DyTE: An Effective Routing Protocol for VANET in Urban Scenarios

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Abstract-A Vehicular Ad-hoc Network (VANET) is a subclass of wireless ad-hoc networks, widely used in on-road vehicles and roadside equipment, having applications in various areas including passenger safety, smart traffic solutions, and connectivity on vehicles The VANET is the backbone of the Intelligent Transport System (ITS) that establishes connectivity between vehicles through a wireless medium. When it comes to the communication between high-speed vehicles there is the challenge of dynamic mobility. In order to provide a higher Packet Delivery Ratio (PDR) and increase the throughput, a new routing protocol called Dynamic Trilateral Enrolment (DyTE) is introduced which chooses a dynamic trilateral zone to find the destination vehicle by allowing only relevant nodes to participate in the communication process using the location coordinates of the source and destination nodes. The proposed routing protocol is compared with Ad-hoc On-demand Distance Vector (AODV), Ad-hoc On-demand Multipath Distance Vector (AOMDV), and Dynamic Source Routing (DSR), and the results show a remarkable improvement in reducing the Network Routing Load (NRL) and in increasing the PDR and throughput of the network. DyTE has performed more efficiently in terms of PDR (23% approximately), throughput (26% approximately) and drastically minimized the NRL by a factor of almost 3.

Keywords-vehicular ad-hoc networks; location aided routing; trilateral zone; broadcast storm

I. INTRODUCTION

Vehicular Ad-hoc Networks (VANETs) are becoming quite popular because nowadays fast moving vehicles are able to communicate with each other and on-road equipment [1]. The network topology in a VANET changes rapidly as it consists of fast moving nodes. A VANET is considered to be an opposite option for the development of ITS [2]. A VANET is a specialized type of Mobile Ad-hoc Network (MANET), through which vehicular communication can take place in urban and highway scenarios. Many applications such as security, information services, accident alarm, road safety and traffic managements are associated with VANETs. The speed of the vehicle is the major factor which affects the communication process due to which rapid changes in network topology occur, so the selection of the intermediate vehicle is very crucial. A typical VANET scenario is depicted in Figure 1 where communication can take place between vehicle-to-vehicle (V-2-V), vehicle-to-infrastructure (V-2-I) and hybrid (either V-2-V or V-2-I) [3]. In a VANET, routing protocols are generalized in five categories [4]: Ad-hoc based, cluster-based, position-based, broadcast-based, and geocast-based routing. Position-based routing protocols use geographical coordinates from the Global Positioning System (GPS). They also use digital maps to obtain road information. Low overhead and its effectiveness for rapidly moving nodes are the key advantages of location-based routing protocols. Geocast-based routing protocols basically limit the area of transmission in a specific portion by identifying the next hop using the node's position. Information related to the position and speed of the node help to decrease overhead packets and to increase PDR [5].

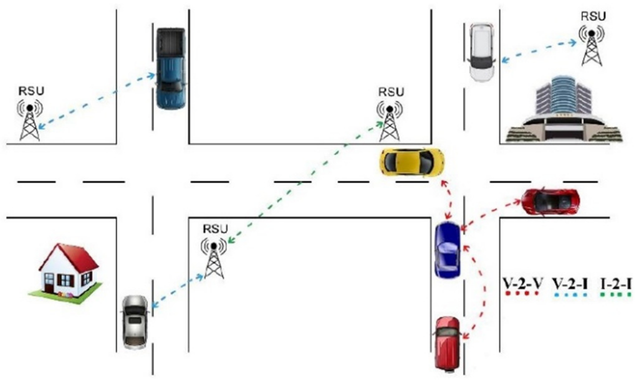

Fig. 1. A VANET scenario.

Location Aided Routing (LAR) is based on the exact GPS location of the destination node [6, 7]. In [8], an advancement of LAR that works on the principle of choosing next-hop with minimum angle difference to the straight line between source and destination node to reduce the packet overhead is reported. In [9], two strategies are opted for the transmission of packets while selecting the next-hop, greedy forwarding strategy chooses the closest node with respect to the destination and perimeter forwarding strategy is opted whenever the distance between the forwarding and the target node is closer than the distance to the destination of its neighbors. In [10], the lifespan of the node is calculated using the speed and position in order to get the time for the node's availability within the transmission range. Greedy Perimeter Coordinator Routing (GPCR) is also a position-based routing protocol which differs from the GPSR because it does not rely on the static global map [11].

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In DSR [12], a complete list of nodes in sequence is attached in the packet header therefore network overhead is increased. AODV [13] is a reactive and loop-free routing protocol which is still considered relevant [14-16]. An optimization in AODV is proposed in [17] by formulating route weight. The Improved AODV (IAODV) is proposed in [18] for dense networks and focuses on forwarding timely and accurate information to nodes by keeping a list of all one hop nodes as a backup route. Multiple routing path is accumulated during the route discovery phase by AOMDV [19] from source to destination node to get an uninterrupted communication in case of failure of the primary path. A variant of the AOMDV protocol is the Speed Direction AODV (SD-AODV) [20], in which the parameters of speed and direction are included in the hop count field during the process of route establishment. In [21], data transfer rate is optimized using Signal-to-Noise Ratio (SNR), improving link quality and minimizing energy consumption. A reactive routing protocol is proposed in [22] that minimizes the routing load by selecting reliable routes during the route discovery phase. An upgraded version of TORA was introduced in [23] where only highly reliable discovered links are used. In ERRRP [24], the disconnection of routes is minimized by the Reliability Factor (RF) which is based on Route Expiration Time (RET) and hop count. Higher RF value routes are selected as reliable paths. Roadside Service Discovery Protocol (RSDP) [25] proposed an application layer beaconing-based protocol to address the problem of service discovery upon request. Velocity-aided routing protocol [26] works on the principle of predicting the moving behavior of mobile nodes. The possible trajectory of the destination node is predicted on the basis of its position and velocity information and determines the packet forwarding region. The incorporation of mobility characteristics in the routing enhances its performance and makes it more adaptive.

Ant Colony Optimization (ACO) algorithms [27, 28] extract the optimal routing information by selecting the best available path among the available routes or by finding an alternate route in case of route failure. ACO algorithms successfully reduce link failures by applying the above strategies. An Improved Genetic Algorithm-based Route Optimization Technique (IGAROT) [29] is implemented by considering road anomalies resulting in prompt notification by road maintenance agencies of persistent road conditions through V2I communication. Using an iterative K-Means algorithm, IGAROT generates clusters into two non-overlapping groups and then updates the size of the successful cluster using likelihood metric in the initial population size. Overhead reduction was achieved in [30] by forwarding the location of the destination to every generated RREQ packet. Efficient Routing Protocol (ERP) [31] minimizes the unnecessary broadcast in the network by finding the minimum set of vehicles for backbone communication that act as forwarders and only those nodes will be having the responsibility to broadcast. Using the GPS system, the selection process of the next forwarding node is based on the lesser distance to destination node in GeOpps [32]. Due to network topology dependence, not every node is needed to calculate the optimal path.

A large number of RREQs leads to frequent change in topology, and thus impede the transmission of information packets. Also excessive requests might cause congestion and ultimately packet loss. In [33], efficiency is achieved by selecting a carrier group of vehicles to relay the data packet to the destination. This group maintains the vehicle information only in those streets that are indispensable in reaching the destination.

It is observed that the problem of broadcast storm during the route finding phase still needs to be addressed. Therefore, in order to address that issue a routing protocol is proposed in this paper which not only minimizes the routing overhead but also increases the efficiency of the overall network. The proposed routing protocol is influenced by the above mentioned protocols. It uses the vehicles' positions and limits the transmission in a specific zone. Extensive simulations have been carried out in the NS2 simulator. Node mobility has been generated by the Simulation of Urban MObility (SUMO) whereas real environment of the traffic was generated by OpenStreetMap.

II. THE PROPOSED ROUTING PROTOCOL

Much research has been being carried out to improve the efficiency of routing protocols in VANETs. Densely populated networks with excessive number of nodes and their scalability issue have drawn much attention. A novel approach is proposed in this work to increase throughput and PDR and to decrease the overhead packet count. The route discovery is initiated from the source by sending route request packets to all neighbors. The neighbor nodes subsequently forward the route request to their respective neighbors. The process continues until the packet reaches its destination. The route reply packet confirms the route establishment. In the proposed protocol, initially the source node generates a trilateral zone using the destination vehicle's last known position where the destination vehicle could reside and makes a list of nodes which lie inside that zone. Information about the list of nodes is added to the RREQ packet header which is sent to the neighbors. Each neighbor who receives the RREQ packet checks the list of nodes. If its information related to the trilateral membership is present in that list, then it can participate, otherwise the packet will be dropped. The receiving node checks whether the packet targets its own vehicle. If not, it then calculates a new trilateral zone using the updated position of the destination vehicle and adds that information in its new RREQ packet. The process continues until the destination node is reached. The proposed protocol avoids unnecessary RREQs, thus efficient usage of bandwidth is achieved during route discovery.

A. DyTE – The Algorithm

The proposed protocol (DyTE) combines the power of position-based routing and Geocast-based routing protocol because it uses the coordinates of the vehicles and limits the packet request in a limited trilateral zone. In Figure 2, an area is shown where the trilateral zone is extracted as a zone of interest and the remaining area (red colored) is excluded.

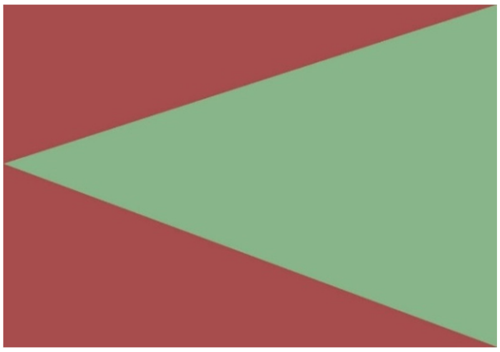

Fig. 2. A trilateral zone example.

The sequence of steps to be taken is (Figure 3):

- Get source and destination location through GPS.
- Calculate the trilateral zone where the broadcast of packets is going to be accepted.
- Add the list of nodes to the RREQ packet.
- Each node that receives the RREQ packet will examine the list to identify its trilateral zone's membership.
- Only if the receiving vehicle (destination/intermediate) lies within the trilateral zone, it can process it further. Else, the packet will be dropped.
- If the request received by a vehicle lies within the trilateral zone, it checks whether that packet was destined to it. If it does not, it will create a new list of trilateral zone's membership to forward the packet but with a newly calculated list of members.
- The above steps are repeated until the destination node is reached.

B. Creation of Trilateral Zone

When an intermediate node receives the request, it checks whether the packet is generated by its own vehicle in order to avoid looping. The request can be seen initially by every neighbor node that lies within the wireless transmission range but the RREQ packet header contains the special array field that consists of a list of nodes which are allowed to take part in the RREQ process. To create a trilateral zone, we used source and destination vehicle's GPS coordinates to find the slope (1) of the straight line between the source (S_x, S_y) and destination (D_x, D_y) vehicle.

$$m=\frac{\Delta y}{\Delta x}=\frac{D_y-S_y}{D_x-S_x} \quad (1)$$

The distance between source and destination nodes is calculated by (2):

$$dist=\sqrt{(D_x-S_x)^2+(D_y-S_y)^2} \quad (2)$$

After calculating the slope and distance, the perpendicular slope is calculated by (3):

$$m_{perpendicular}=-\frac{1}{m} \quad (3)$$

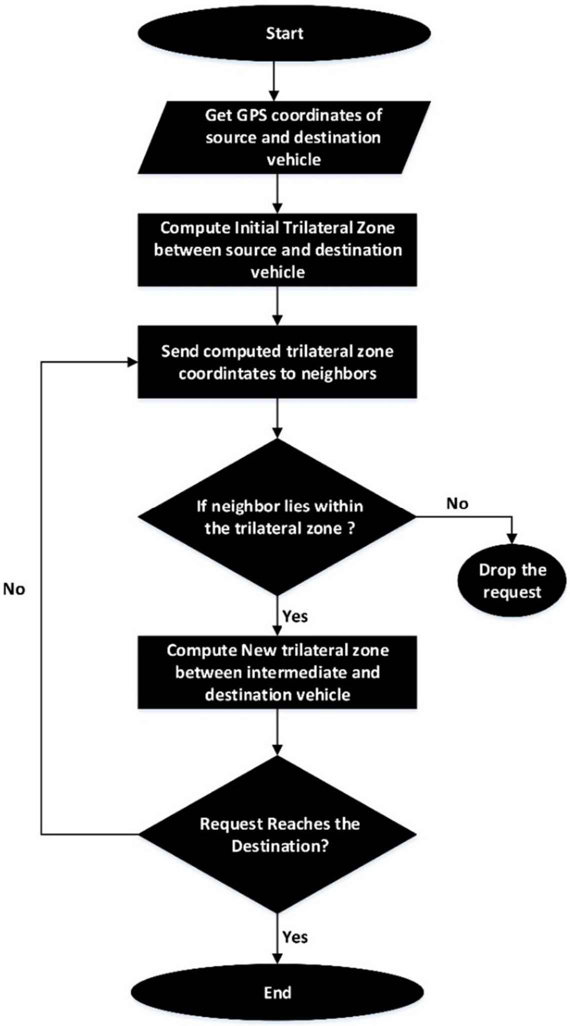

Fig. 3. Flowchart of the lgorithm.

C. Trilateral Enrolment Identification Process

The next step is to identify whether the receiving node exists within the trilateral zone. To find out that a given node can participate in RREQ flooding, consider the trilateral zone, as shown in Figure 4, where the coordinates of A, B, C and an arbitrary node P are given as (A_x , A_y), (B_x , B_y), (C_x , C_y) and (P_x , P_y) respectively. In order to allow the node to get the enrolment for the RREQ forwarding process, DyTE goes through calculating the area and sub areas for each node.

The area of the trilateral zone (Triangle ABC) as shown in Figure 4 is calculated by:

$$Area_{total}=\frac{|A_x\times(B_y-C_y)+B_x\times(C_y-A_y)+C_x\times(A_y-B_y)|}{2} \quad (4)$$

The sub area #1 of the trilateral zone (triangle PAB) is calculated by:

$$Sub_{Area1}=\frac{|A_x\times(B_y-P_y)+B_x\times(P_y-A_y)+P_x\times(A_y-B_y)|}{2} \quad (5)$$

The sub area #2 of the trilateral zone (triangle PBC) is calculated by:

$$Sub_{Area2} = \frac{|P_x \times (B_y - C_y) + B_x \times (C_y - P_y) + C_x \times (P_y - B_y)|}{2} \quad (6)$$

The sub area #3 of the trilateral zone (triangle PAC) is calculated by:

$$Sub_{Area3} = \frac{|A_x \times (P_y - C_y) + P_x \times (C_y - A_y) + C_x \times (A_y - P_y)|}{2} \quad (7)$$

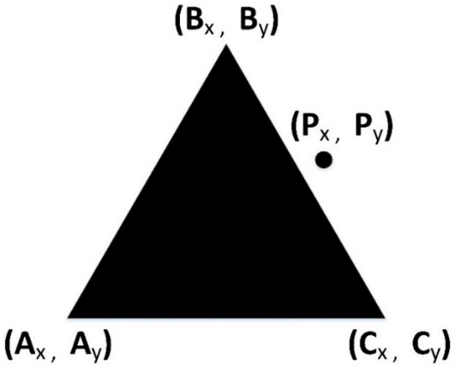

Fig. 4. Coordinates of a trilateral zone of an arbitrary point P.

D. Forwarding Path and Request / Reply Process in DyTE

Each participating node during the phase of RREQ discovery sets up a special entry called reverse route which contains the IP address of the source node, a sequence number along with hop counts to the source node, and the IP address of the neighbor from which the RREQ was obtained. Since no information should be kept in forever in the routing table, a timer variable called lifetime is associated with the reverse route so that if the route entry is not used for the specified allocated time, then the information will be wiped off from the table to minimize the routing overhead. Routing loops are handled by the sequence numbers with source node information in order to check the freshness of the RREQs of the unicasted response of the RREP back to the node. Broadcasting of a route request within a trilateral zone is permitted again only when an intermediate node gets out of contact, because disconnection of the intermediate node will make the destination node inaccessible. The RREP packet contains the information of the source and the IP address of the destination. If the destination node is able to reply, then it resets the hop count information and the sequence number and lifetime are also updated in the RREP packet. In case the intermediate node is able to reply, then the hop count will be updated as per the intermediate node's distance to the destination node along with the destination sequence number information and the time validity of routes is calculated within the routing table.

A forwarding path is stored in the routing table when the RREP packet is received by an intermediate node. This path entrance contains the neighbor's IP address from which the RREP is received, the IP address of the destination and the hop counts to the destination. To obtain the distance of the destination, the receiving node increases the value in the hop count by one and also associates this entry with the lifetime. The associated lifetime gets updated whenever the route is used and is deleted when the route is not used within the specified time limit. An RREP can be received from multiple neighbors for a similar destination. In that case the RREP which is received first will be considered and the alternative RREPs are only used if they contain information with smaller hop count or if the destination sequence number is greater to ensure quick and updated routing. In other words, after receiving the first RREP, the source node will begin the data transmission process and if it discovers, at a later stage, a better route, then the routing information will be updated and a different path will be taken for data transmission.

III. SIMULATION AND RESULTS

Network simulation was performed on NS-2 simulator [34]. For mobility simulation within urban environment, SUMO [35] was used. Figure 5(a) shows the simulation plot which is an original image containing a map portion of Karachi extracted from OpenStreetMap [36] whereas Figure 5(b) is the network animation within the NS-2 simulator and Figure 5(c) is the converted map using SUMO. The performance of the proposed protocol is compared with the performance of other popular routing protocols (AODV, AOMDV, and DSR). The metrics considered for comparison are PDR, network routing load (overhead), and throughput. To avoid the possibility of fluctuations in simulations, the presented results are the average of multiple simulations. The network is considered from moderate to highly-dense and random distribution of nodes was incorporated. The simulation parameters are given in Table I.

TABLE I. SIMULATION PARAMETERS

Parameter	Value
Mobility	Manhattan
Channel type	Wireless
Antenna	Omni directional
Model	Two ray ground
No. of vehicles	50, 100, 150, 200, 250
Simulation area	$2500 \times 2000m^2$
Simulation time	100s
Routing protocols	AODV, AOMDV, DSR, DyTE
Speed range	50–100Km/h
Transmission zone	250m
Connection type	UDP
Traffic type	CBR
Packet rate	4 per second

In Figure 6, the NRL is depicted which can be defined as the proportion between the number of packets generated by each node and the number of packets successfully transmitted to the destination nodes. Since only relevant packets are allowed to get transmitted over the network, improvement is achieved by the proposed DyTE protocol. Figure 7 represents the PDR which is defined as the ratio of data packets that are successfully received at the destination with the number of data packets generated at the source node. The nodes enrolled in the trilateral zone are the most favorable to transmit the request to the destination, therefore the results are improved. Figure 8 depicts the throughput of the network which is the cumulative number of packets transmitted successfully to the destination over the entire simulation. The comparison shows a direct relation between the number of nodes and the number of delivered packets to the destination node, reflecting a higher throughput.

(a) (b) (c)

Fig. 5. (a) The map of a part of Karachi, (b) Network animation in NS-2, (c) SUMO map conversion.

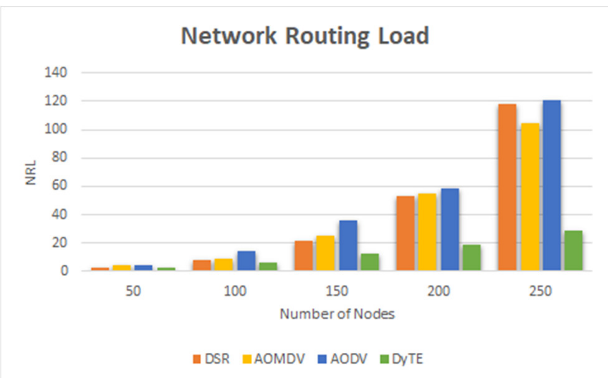

Fig. 6. NRL against node density.

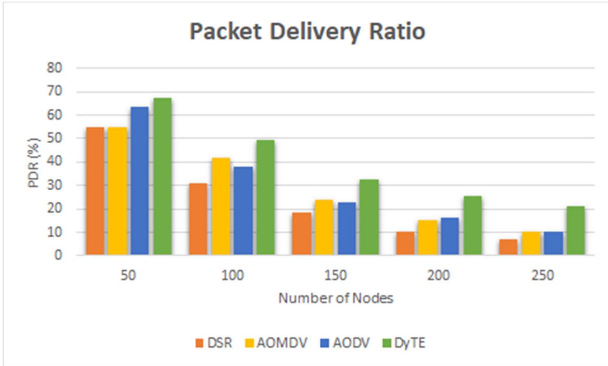

Fig. 7. PDR against node density.

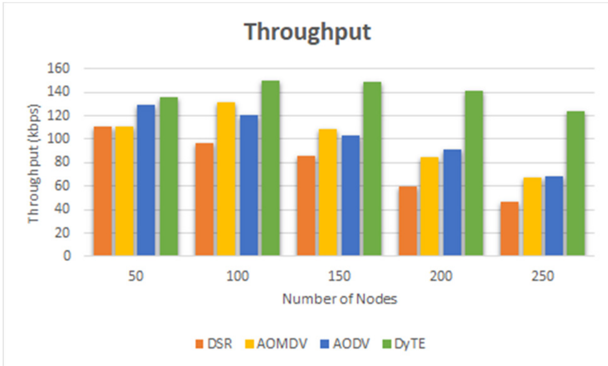

Fig. 8. Throughput against node density.

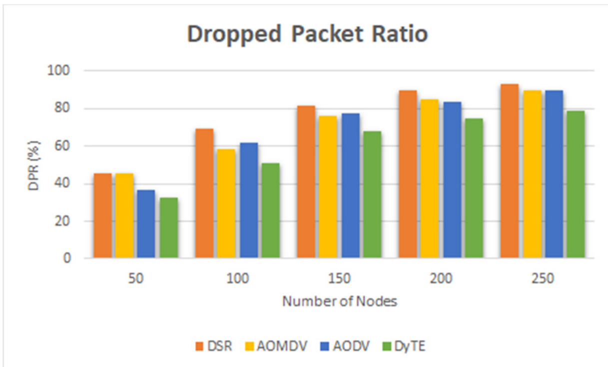

Fig. 9. Dropped packet ratio against node density.

Figure 9 shows the dropped packet ratio which is a reciprocal of PDR, since PDR is increased therefore it is quite understandable that the dropped packet ratio is decreased. The request packets are controlled before sending the actual data to minimize the unnecessary overhead. It is conclusive that minimizing the unnecessary route request within the network actually lowers the burden on the overall network. Since only expected and reachable nodes can participate in the route request phase, NRL is minimized, the chance of reaching the packet to the destination is increased, and therefore PDR is increased.

IV. CONCLUSION

A novel way of limiting the request zone for the effective communication is presented in this paper with focus given in essential parameters such as NRL, throughput, and PDR. The main challenge in VANETs is designing routing protocols for dynamic topology along with the consideration of mobility. The proposed routing protocol DyTE uses the location of the vehicles and limits the area of communication. The results have shown that DyTE is not only efficient in increasing the PDR and throughput but also greatly minimized the NRL. DyTE has been found to have better performance than AODV, AOMDV, and DSR in VANETs.

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