DELAY AWARE AND LINK INTERFERENCE AVOIDANCE BASED REACTIVE ROUTING PROTOCOL (DALIA – RRP) FOR VANET

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Abstract - Video transmission in vehicular ad hoc networks is the ever demanding research problem in the field of wireless communications. Video data contains denser in terms of size which leads to more delay. Hence this part of research work aims in proposing delay aware and link interference avoidance based reactive routing protocol for VANETs. The VANET is modeled based on graph theory. After that many to one traffic pattern is considered and the DALIA – RRP communication follows multipath routing with fault tolerance. Metrics such as route length, packet end-to-end delay, freezing delay, number of delivered packets and packet loss ratio are taken to analyze the performance of the proposed work. Simulation results portray better performance than the chosen protocol obtained for comparison.

Keywords: multipath routing, VANET, delay, fault tolerant, traffic, vehicular nodes.

I. INTRODUCTION

A VANET is formed of vehicles (cars, buses, and so on) that are equipped with positioning systems (i.e., GPS devices), wireless communication devices (such as IEEE 802.11p/WAVE network interfaces), and digital maps. The set IEEE 802.11p and WAVE (Wireless Access for Vehicular Environment) form the DSRC (Dedicated Short Range Communication) standard [1] for VANETs communications. The WAVE standard describes the set of standards IEEE 1609.x (.1/.2/.3/.4) deployed at the MAC layer (Layer 2) and the network layer (Layer 3) of the OSI model. At the physical layer (Layer 1), the IEEE 802.11p standard is used. DSRC is actually considered as the most appropriate standard for wireless communications in vehicular ad hoc networks. Its first objective is to provide high data transfers and low communication latency in small communication zones. Hence, using the DSRC standard, it is possible to establish a vehicle-to-vehicle (V2V) communication and a vehicleto-infrastructure (V2I) communication. It supports a vehicle speed exceeding 200 km/h, it offers a wireless range between 300 and 1000 meters, and provides a theoretical bandwidth up to 6 to 27 Mbps.]

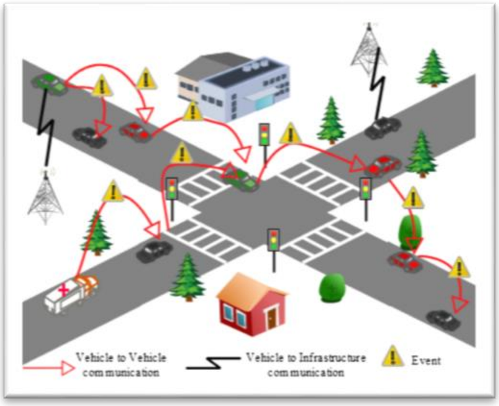

Fig. 1. A typical VANET scenario

In a VANET (Fig. 1), vehicles are autonomous and move in a self-organized way along roads and, exchange information with other vehicles and road infrastructures within their radio range. They allow, on the one hand, a direct Vehicle-to-Vehicle communication (V2V) and on the other hand, a Vehicle-to-Infrastructure communication (V2I). V2V communication operates in a decentralized architecture, and it is a particular case of mobile ad hoc networks. It is based on the simple inter-vehicle communication without access to any fixed infrastructure. Indeed, a vehicle can communicate directly with another vehicle if it is within its radio range, or through a multi-hop wireless communication using neighboring nodes as relays. It can be used to provide information on traffic conditions and/or vehicle accidents via wireless communication. V2V communications are very efficient for the transfer of information services related to road safety, but they do not ensure a permanent connectivity between vehicles due to the high mobility of the vehicles.

A VANET has unique characteristics, including the frequent changes of the topology and the high vehicle speeds. Therefore, routing and forwarding packets in VANETs is a challenging task. Traditional ad hoc routing protocols have difficulties in dealing with the high mobility specific to the vehicular ad hoc networks as demonstrated in many studies [2][3][7][8] which compare the performance of the topology-based routing (such as AODV [6] and DSR [4]) against position-based routing strategies in urban as well as in highway traffic scenarios. The requirements imposed by vehicular ad hoc networks are slightly different from other forms of mobile ad hoc networks [9][5]. On one hand, memory storage and energy consumption are not a constraint since in modern vehicles, the battery power and the storage space are unlimited, and each vehicle can get its own geographic position since nowadays vehicles can be equipped with a positioning system (GPS). On the other hand, the network is highly dynamic due to the high mobility of the vehicles which do not move randomly but follow a particular mobility pattern compared to those of general ad hoc networks.

This paper is organized as follows. This section provides introduction to VANET. Section 2 reviews the related works / literatures. Section 3 presents VANET modeling. Section 4 delas with the proposed work. Section 5 portrays simulation settings. Section 6 provides simulation results with discussion. Section 7 gives concluding remarks of the paper.

II. RELATED WORKS

Considering its unique feature, many routing solutions have been proposed for VANET, and we only list a small subset of the most relevant ones here. Interested readers are referred to a recent survey [11]. For VANETs with high vehicle densities, it is critical to find the connected routes with low congestion and delay [12]. For sparse VANETs, routing protocols often need to consider the tradeoff between reliability and delay [13]. The carry-and-forward mechanism is promising for sparse VANETs and delay minimization is often the main objective of routing protocols in this paradigm [14], [15]. These works relied on rough estimations of the delay for routing decisions. Great efforts have been devoted to analyzing the delay performance in VANETs. [10] analyzed the time to propagate a packet between two disconnected vehicles. [20] and [21] investigated the expected delivery delay from a vehicle to an Internet access point, and the multi-hop packet delivery delay in a low density VANET, respectively, both considering one-way traffic. In [13], [18], a one-dimensional, two-lane road was considered, and an analytical model was developed to calculate the message delay distribution.

The authors in [19] proposed several information release mechanisms to minimize the information delivery delay in the context of an intermittent roadside network, while the intersection and bidirectional road are not considered. [16], [17] investigated the delivery delay given the delivery distance and vehicle density, where a one-dimensional road with bidirectional traffic is considered. [22] provided an accurate analysis framework to estimate the information propagation speed considering one-dimensional road and bidirectional traffic scenario. The previous delay analysis works are mostly confined to one-dimensional roads only, and an accurate analysis on delay statistics for two-dimensional VANET remains unsolved. Modeling and analysis of carry and-forward delay in VANETs is complicated due to the intermittent connectivity, temporal-dynamic motions, and random forwarding process. As summarized in [11], how to refine the existing models or to design new ones for accurate delay estimation and video transmission over VANET is an open issue, which inspires this work.

III. VANET MODELING

In this research work, the VANET is modeled by the graph $G=(V,E)$, where V and E denotes the sets of vehicular nodes and links separately. It is modeled as all links in graph G are bi-directional. (u,v) denote the link between u and v, and $|u,v|$ represents the Euclidean distance between u and v. A link $(u,v)\in E$ represents that vehicular nodes u and v is capable enough to communicate with each other directly. Each vehicular node has the ability to later its transmission power from 0 to $p_{\max}$ ad infinitum. Here, $p_{\max}$ is the maximum transmission power. Let p_u and r_u denotes vehicular node u's transmission power and transmission radius, respectively. At the point when each vehicular node is operating at $p_{\max}$, the graph is called $G_{\max}=(V,E_{\max})$. $E_{\max}=\{(u,v)|u,v\in V, p_{uv}\le p_{\max}\}$, where p_{uv} is the minimum transmission power required to set up a straight link from node u to v. $G_u=(V_u,E_u)$ denote the local topology of vehicular node u when u works at $p_{\max}$. V_u denotes the one-hop neighborhood set of vehicular node u, where $V_u=\{v|\,v\in V,(u,v)\in E_{\max}\}+\{u\}$. E_u denote the set of links between the vehicular nodes in V_u, where $E_u=\{(x,y)|\,x,y\in V_u,(x,y)\in E_{\max}\}$. $d(u,|u,v|)$ denote the circumference whose center is vehicular node u and radius is $|u,v|$. The communication interference of a link (u,v) is represented as $I(u,v)$. $I(u,v)$ is equal to the number of vehicular nodes that are in the range of $d(u,|u,v|)$ and $d(v,|v,u|)$, i.e.,

$$I(u,v)=\left|\left\{ w\in V,|u,v|\le|u,v|\cup|v,w|\le|u,v| \right\}\right| \ldots(1)$$

IV. DELAY AWARE AND LINK INTERFERENCE AVOIDANCE BASED REACTIVE ROUTING PROTOCOL (DALIA – RRP) FOR VANET

Delay Aware and Link Interference Avoidance based Reactive Routing Protocol (DALIA – RRP) is a new efficient solution which provides fault tolerant capability for multi path routing protocol in mobile ad hoc networks. First, we will introduce a new paradigm for heterogeneous mobile ad hoc networks: energy-node-disjoint routes. Next, we will describe DALIA – RRP which constructs multiple routes between the sink and each node in the network. Specifically VANET is built for typically for cooperative working of mobile nodes and requires data collection at a specific mobile node called Sink node. Here, we are considering many-to-one traffic pattern where source node data is sent to the Sink node through intermediate master nodes called as relay nodes. As in several literature works and real-world mobile ad hoc networks implementations [14, 15, 16, 17], we assume the existence of few robust powerful relay nodes in the network. In DALIA – RRP, sink neighbors are called primary nodes or master nodes and primary node neighbors are called sub primary or standard nodes. The master node is powerful node with sufficient energy and ensures high connectivity and hence they can send data in several routes simultaneously. The standard node will have energy constraint and are able to send the packet to the discovered neighbor. The protocol uses Route REQuest (RREQ) message which, propagates through sub-primary nodes to primary nodes to construct multiple energy-node-disjoint routes between each source node and the sink node. Each non primary node maintains a routing table which contains an entry for each discovered route. A RREQ message has the format which corresponds to a route. During the construction of routes, a node will receive many RREQ messages which corresponding to one or more routes. For guarantying the node disjointness among the nodes, each node forwards only one RREQ message to its neighbor nodes and acts as a reducing element. However, primary nodes which are powerful nodes are able to ensure relatively high connectivity degree and can transfer data on several routes. Other than using all nodes as reducing elements that belonging to only one route, DALIA – RRP will introduce a controlled intersection at primary nodes by allowing them to forward many RREQ messages to their neighbors. In order to determine link interference, MAC layer information is obtained as per IEEE 802.11 CSMA/CA standards. The interference of the entire VANET is measured as the maximum link interference occurring in a graph G, i.e.,

$$MI(G)=\max I(e), e\in E \ldots(2)$$

where e represents the link in topology G. In this research work, average interference $AI(G)$ and the average route interference $PI(G)$, are also measured using (3) and (4).

$$AI(G)=\sum_{e\in E} I(e)/n \ldots(3)$$

$$PI(G)=\sum_{P\in G} I(P)/(n(n-1)/2) \ldots(4)$$

The transmission delay through route P is calculated with the help of the metric known as hop count of the corresponding route and is denoted as $D(P)$. In this research work, an integer value is given named $K(K\geq 1)$ that denotes the delay constraint. As the first part of the proposed work, reduction of maximum interference is performed by building a topology denoted as G_{MDTC} that results in reduced interference and is denoted as $MI(G_{MDTC})$. All vehicular nodes in the network G_{MDTC} possibly will contact all other vehicular nodes through route P and $D(P)\leq K$. The reducing maximum interference with delay constrained scheme is given below

```
input : $G_{max} = (V, E_{max})$
initialize $G_{MDTC}(V, E_{MDC})$, where $E_{MDTC} = \phi$
for $\forall_e \in E_{max}$ do
  compute the int erference of each link e with $I(e)$ according to Eq.(1)
end for
sort each link e by $I(e)$ in ascending order
 while $E_{max} \neq \phi$ do
   choose link $e = (u, v) \in E_{max}$ with the max $I(e)$
     while $D(P_{G_{MDTC}}(u, v)) > K$ do
         choose link $l \in E_{max}$ with the min imum iterference and insert $l$ in $E_{MDTC}$
         delete $l$ from $E_{max}$
       end while
   delete e from $E_{max}$
 end while
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In the above proposed mechanism is based on a greedy policy which begins from $G_{MDTC}(V, E_{MDTC})$, where E_{MDTC} is initialized as an empty set. The first two steps of $MDTC$ are to calculate the $I(e)$ for each link $e\in E_{\max}$ and sort them in ascending order. In line 8, $P_{G_{MDTC}}(u,v)$ denotes the minimum hop route between nodes u and v in G_{MDTC}. If a route between nodes u and v does not exist in G_{MDTC}, $D(P_{G_{MDTC}}(u,v))=\infty$. If $D(P_{G_{MDTC}}(u,v))\leq K$, it is called a delay constrained route, and if all pairs of nodes in G_{MDTC} have a route $P_{G_{MDTC}}(u,v)$ and $D(P_{G_{MDTC}}(u,v))\leq K$, then G_{MDTC} is delay constrained. $MDTC$ always attempts to replace the maximum interference link of $G_{\max}$ by a delay-constrained route that already exists in G_{MDTC}, and it continues to insert the minimum interference link of $G_{\max}$ into G_{MDTC} until a delay-constrained route exists. After that, a distributed algorithm to construct a local delay-constrained topology in which the average interference is reduced as much as possible is proposed.

In order to reduce average interference, a spanning tree is proposed in which the weight of each link is the link interference is measured. The interference minimum spanning tree is the optimal solution for minimizing average interference. In the spanning tree, each vehicular node v maintains a parameter $hop(x)$ that represents the hop count from x to the root node of the tree. For representation of delay minimum spanning tree, it is denoted by $G_{DMST}\left(V_{DMST}, E_{DMST}\right)$. During the starting stage, V_{DMST} only contains the root node, and E_{DMST} is initialized as an empty set. After that vehicular nodes are added to V_{DMST}. If hop $(x)+1 \leq K$, then node y will be added to V_{DMST}, and link (x, y) will be added to E_{DMST}.

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Inputs : A connected graph $G(V,E)$, a root vehicular node $u$, and the interference of each link $\in E$
initialize $G_{DMST}(V_{DMST}, E_{DMST})$, where $V_{DMST} = \{u\}, E_{DMST} = \phi$
for each node $v \in V$ do
    $hop(v)=0$        // $hop(v)$ is the hop count to source node $u$
end for
while $V_{DMST} \neq V$, do
    find the minimum interference link $(x,y)$, where $x \in V_{DMST}, y \notin V_{DMST}$
    if $(hop(x)+1 \leq K)$ then
        $hop(y)=hop(x)+1$
        $V_{DMST}=V_{DMST} \cup \{y\}$
        $E_{DMST}=E_{DMST} \cup \{(x,y)\}$
    end if
end while
Output : $G_{DMST}(V_{DMST}, E_{DMST})$
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V. SIMULATION SETTINGS, RESULTS AND DISCUSSIONS

Table 1 shows the simulation settings. Route length, packet end-to-end delay, freezing delay, number of delivered packets and packet loss ratio are the performance metrics chosen in order to analyze the efficacy of the proposed work. The proposed DALIA – RRP is compared with EPLR – MRT protocol and AMGR protocol on the obtained performance metrics. The total network area has 1000 numbers vehicular nodes. The deployed vehicular nodes are shown in Fig.2. Based on the network topology, when the route length is increased the quality of video transmission also increases. From the Fig.3 it is obvious that the proposed DALIA – RRP has better route length than that of EPLR – MRT and AMGR protocols. It is noteworthy that when the end-to-end delay is reduced it results in better video transmission speed. Fig.4 portrays the results of simulation time versus packet end-to-end delay. From the obtained results it shows that the proposed DALIA – RRP acquires less packet end-to-end delay than that of EPLR – MRT and AMGR protocol. Freezing delay also taken into account in order to witness the quality of video transmission. Less freezing delay results in better video quality. Fig.5 presents the simulation results in terms of simulation time versus freezing delay. From the results it is obvious that the proposed DALIA – RRP consumes lesser freezing delay when compared to EPLR – MRT and AMGR protocols.

Throughput or number of packets delivered is the measure used to evaluate the performance of the protocol by which the total number of successful packets reached towards the destination. Fig.6 shows the performance comparison of the protocols in terms of simulation time versus number of delivered packets. It is evident that the proposed DALIA – RRP attains better throughput than that of EPLR – MRT and AMGR protocols. Fig.7 presents average packet loss ratio of the protocols and from the results it can be perceived that the proposed has less packet loss ratio that ensures better video transmission. The result values are presented from Table 2 to Table 6.

Table 1 - Simulation Settings

Parameters	Values
Simulation area	2.5 km X 3.5 km
Number of nodes	1000
Number of intersections	250
Number of streets	513
Vehicle speed	3 – 13 meter/second
Transmission range	250 meters
Minimum data rate	6 Mbps
Simulation time	12 seconds
Beacon interval	5 seconds

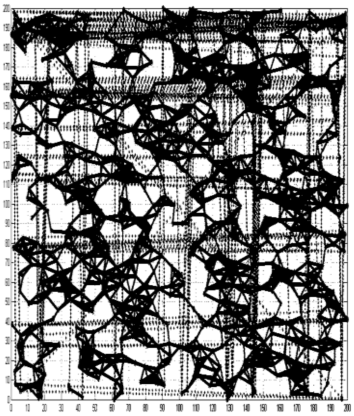

Fig.2. Network Setup

Table 2 - Client – Server Pair Index Vs Route Length

	Route Length (count)		
Pair Index	AMGR-VT	EPLR – MRT	DALIA – RRP
1	8	15	18
2	11	19	24
3	12	23	27
4	9	26	31
5	11	29	34
6	26	34	39

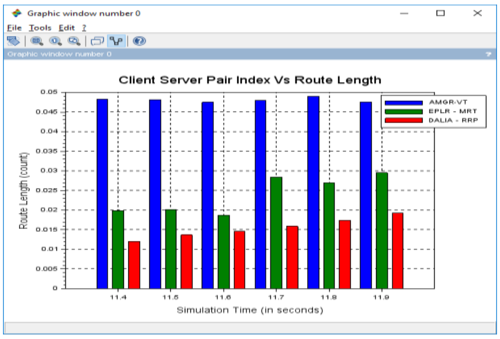

Fig.3. Client – Server Pair Index Vs Route Length

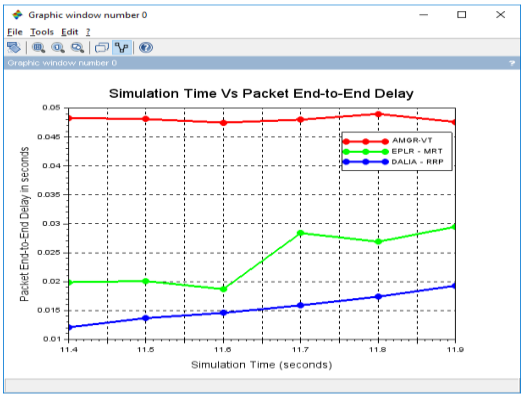

Fig.4. Simulation Time Vs Packet End – to – End Delay

Table 3 - Simulation Time Vs Packet End-to-End Delay

	Packet End-to-End Delay (seconds)		
Simulation Time (seconds)	AMGR-VT	EPLR – MRT	DALIA – RRP
11.4	0.0483	0.0199	0.0121
11.5	0.0481	0.0201	0.0137
11.6	0.0475	0.0187	0.0146
11.7	0.048	0.0284	0.0159
11.8	0.049	0.0269	0.0174
11.9	0.0476	0.0295	0.0193

Table 4 - Simulation Time Vs Freezing Delay

	Freezing Delay (seconds)		
Simulation Time (seconds)	AMGR-VT	EPLR – MRT	DALIA – RRP
11.15	0.042	0.018	0.009
11.16	0.012	0.003	0.001
11.17	0.012	0.004	0.002
11.18	0.012	0.004	0.001
11.19	0.012	0.003	0.001
11.20	0.012	0.002	0.001
11.21	0.014	0.005	0.002
11.22	0.017	0.004	0.002
11.23	0.028	0.007	0.003
11.24	0.038	0.008	0.004
11.25	0.045	0.011	0.005

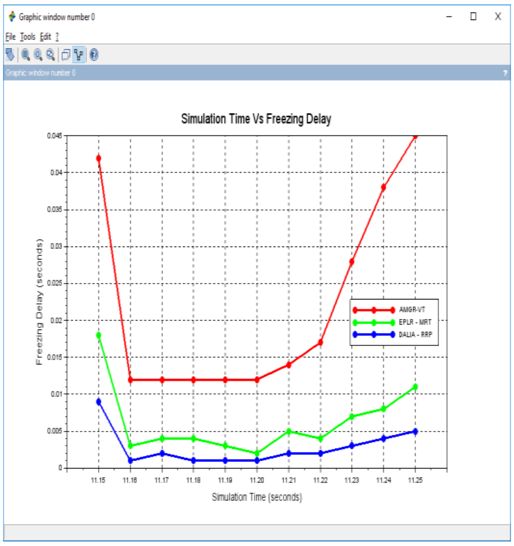

Fig. 5. Simulation Time Vs Freezing Delay

Table 5 - Simulation Time Vs Number of Packets Delivered

	Number of Packets Delivered (packets)		
Simulation Time (seconds)	AMGR-VT	EPLR – MRT	DALIA – RRP
10.5	332	649	809
11	958	1385	1552
11.5	1759	2204	2894
12	2658	4193	4772

Table 6 - Packet Loss Ratio of Protocols

Packet Loss Ratio (count)		
AMGR-VT	EPLR – MRT	DALIA – RRP
8.65	0.87	0.61

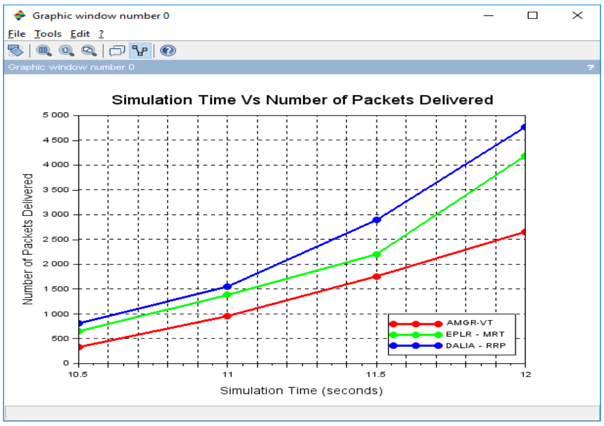

Fig.6. Simulation Time Vs Number of Delivered Packets

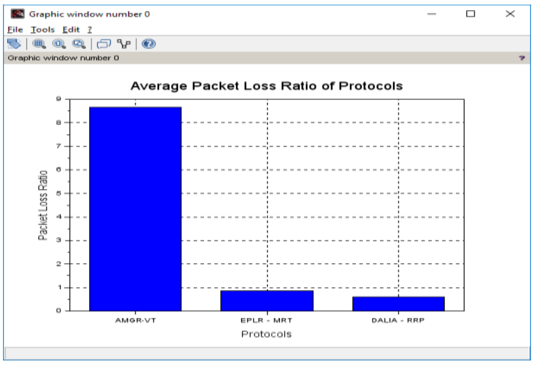

Fig.7. Protocols Vs Average Packet Loss Ratio

VI. CONCLUSIONS

This paper presents DALIA – RRP which is the extended work of the previously published three research works [23], [24] and [25]. DALIA – RRP follows multipath routing strategy. Certain VANET conditions are modeled using graph theory. The vehicular nodes are considered as vertices and link are considered as edges. The established links are connected to reach the destination nodes through multipath routing strategy. Then delay aware link interference avoidance mechanism is used in order to obtain better video transmission. From the obtained simulation results, it is evident that the proposed DALIA – RRP outperforms the base paper work and the works done before.

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