV offers low network overhead compared to proactive routing protocols by reducing control packets flooding in the network. The AODV routing protocol allows self-starting and dynamic routing between the vehicles. It uses the idea of destination sequence numbers to remove loops in the routes and enhances the network utilization. AODV is suitable to large scale network and highly dynamic network topology. Nevertheless, it incurs a delay in a route discovery and route failure phase.

AOMDV routing protocol [21] is an extension of AODV protocols which find many routes during route discovery phase. In route discovery phase, it finds multiple routing paths between source and destination vehicles and stores them in the routing table. In route recovery phase, it first finds an alternate path in the routing table when there is a break in path. This mechanism makes it more efficient and provides uninterrupted communication between the communicating vehicles for data dissemination. It reduces control packets by minimizing frequent route discovery.

Hybrid Routing Protocols

Hybrid routing protocols combines the techniques and features [22] of the reactive and proactive routing protocols to route the packets. The best known hybrid routing protocols are Zone Routing Protocol (ZRP), Hybrid Ad hoc Routing Protocol (HARP) etc. The brief descriptions of these protocols are detailed below.

ZRP [23] is a hybrid routing protocol with proactive and reactive characteristics. It is created to increase the scalability and to minimize the control packets. This protocol splits the network into multiple zones of different size. In ZRP, proactive routing protocol mechanism has been used for intra-zone vehicles, a reactive routing protocol mechanism is used to route inter-zone vehicles. Nevertheless, the drawback of this protocol is high latency while finding new routes.

In HARP [24], the complete network has been broken down into non-intersecting zones and plans to establish a route which is stable from source to destination vehicles to reduce the delay in transmitting the data packets. Moreover, it executes route discovery process between the zones to restrict in the network and selects the best routing path based on the consistency features.

B. Position based routing protocols

Numerous position-based routing protocols [7] have been proposed for VANET to provide communication between vehicles. Geographic coordinates are known by using Global Position System (GPS) devices equipped with each and every vehicle and they are used to find the routes to route the packets.

From the survey conducted on the unicast routing protocols in VANETs, it is observed that there exists scope to develop unicast routing protocols and design a framework to integrate those unicast routing protocols.

III. Adaptive Unicast Routing Framework

A framework has been designed to integrate three unicast protocols namely On-demand Proactive with Route Maintenance Protocol (OPRM), Efficient Reactive routing Protocol (ERP) and Stable Reactive routing Protocol (SRP) and selects the best protocol based on the network context and user requirements. The input parameters namely number of vehicles, average speed of the vehicles have been derived from the network and delay requirement in delivery has been accepted from the users input it selects the best suitable protocol and route packets to the destination vehicles from the source vehicles. The three unicast routing protocols are briefly explained in the subsequent sections.

A. On-demand Proactive with Route Maintenance Protocol (OPRM)

The number of vehicles is less in sparse network which increases frequent disconnections in the route and makes route maintenance phase more complicated. A unicast routing protocol OPRM [25] has been proposed for such sparse VANET to address frequent disconnection problems. The OPRM routing protocol has two modules namely viz. discovery of route and the maintenance of route modules. The route request and route reply packets are used to find the route in the discovery of route phase. Route error, the Local Adjacency Matrix (LAM) and Squared Adjacency Matrix (SAM) are used to find another path with less delay when there is a link failure occurs in the route maintenance phase.

The LAM contains the network topology information. Every vehicle in the VANETs maintains its SAM by squaring the LAM and it gives two hop neighbors information. This information has been used in the route recovery phase to find an alternate path when there is a route failure and reduce the control overhead packets and average end-to-end delay.

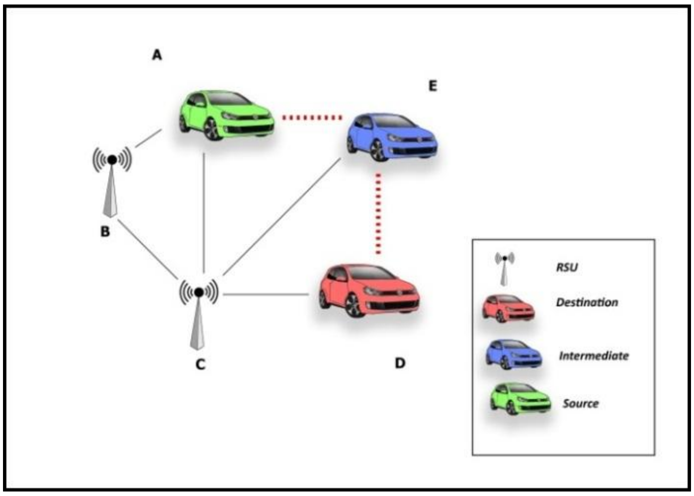

Figure 2. A road segment in rural area

B. *Efficient Reactive routing Protocol (ERP)*

In dense network, the number of vehicles is more and hence more control packets are needed for effective routing. Thus, a robust routing protocol which reduces the control packets is required in dense network. A routing protocol namely ERP for dense network has been developed to reduce the control packets. In the proposed protocol, the concept of Minimum Connected Dominant Set theory is used to group the vehicles into Minimum Connected Dominant Set of Vehicles (MCDSV) and non-MCDSV. The vehicles in the MCDSV are used to create a virtual backbone that connects all the vehicles in the network.

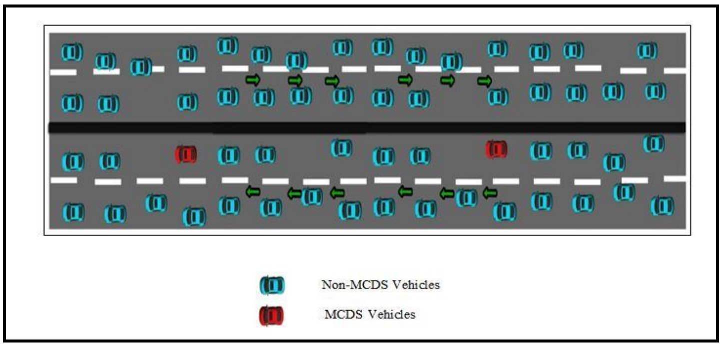

Figure 3. A road segment in urban area

In ERP, the route establishment and route maintenance phase use the vehicles in the MCDSV to rebroadcast the route request packets to establish the route. But, in the conventional routing protocols, all the vehicles in the network rebroadcast the control overhead packets for route establishment and route maintenance. Hence, the number of control overhead to find the route in the proposed protocol is drastically reduced compared to the conventional protocols. Further, ERP improves the bandwidth utilization by avoiding the broadcast storm problem. ERP protocol uses the Hello packets for creating the MCDSV without using any additional control packets. The proposed protocol is implemented using NS2 and SUMO simulators.

C. *Stable Reactive routing Protocol (SRP)*

To address the frequent disconnection and broadcast storm problems in VANET, a new unicast routing protocol SRP [26] has been proposed. It uses Reliability Index (RI) metric to calculate the reliability of the link of two vehicles. RI vector of the link between two vehicles is calculated using the formula explained in the equation (1).

$$RI(S,T) = \sum_{i=1}^{n-1} \mathrm{RI}\,(i, i+1) \qquad (1)$$

Where S and T are source and target vehicles
n – number of forwarder vehicles
RI (i , j) = { r, d, s }
i & j are the vehicles
r – range
d – direction of the vehicles
s – speed of the vehicles

To enable reliable routing, RI metric has been utilized to select the best route. The new protocol SRP has two modules, namely the discovery of route and the maintenance of route module. The discovery of route module utilizes the route request and route reply packets for find many paths between source and destination vehicles and stores them in the Sorted Route Table (SRT) and sort the routes based on RI metric. The maintenance of route module selects the subsequent route from the SRT when there is a link failure. Keeping multiple routes decreases the delay in finding an alternate path. This mechanism will increase the throughput, Packet Delivery Ratio (PDR) of the network and reduces the CO packets.

D. *AURO Framework*

Figure 4 depicts the proposed framework which integrates OPRM, ERP and SRP unicast routing protocols.

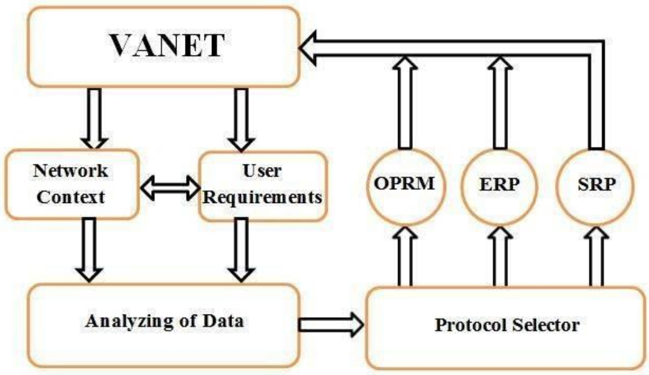

Figure 4: AURO framework for VANETs

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This framework gets input parameters namely number of vehicles (density, i.e., {low, medium, high}), average speed of the vehicles ({low, medium, high}) and delay requirement in delivery ({sensitive, non-sensitive}) from VANET and users. These inputs have been normalized and based on the normalized values of the input parameters, weighted average score is calculated using the formula depicted in the equation (2).

$$\text{Weighted Average Score } ø = \frac{\sum_{n=1}^{3} I_n * W(I_n)}{\sum_{n=1}^{3} W(I_n)} \qquad (2)$$

In the framework, Protocol Selector (PS) selects the protocol based on the weighted average score given in the equation (3).

$$\text{Protocol Selector (PS)} = \begin{cases} OPRM, 0 < ø \leq 35 \\ ERP,\ 35 < ø \leq 60 \\ SRP, 60 < ø \leq 100 \end{cases} \qquad (3)$$

This proposed framework has been simulated using NS2 by combining the OPRM, ERP and SRP unicast routing protocols. When the weighted average score (ø) of the network lies between 0 and 35, this framework selects the OPRM protocol to route the packets and implies that the VANET is a sparse network. When the weighted average score (ø) of the network lies between 36 and 60, this framework selects the ERP protocol to route the packets. It is found that it selects OPRM when the speed of the vehicles is high or number of the vehicles is low, selects ERP when the number of vehicles is high or speed of the vehicle is low otherwise selects SRP.

E. Simulation and Results

The proposed AURO framework has been simulated using NS2 and its performance has been compared with other protocols like AODV, DSDV and AOMDV due to non-availability of framework for routing protocol for VANETs. All the vehicles are configured with a wireless interface operating at a speed of 2 Mbps. The proposed AURO framework is evaluated and compared with the existing protocols using PDR, Average end-to-end delay (Average delay) and Control Overhead Ratio (COR) metrics. The effectiveness of the proposed protocol is demonstrated by running the simulation for 10 times and the mean values of PDR, COR and Average delay is considered for its performance evaluation.

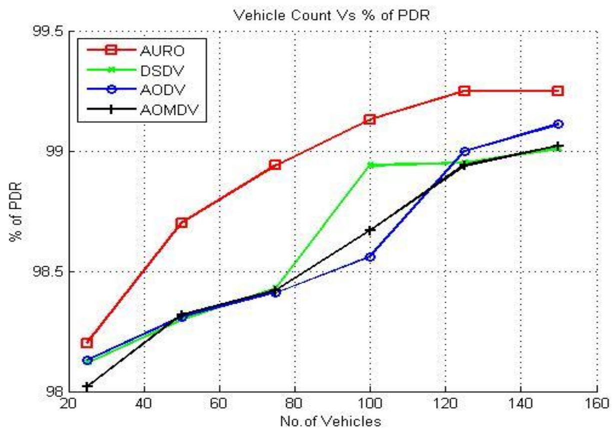

Figure 5. Effect of vehicle count on PDR in sparse network with high average speed

Figure 5 and Figure 6 show the PDR evaluated for different protocols by increasing the number of vehicles (vehicular density). The performance of Packet Delivery Ratio (PDR) of AURO is higher than other routing protocols.

Figure 7 and Figure 8 show the effect of number of vehicles on the COR in sparse and dense networks. Routing protocols like AODV, DSDV and AOMDV are using route request and route reply again when there is a break in routing path. The proposed framework protocol has lesser COR compared to other routing protocols due to flooding of packets for route discovery is controlled by selecting ERP routing protocol.

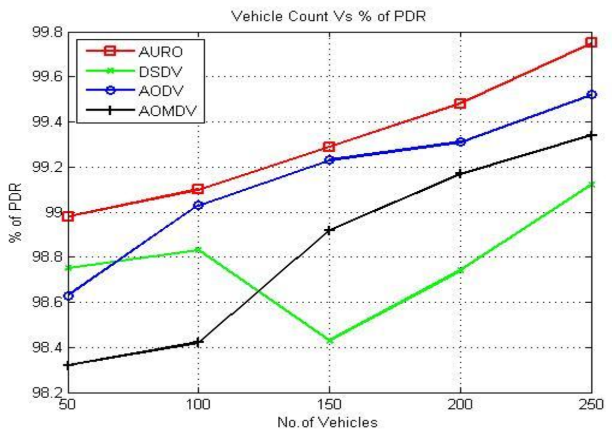

Figure 6. Effect of vehicle count on PDR in dense network with low average speed

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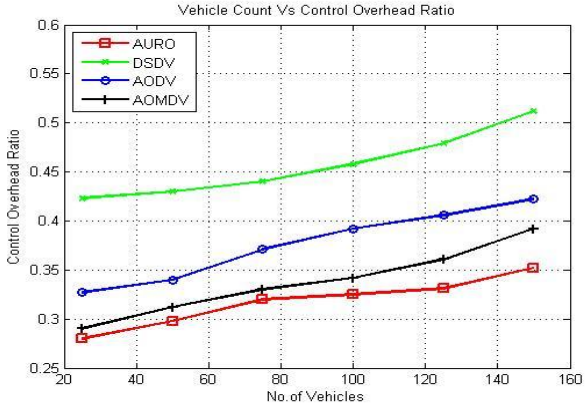

Figure 7. Effect of vehicle count on COR in sparse network with high average speed

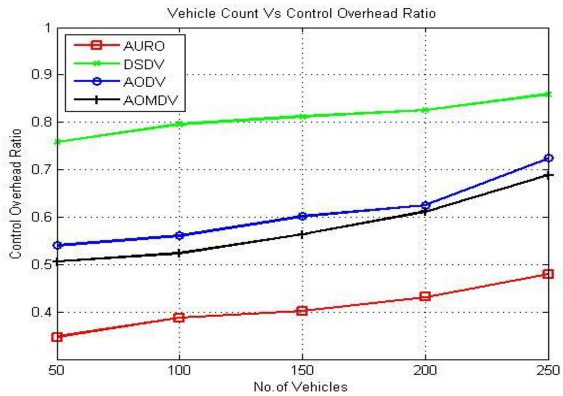

Figure 8. Effect of vehicle count on COR in dense network with low average speed

Figure 9 and Figure 10 show the effect of the number of vehicles on Average delay in sparse and dense network. Among the four, AURO framework achieves the best Average delay performance compared to other routing protocols due to better utilization of network bandwidth by avoiding unnecessary CO packets. Hence, the results of this proposed ERP routing protocol increases the PDR and decreases the COR and Average delay.

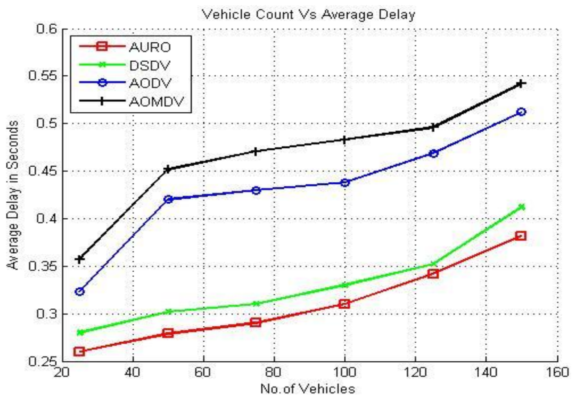

Figure 9. Effect of vehicle count on average delay with high average speed

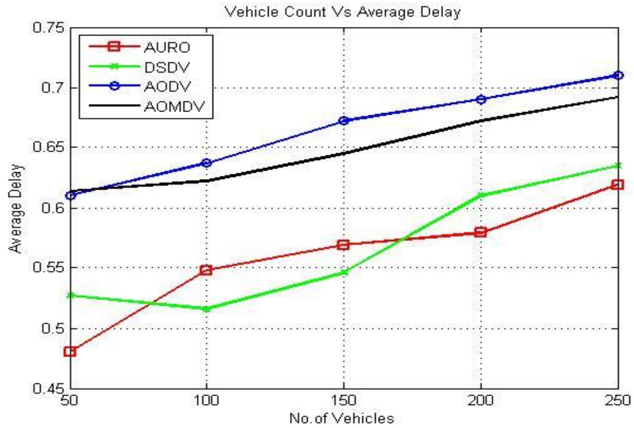

Figure 10. Effect of vehicle count on average delay with low average speed

IV. Conclusion and Future Enhancement

AURO framework for vehicular ad hoc network has been presented in detail in this paper. This framework is choosing a suitable routing protocol to find a route using network context and user requirements. This type of communications within the network eliminates the frequent disconnection and broadcast storm by selecting a suitable routing path or quick route maintenance process or avoiding unnecessary local broadcast of the packets in the network. The performance of this framework has been compared with other unicast routing protocols like AODV, DSR, DSDV and AOMDV in a highly dynamic environment through simulations. The simulation results show that framework provides about 10 to 12% improvement in the PDR and 12% to 15% decrease in Average delay and 15% to 40% decrease in COR compared to other unicast routing protocols in sparse and dense networks. The results indicate that framework is an efficient for selecting the unicast routing protocols for VANET. The Future Enhancement of this paper is to design and develop for multicast routing protocols and asses its performance in rural and dense scenarios.

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