Delay and Hop Count Estimation of Directional-Location Aided Routing Protocol for Vehicular Ad-hoc Networks

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Submitted in January, 2016; Accepted in June, 2016

Abstract – Vehicular ad-hoc network (VANET) is an integral component of intelligent transportation systems. Due to continuous movement of vehicles, network formation and de-formation is very frequent. Furthermore, for safety applications, we wish to create the communication without any delay or collision. Therefore, communication among the vehicles is even more challenging. D-LAR (Directional–Location Aided Routing) is one of the position based routing protocol which works efficiently in VANETs. We want to analyze the performance of D-LAR protocol in a city traffic scenario. To do a quality performance evaluation, extensive simulations has been done in realistic environment created with SUMOatraffic simulator and NS-2 network simulator. The performance of D-LAR protocol has been compared with LAR on various metrics like routing overhead, packet delivery ratio and delay.

Index Terms - Delay, D-LAR, Hop count, LAR, Routing protocol, Vehicular ad-hoc networks

NOMENCLATURE
DIR - Directional Routing, D-LAR – Directional-Location Aided Routing, ITS- Intelligent Transportation Systems, LAR - Location Aided Routing, PDR – Packet Delivery Ratio, VANETs - Vehicular Ad-hoc Networks,

1.0 INTRODUCTION

Traffic and transport management systems are using the new generation information and communication technologies to have intelligent transportation systems (ITS). Their aim is to ease the citizen's Life by providing them facilities like smart parking, intelligent traffic management systems,etc.VANETacts as a vital innovationfor ITS. It's a kindof network where vehicles can communicate with eachother as per therequirements.

To do this, intelligentvehicles that have wireless transceivers and computerized control modules are required.

There are two kinds of communication in VANETs. One is vehicle-to-vehicle communication which is among vehicles only. Another type of communication is vehicle-to-infrastructure which is among the vehicles and roadsideinfrastructure units. Here,we are considering only vehicle-to-vehiclecommunication which is purely ad-hoc and completely infrastructure-less. The two vehicles can communicate when they lie in the communication range of each other. Vehicles movements are restricted as per the road-maps. Another important characteristic of VANETs is uneven distributions of vehicles on the roads. On top of that vehicles speed is irregular and generally it is high, therefore network formation and de-formation is very frequent. Due to all these characteristics, doing the communication and maintaining it is very challenging.

A number of researchers introduced a variety of routing protocols. These protocols have been grouped into two categories: position based and topology based routing protocols. Due to various characteristics of VANETs mentioned in the above paragraph, topology based routing protocols such as DSR, DSDV and AODV have poor adequacy and adaptability.

Position based routing protocols works on the concept of greedy forwarding. Here, each node knows the positional coordinates of its neighboring nodes. After getting the positional information, source node selects the one as a next hop node who is geographically nearest to the destination. These protocols are also called as geographic or spatial aware routing protocols. In position based routing protocols, there is no requirement of establishment and maintenance of route. Also, these protocols do not require the knowledge about the complete network connectivity. These protocols utilize the spatial knowledge like lanes and maps of cities for routing decisions. Therefore, position based routing protocols performance is better than topology based protocols.

However, position based routing protocols require extra information in terms of its own position, neighboring nodes and destination position. To get its own position, all the nodes utilize the Global Positioning System. To get the destination node positional information, source node takes the help of any location service. After getting the destination position, source node mention it in the packet's destination address. Neighboring nodes gather the positional information of each other by periodic exchange of beacon or hello messages. GPSR[HYPERLINK \l "BKa00" *1*], A-STAR*2*]**}**, GEDIR[HYPERLINK \l "Iva99" *3*], LAR*4*]**}**, GSR[HYPERLINK \l "CLo05" *5*], D-LAR *6*]**}**etc. are different examples of position based routing protocols.

D-LAR (Directional-Location Aided Routing) [HYPERLINK \l "Ram12" *6*]proposed by Raw etal.is a position based routing protocol. This is amalgamation of two routing protocols, LAR and DIR. LAR (Location Aided Routing) protocol has been

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proposed by Young and Vaidya*4*]**}**. In this protocol, they proposed the ideaof limited flooding for reducing the route discovery overhead. By getting the destination location and speed information, source node constructs an area, called as request zone which covers both source and destination. Now, route discovery is restricted to this constructed request zone. It helps in reducing the route discovery overhead. D-LAR protocol utilizes this concept for limiting the search area of route selection. Once the search area has been limited, now next-hop node would be selected from this search area. For the selection of next-hop node,D-LAR uses the concept of directional routing (DIR). D-LAR selects the next-hop node amongst the available neighboring nodes that has the minimum angular deviation from the connecting line of source and destination.

Raw et al. [HYPERLINK \l "Raw15" *7*]proposed D-LAR with a mental make-up that it achieves a remarkable performance in city traffic scenario because routing overhead would be reduced with the partial flooding concept of LAR protocol and directional greedy forwarding provides a stable route in comparison to other greedy forwarding techniques. They have provided the results of D-LAR for hop count and path throughput metrics. As we know that delay is an important metric for safety applications of VANETsbut they have not validated their proposed idea for this metric, while proposing the idea they said it is better for safety applications. D-LAR protocol is based on LAR even then D-LAR results have not been compared with the LAR protocol.

In this work, we have evaluated the performance of D-LAR protocol in terms of delay, packet delivery ratio and routing overhead metrics. Its performance has beencompared with the existing LAR protocol. We have also analyzed how delay gets affected by the both MAC layer and routing layer parameters.

The remaining article is organized as follows. The next section presents a brief overview of D-LAR routing protocol. Section 3 presents the review of some articles where authors did the mathematical modeling of delay with respect to wireless networks. Hop Count and delay analysis is provided in section 4. Section 5 and 6 presents the simulation results and conclusion respectively.

2.0 OVERVIEW OF D-LAR PROTOCOL

Among the available position based routing protocols in the literature *8*]**}**[HYPERLINK \l "Ber09" *9*]**,** D-LAR is one of the most suitable position based routing protocol specially meant for highly dynamic dense networks. D-LAR is the extension of LAR protocol. LAR limits the route discovery area with the knowledge of speed and location of destination. Suppose, the destination node **}**is moving with the speed and at time , it is at location. With this information source node can expect that the destination node would be somewhere in the circular region around attime . This circular region is of radius . This region is called as expected zone where source node can expect that destination node would be at time . After constructing the expected zone, source node startsdefining the request zone. Request zone is the smallest rectangle whose bottom left corner is the current location of and top right corner covers the expected zone. The sides of the request zone are parallel to X and Y axis.

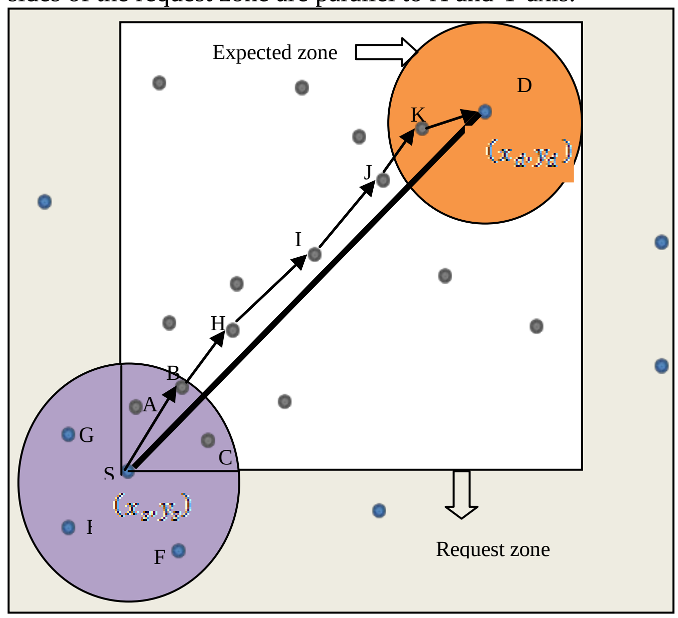

Figure 1: Working of D-LAR protocol

Source node initiates the route discovery process by broadcasting a route request message to its neighbors. Route request message encompasses the coordinates of the request zone. When a neighboring node receives the route request message, it checks its own positional information with the content of the route request message. If the neighboring node lies within the request zone it forwards the message further to its neighbors else it will drop the message.

It can be visualized from figure 1 that A, B, C, G, I and F are the neighbors of S. Source node sends the route request message to all its neighbors. However, only three nodes A, B and C propagate the message further because they lie in the request zone. In this way the message is not propagated to all the nodes of the network. There is an involvement of few nodes which lies in the request zone. The route would be searched in the direction of destination; as a result the routing overhead is reduced. S would choose node B as the next-hop node because it has the minimum angular deviation in comparison to other two neighboring nodes. By using the same selection criteria, node B will select the next-hop node as H and then similarly H selects I and so on.

This concept of LAR is used by D-LAR protocol for broadcasting of control packets, so that within the request zone all the nodes knew the location information about itself and its neighbors. After this, D-LAR selects the next-hop node among the neighboring nodes within the transmission range and the request zone. The next-hop node would be the one which has the minimum angular deviation from the line connecting source to destination. By using this next-hop selection strategy, message will not go out of way.

By using the strategy of LAR, D-LAR routing overhead is reduced and with the use of directional greedy forwarding, the selected path is always stable. Both routing overhead and stable path are desirable parameters for safety applications of VANETs.In all applications of VANETs but specifically in safety applications, delay is very important measuring metric for evaluation of the performance of a routing protocol. If the information is delivered in a timely manner then the driver got the time to react in order to avoid the problem ahead.

Raw et al. asserted the performance of D-LAR protocol in city environment although they have not provided any proof for their claim in terms of delay, the important performance measuring metric. It has not been tested in a real traffic simulation. Therefore, the mathematical analysis of delay for D-LAR protocol has been done. The performance of D-LAR protocol has been tested in a real traffic scenario.

3.0 RELATED WORK

This section presents an overview of articles where researchers analyzed the delay with respect to different conditions. In the first article, Abdullah et al. [*10*] has shown the impact of hidden nodes on delay and throughput metrics. They have assumed that interference range, transmission range and sensing range, all are equal. Therefore, the communication area is divided into two parts: hidden node area and other area. As per these considerations, they have calculated node transmission and collision probabilities.

In another article, Ding etal. [*11*]presenteda model for a wireless node using Markov chain analysis and derived the various probabilities like idle, successful transmission etc. as per state transitions in respect of multi-hop ad-hoc networks. They have measured the delay by calculating the steady state probabilities of each state and time duration spent by each state. Bianchi etal.[*12*] have analyzed the performance of 802.11 DCF in terms of throughput for both basic access and RTS/CTS mechanisms. They have assumed the finite number of nodes and ideal channel conditions for the calculation. Also, they have calculated the various probabilities and throughput performance of the system with saturated nodes by providing the Markov chain model for back-off window size. In another work, a Markov chain model for single node using IEEE 802.11 has been presented by Ghadimiet. al. [*13*]. This model is established on the Bianchi's work [*12*]. Here they measured end-to-end delay for multi-hop wireless ad hoc networks by considering hidden and exposed terminals conditions under unsaturated traffic.

In all the above cited articles researchers have figured out either the delay or throughput concerning various traffic situations and channel conditions. Performance of any system can be estimated by considering the node transition probabilities like collision, transmission, idle, etc. The Markov chain model is the prominent model to measure the performance of any system. In this article, we have approached in the same way by considering the real traffic scenario for VANETs and all the simulations has been done using SUMO[*14*] as a traffic simulator.

4.0 HOP COUNT AND DELAY ESTIMATION

Path delay is also labeled as end-to-end delay; the delay a packet experiences before its successful delivery at destination. If the expected delay with respect to one link is known then path delay can be computed as,

$$d_P = H * d_H \qquad (1)$$

Where*H* is the expected number of hops from source to destination that can be calculated from the Hop Count Algorithm described in the sub-section 4.1. is one hop delay that is further examined in sub-section 4.2.

4.1 Hop Count Estimation

For the calculation of H, refer the algorithm proposed by pandey et al. [*15*] [*16*]. Here, that algorithm has been used with one difference that is estimation of distance covered with in one hop. Therefore, the expected distance is calculated here. Suppose, expected $\mathcal{D}_{si}$(estimated one hop distance)is represented by a random variable *x*.

There is an assumption that ‘ ’neighboring nodes are available in the forwarding region and transmission range of *S*, the source node. $\mathcal{D}_{si}$is a random variable that represents the Euclidean distance between the current node *s* (first time it is source, next time onwards the chosen next-hop node in previous step) and the chosen next-hop node *i*(according to the criteria of minimum angular deviation). Therefore, cumulative distribution function of $\mathcal{D}_{si}$can be written as [*17*]

$$F_{\mathcal{D}_{si}}(x) = P(\mathcal{D}_{si} \leq x) = \frac{\pi x^2}{\pi R^2} = \frac{x^2}{R^2} \qquad (2)$$

Thus, the probability distribution function of $\mathcal{D}_{si}$is

$$f_{\mathcal{D}_{si}}(x) = \frac{dF_{\mathcal{D}_{si}}(x)}{dx} = \frac{2x}{R^2} \qquad (3)$$

Expected one hop distance, $\mathcal{D}_{si}$can be calculated as

$$E(\mathcal{D}_{si}) = \int_0^R x\frac{2x}{R^2}dx = \left|\frac{2x^3}{3R^2}\right|_0^R = \frac{2R}{3} \qquad (4)$$

Hop count value computed with the help of algorithm and expected one hop distance would be used in the following subsection for calculation of delay.

4.2 Delay Estimation

One hop delay can be dictated as the summation of all types of delays the packet experiences while travelling from one node to the next-hop node. It can be written as

$$d_H = Trans.delay\ (d_T) + Prop.delay\ (d_{Pr}) + Queuing\ delay\ + Pro$$

Here, a city traffic scenario has been considered where average speed of vehicles is approximately 50 km/hr. Therefore, propagation delay can be written as

$$Prop\ delay\ (d_{Pr}) = \frac{one\ hop\ distance}{avg\ speed} = \frac{\mathcal{D}_{si}}{50}.$$

Therefore, from the equation (4), can be written as

$$d_{Pr} = \frac{R}{75} \quad (6)$$

Processing delay is assumed to be negligible. Queuing delay is the period of time that a packet experiences at the interface queue. At the most a node can have one packet waiting for transmission so queuing delay is ignored.

Transmission delay is defined as the time when the packet is ready for communication until it is transmitted successfully. Successful transmission is possible only if at an instant of time only one node is transmitting and the channel is error-free. If two or more nodes will transmit at the same time then collision will occur. Sometimes, transmission gets interfered due to hidden nodes or interfering nodes. In both the cases, there is a need of retransmission of packet. So, transmission delay accounts for the wasted time due to failed transmission and time taken in successful transmission. It can be written as

$$d_T = T_C + T_S.$$

is the wasted time for a failed transmission due to collisions and is the duration of successful transmission. Therefore, one hop delay can be re-written as

$$d_H = T_C + T_S + d_{Pr} .$$

5.0 RESULTS AND PERFORMANCE ANALYSIS

NS-2, network simulator and SUMO, a traffic simulator has been used to validate the proposed concept. Realistic city traffic environment scenarios have been designed using SUMO. All the vehicles were deployed as per the road constraints in an area of 600 * 800 m^2. The whole area has 20 junctions. Figure 2 shows a small segment of the map and vehicle movements on the roads. The yellow objects are depicting as vehicles. Different scenarios have been created by varying the number of vehicles.

Simulation results have been presented in the form of three metrics by varying the number of vehicles. Results of D-LAR protocol have been compared with LAR protocol on routing overhead, delay and packet delivery ratio metrics. In the graphs, each result value is an average of 5 iterations so the complete simulation has been run 5 times, therefore 5 different route and mobility files have beengenerated using various python files of SUMO. These files were converted into NS-2 [*18*] supported mobility files using traceExporter.py, python file of SUMO.

All the parameters used in our simulations are summarized in table 1.Routing overhead is an important metric because of extensive change in topology in VANETs. It is defined as the number of control packets to be sent to receive the sent data packets.

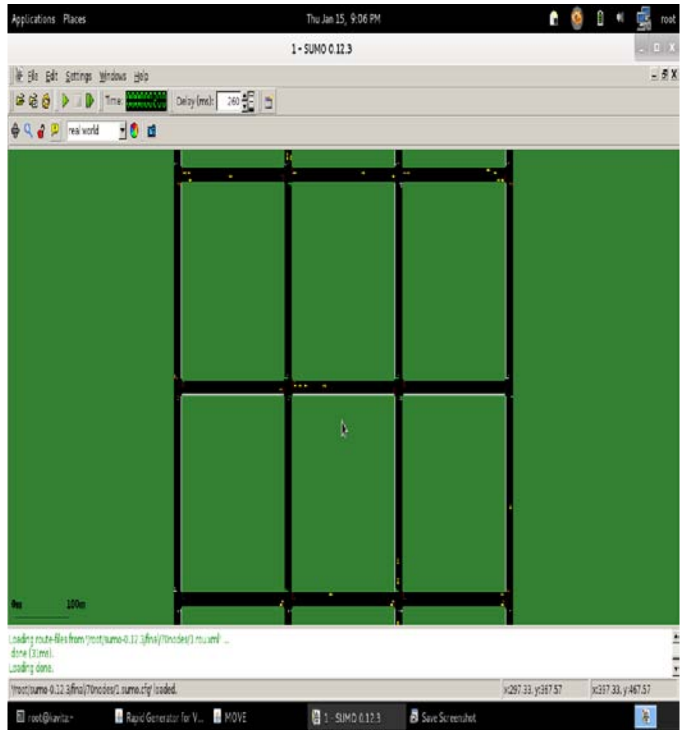

Figure 2: Map and vehicle movements in SUMO

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Parameters	Value
Network Simulator	NS-2.32
Traffic Simulator	SUMO-0.21
Simulation area	600 * 800 m^2
Simulation time	1000 sec / iteration
Propagation Model	Two-ray ground
Transmission range	250 meters
Traffic source	CBR
MAC protocol	IEEE 802.11 DCF
Routing Protocol	D-LAR, LAR
Transport Protocol	UDP
Data Packet Size	512 Bytes
Packet rate	4 packets/sec
Bandwidth	2 Mbps
Number of Vehicles	100 to 300 with a variation step 50
Speed	50 km/hr.

Table 1: Simulations parameters

As we have already explained that delay is an important metric especially for safety applications in VANETs. Therefore, we have chosen this metric for validation of proposed concept. Delay value shows the average amount of time taken by the packets to reach from source to destination. The performances of both the protocols, D-LAR and LAR have also been compared on packet delivery ratio. The ratio of successfully received data packets upon sent data packets is called as packet delivery ratio (PDR).

All the three figures 3, 4 and 5show the better performance of D-LAR over LAR protocol. Figure 3 shows the routing overhead of D-LAR is less in comparison to LAR. It is because of the routing strategy of D-LARi.e. a node which is present in the request zone and having minimum angle will forward the packet. Whereas in LAR, all nodes present in the request zone forward the packet further. As the number of nodes increases, the probability of more number of nodes in the request zone also increases and therefore as a result routing overhead increases.

Figure 4 presents the average end-to-end delay results against number of nodes. It can be visualized that delay of D-LAR protocol is better than LAR and its value increases as the node density increases. This is due to the fact that with an increase in node density nodes in the request zone area increases and therefore collision probability increases. As a result, delay value increases.

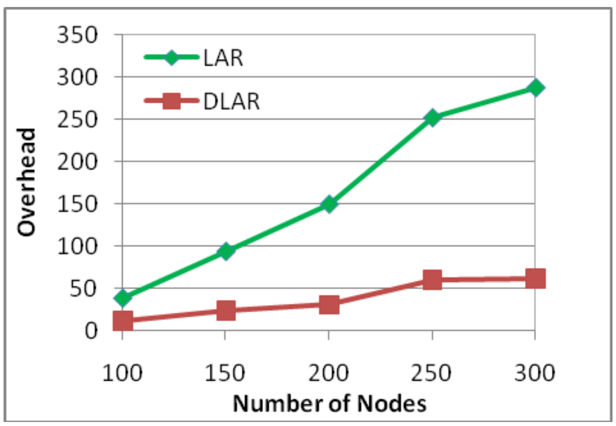

Figure 3: Routing overhead vs. number of nodes

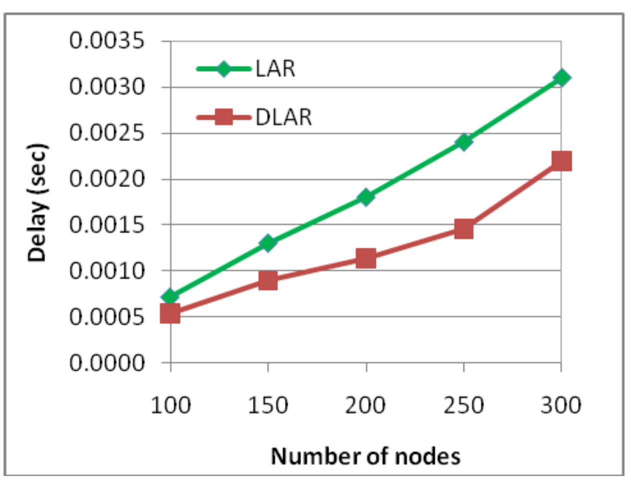

Figure 4: Delay vs. number of nodes

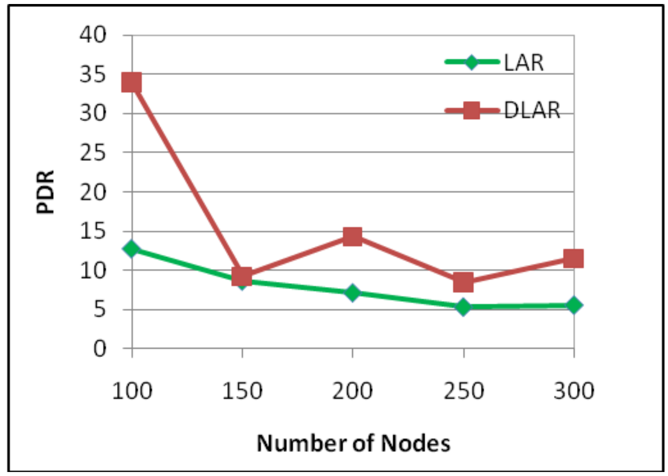

Figure 5: PDR vs. number of nodes

Figure 5 demonstratesthe PDR results against the node density. The packet delivery ratio of both the protocols decreases with an increase in number of nodes. It is because as the node density increases, the probability of collision among the data packets also increases, which results into a lower packet delivery ratio. Even though, PDR of D-LAR is better than LAR. From all the results, it can be said that D-LAR performance is better than LAR.

6.0 CONCLUSION

In this article, we have mainly analyzed the hop count and delay for D-LAR position based routing protocol. D-LAR is a mixture of DIR greedy forwarding and LAR protocol. So, D-LAR protocol performance has been compared with the LAR protocol on routing overhead, packet delivery ratio and delay metrics. For a quality performance evaluation, simulations have been done using SUMO and NS-2. Various scenarios have been created by differing the number of vehicles. It can be visualized from the results that with an increase in number of vehicles, collision probability increases, so delay increases and PDR decreases. As per the routing strategy of D-LAR, its routing overhead is less in comparison to LAR. Form the results it has been verified that D-LAR is better than LAR, so, it is suitable for city traffic environment for VANETs.

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