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Enhancing VANETs' Routing Operation with the Route Lifetime Policy

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ABSTRACT
Routing is continuous challenging issue in Vehicular Ad Hoc Networks (VANETs) given the intrinsic characteristics of these networks, especially limited resources and high mobility. Indeed, for any routing protocol to achieve acceptable network throughput performance it should adapt its operation to VANET high frequency topology change dynamics. In this paper an enhancement of such routing protocols is proposed using the Route Life Time (RLT) policy which purpose is to maintain the established route as long as possible in VANET likely dynamic environments. Indeed, the well-known VANET routing protocols AODV and DSR are enhanced to their respective versions baptized AODV-RLT and DSR-RLT. A realistic VANET model is defined for the purpose of simulation experiments and both single and a comparative evaluation of the proposals is performed. These experiments show that both of the AODV-RLT and DSR-RLT exhibit good performance as far as the network throughput was considered. The comparative study lightens that the DSR-RLT protocol overcomes the AODV-RLT to achieve a higher network throughput.

General Terms
VANET routing, AODV, DSR, simulation, network throughput.

Keywords
Route Life Time (RLT), AODV-RLT, DSR-RLT.

1. INTRODUCTION
Routing in Vehicular Ad Hoc NETworks (VANETs) has attracted a lot of attention during the last few years. VANET is a special type of Mobile Ad Hoc NETwork deployed in a varying communication environment (e.g., highways and city center roads) and often associated with delay constraints [1]. VANETs are indeed characterized by a strong mobility of the nodes, a highly dynamic and specific topology, a significant loss rate and a very short duration of communication (due to frequent disconnections).

Routing in VANETs is among the most important concerns to ensure correct and safe data transfer for these applications. It is well known that several routing protocols have been proposed for MANETs to deal with nodes' mobility, discover routes using geographical information, detect stable structures (clusters), use nodes' movements for message transfers and apply the broadcasting approach for message forwarding. However, the specific characteristics of VANETs, especially the highly dynamic topology, directly affects the performances of MANET routing solutions making the routing process in VANET a major challenge. The strong mobility, the error-prone wireless medium and scarce resources in the network do impose specific constraints in the design of any VANET routing protocol. To address this issue several proposals have been presented and evaluated in the literature [2-3]. These VANET routing protocols can be generally classified into three major categories: reactive routing protocols such as AODV (Ad-hoc On-Demand Distance Vector) and DSR (Dynamic Source Routing), proactive routing protocols such as DSDV (Destination Sequenced Distance Vector), OLSR (Optimized Link State Routing) and TBRPF (Topology Broadcast based on Reverse Path Forwarding) and finally position based routing protocols which include road-based routing protocols such as GPSR, DREAM (Distance Routing Effect Algorithm for Mobility), CAR (Context-aware Adaptive Routing), GFC (Generic Flow Control) and GOAFR (Greedy Other Adaptive Face Routing).

Unfortunately, as long as all of these routing protocols make use of a fixed succession of nodes when establishing a route between the source and the destination, the problem of route instability arises when they are deployed in a VANET context characterized by frequent route breakdowns. This is shown in [4] across analytical and numeric simulation results. It is to address this issue that this work focuses on the enhancement of the routing process's robustness against typical frequent link failures in VANETs due to the high mobility of nodes. To achieve this goal the Route Life Time (RLT) policy, proposed in [5], is used. This policy operates to make the underlying routing protocol establishing a route with the maximum expected lifetime. Such a route can resist to frequent VANET link failure to ensure packet transfer stability on the network and to achieve by the mean high network throughput. The AODV and DSR routing protocols have been selected to implement and evaluate the RLT policy enhancement and the new proposals are baptized AODV-RLT and DSR-RLT respectively.

The rest of the paper is organized as follows. Section 2 goes through various AODV and DSR enhancement proposals for VANET application. Section 3 is devoted to the presentation of the RLT policy concept and rules along with the design of the proposed AODV-RLT and DSR-RLT routing protocol. Section 4 presents the performance evaluation of these two proposals using the performance metric Network throughput. Finally, in section 5 a conclusion is given with some perspectives.

2. RELATED WORK
In this section a synthesis of the most relevant proposal to enhance the AODV and DSR routing protocols in a VANET context consideration is given.

The I-AODV, introduced in [6], uses the speed information and direction of vehicles to optimize route discovery and the route selection process. In this way, routes are more stable while the control overhead is reduced because the discovery phase is restricted to certain number of nodes rather than the whole network. In [7], the authors proposed the V-AODV protocol to add a packet header to the RREQ (Route Request) packet. Simulation results show that the transmission delay is more relevant in terms of QoS than Bit Rate Error (BRE).

In [8], the authors carry out a comparative study of the AOMDV protocol (Ad Hoc On-demand Multipath Distance Vector) along with the standard AODV (as implemented in the ns-2.34 network simulator) and two tuned-AODV proposals, the first as specified in the RFC 3561 and the second based on a PDR optimization strategy. The results show that AOMDV gives the best results over the three proposals. However the AOMDV achievements are still poor and are not sufficient for high quality QoS communications. In [9], the authors propose the AODV-BD, a cross layer technique which provides the AODV routing protocol with channel security from link layer level to improve the communication in vehicles for safety purposes. This reduces the packet delay and makes routes more stable but some problems such as search latency may degrade the performance of interactive applications and the quality of a path is not known a priori. The AODV-RLT routing protocol proposed here applies a three-step optimization policy in route discovery and route selection to maximize the expected route lifetime. This policy uses both node speeds and the distances between the nodes to achieve the required optimization.

The Ant-DSR, introduced in [10], implements a distributed topology discovery mechanism through mobile agents to maintain DSR cache. The use of the slight Ant-agent packets limited the diffusion of RREQs without overloading the network. In [11], the authors proposed the E-DSR protocol to improve the route maintenance of DSR using two levels of thresholds: the battery power given by each node at the primary route and the signal power received by each intermediate node at all time. When the battery power or/and the received signal power of any node fall, the node informs the source to select the most fresh route in its route cache and to remove the outdated routes. If the route cache becomes empty the source starts a new route discovery to avoid link breakage. In [12] the authors propose the DSR-TTL which improves the conventional DSR routing protocol using TLL based scheme. As each protocol has its own time to live (TTL), this value was changed to find which get along with the DSR protocol.

3. DESIGN OF AODV-RLT AND DSR-RLT PROTOCOLS

This section introduces the Route Life Time policy concept and rules, then the basics of the AODV-RLT and DSR-RLT VANET routing protocols are presented. The AODV and DSR protocols were selected as it is well-known that the reactive routing operation is most suitable then the proactive one for VANETs characterized by frequent topology changes.

3.1 The Route Life Time (RLT) Policy

The RLT policy, first proposed in [5] seeks the optimal choice of next-hop based on the node's speed and the inter-node distances and this for a given approximation of the optimal number of hops in a VANET. Indeed, when integrated to a routing operation, this policy tries to find an optimal choice of next hop (relay node) in order to maximize the associated link lifetime and hence the overall route lifetime. This optimal choice can be reasonably approximated from the knowledge of the transmission range and the position of source and destination nodes obtained from receiver's Global Positioning System (GPS).

Let's consider an infinitely long straight highway with L lanes where vehicles are travelling in a straight line and let's consider the VANET formed by only those vehicles that are moving on the same side of the highway. It is assumed that nodes spread out along the highway such that in a sufficiently small neighborhood of any point on a lane one can always find at least one node on the same lane. It is also assume that the width of the lanes is negligible when compared to the transmission range of mobile nodes along the length of the highway, which is the straight line communication assumption.

Each lane l, ($1 \leq l \leq L$) has an associated speed limit s_l with the convention that $s_1 < s_2 < \ldots < s_L$. It turns out that all nodes move on the highway with a discrete set of speeds restricted by the individual speed limit of their corresponding lane. Now, when a node transits to an adjacent lane its speed moves to the value associated with the new lane.

Let's now consider the established route between a source node, Node 0 and a destination node, Node (M+1). That is a route composed of M relay nodes as illustrated on Fig. 1.

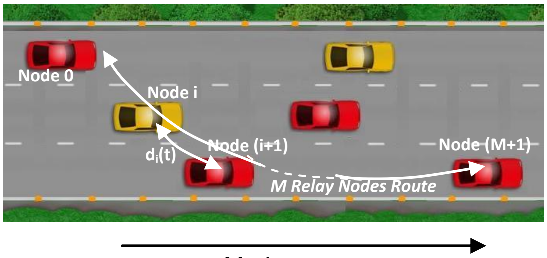


Fig 1: Node placement

Let's now consider any two successive nodes Node i and Node (i+1) on this route moving with the respective velocities $v_i(t)$ and $v_{i+1}(t)$. The quantity $d_i(t)$ $0 \leq i \leq M$ is defined to be the distance between these two successive nodes at time t with the assumption that they are apart by a distance d at time zero, i.e $d_i(0)=d$. It is also assumed that these two successive nodes are initially in lane k and lane l respectively, which means that $v_i(0)=s_k$ and $v_{i+1}(0)=s_l$. (where s_k and s_l are the speed limit of lane k and lane l respectively).

Given this framework, the link lifetime between the successive nodes Node i and Node (i+1) is defined in [5] by the quantity T (d, v_i,v_{i+1}) which expresses the expected time after which the link between these two nodes breaks.

For a route consisting of (M+1) links, the problem is to find both an optimal inter-node distance assignment, denoted by $d^* = (d_0, \ldots, d_{M-1})$ and an optimal speed assignment, denoted by $v^* = (v_1, \ldots, v_M)$, to the M relay nodes such that the maximum route lifetime is achieved. Thus, the RLT policy seeks the optimal distance and speed vectors, i.e d^* and v^*, allowing maximizing the least of the link lifetimes of the established route. This optimization problem is then defined by the following equations:

$$\underset{v,d}{Maximize}\ \underset{i=0..M}{Minimize}\ T(d_i, v_i, v_{i+1}) \qquad (1)$$

$$\underset{v,d}{Minimize}\left[\sum_{j=0}^{M}(T(d_j,v_j,v_{j+1}))^{-\alpha}\right]^{\frac{1}{\alpha}} \quad (2)$$

Since the time the RLT policy has been proposed, VANET node architecture did evaluate so that the typical transmission range varies between 280 and 400 meters. This makes it possible to extend the RLT policy for both sides of a highway, as illustrated in Fig 2.

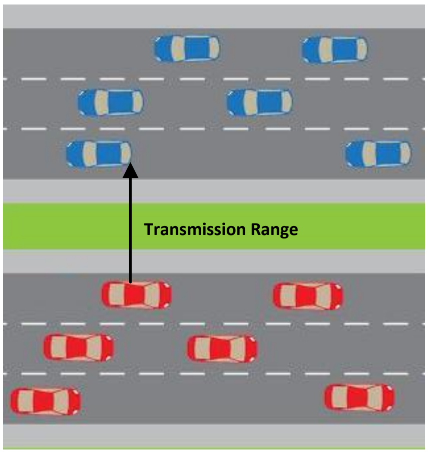


Fig 2: Cars layout (two highway sides)

3.2 The AODV-RLT Routing Protocol

The AODV-RLT keeps all the operation fashion of the AODV routing protocol, which is a reactive routing protocol. On the receipt of a packet, a source does initiate a query to establish a route to the destination, using four types of control messages [13]: Route Request (RREQ), Route Reply (RREP), Route Acknowledgment (RREP-ACK) and Route Error (RERR) messages. When a source has data to transmit to an unknown destination, it broadcasts a Route Request (RREQ) for that destination. At each intermediate node, when a RREQ is received a route to the source is created. If the receiving node hasn't got this RREQ before, that it is not the destination and does not have a current route to the destination, it rebroadcasts the RREQ. If the receiving node is the destination or has a current route to the destination, it generates a Route Reply (RREP). The RREP is unicast in a hop-by-hop fashion to the source. As the RREP propagates, each intermediate node creates a route to the destination. When the source receives the RREP, it records the route to the destination and can begin sending data. If multiple RREPs are received by the source, the route with the shortest hop count is chosen. If a failure in the route is detected during the data transfer, a Route Error (RERR) is sent to the source of the data in a hop-by-hop fashion. As the RERR propagates towards the source, each intermediate node invalidates routes to any unreachable destinations. When the source of the data receives the RERR, it invalidates the route and re-initiates the route discovery process.

What is new with the AODV-RLT is that this protocol starts with a VANET layout fulfilling the RLT policy requirements (Highway and Lane layout, vehicles" speeds …) and continue to make sure they are still respected during the routing operation process. To do so, the AODV-RLT executes the computations defined by the Eqs (1) and (2) on the defined VANET topology.

3.3 The DSR-RLT Routing Protocol

In a same manner the DSR-RLT protocol acts as the DSR protocol [14] in establishing a route for a date packet to be send on the VANET. Indeed, in a reactive operating mode, the source does initiate a Route Request packet. This Route Request is flooded throughout the network. Each node, upon receiving a Route Request packet, rebroadcasts the packet to its neighbors if it has not forwarded it already, provided that the node is not the destination node and that the packet's time to live (TTL) counter has not been exceeded. Each Route Request carries a sequence number generated by the source node and the path it has traversed. A node, upon receiving a Route Request packet, checks the sequence number on the packet before forwarding it. The packet is forwarded only if it is not a duplicate Route Request. The sequence number on the packet is used to prevent loop formations and to avoid multiple transmissions of the same Route Request by an intermediate node that receives it through multiple paths. Thus, all nodes except the destination forward a Route Request packet during the route construction phase. A destination node, after receiving the first Route Request packet, replies to the source node through the reverse path the Route Request packet had traversed. Nodes can also learn about the neighboring routes traversed by data packets if operated in the promiscuous mode (the mode of operation in which a node can receive the packets that are neither broadcast nor addressed to itself). This route cache is also used during the route construction phase.

The DSR-RLT applies the same strategy to the native DSR as the ADOV-RLT does to the native AODV.

4. EVALUATION THE AODV-RLT AND DSR-RLT IMPLEMENTATIONS

To proceed with the evaluation of the AODV-RLT and DSR-RLT routing protocols proposed to enhance the routing operation in VANETs, their new respective packages were developed and integrated to the ns-2.34 network simulator. In this section the simulation model and parameters are presented, along with the performance results.

4.1 Simulation Model and Parameters

The defined VANET topology is illustrated on Fig 3. with the following characteristics: two lanes in each direction of the highway, i.e L=2, with respective speeds s_1=14m/s and s_2=28 m/s (which correspond to s_1=50km/h and s_2=100 km/h respectively, to keep within the world allowed speeds [15]). The transmission rage of a node varies between 280 and 400 meters.

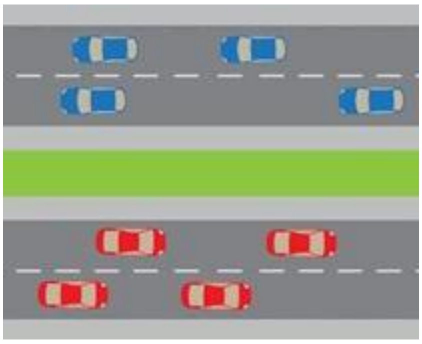


Fig 3: Cars layout (two highway sides)

The various simulation parameters are listed in Table I below.

Table 1. Simulation parameters

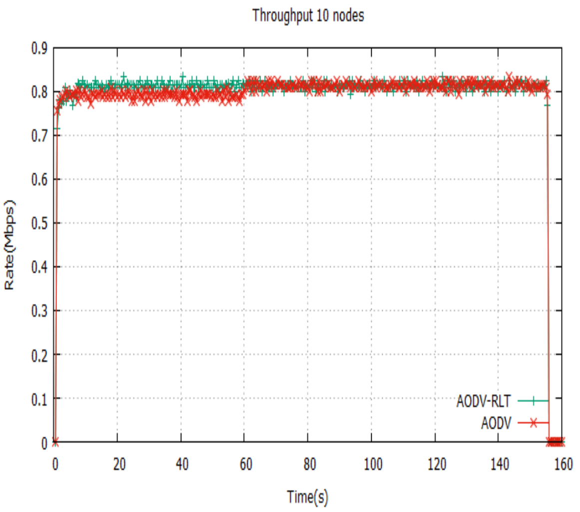
Parameter	Value
MAC layer	MAC IEEE 802.11
Node buffer size	50 packets
Propagation model	Two Ray Ground
Network bandwidth	2 Mbps
Communication ray	280 - 400 m
Network grid	1000x1000 m
Simulation time	160 seconds

A Constant Bit Rate (CBR) traffic generator is used over a User Datagram Protocol (UDP) protocol to initiate three bidirectional connections. The Network throughput is chosen to be the performance indicator in this study, as it is the major performance metric for the evaluation of a routing protocol.

The network node numbers varies as follows: 10, 20 and 30 nodes to assess the impact of the network density on the AODV/DSR-RLT performance.

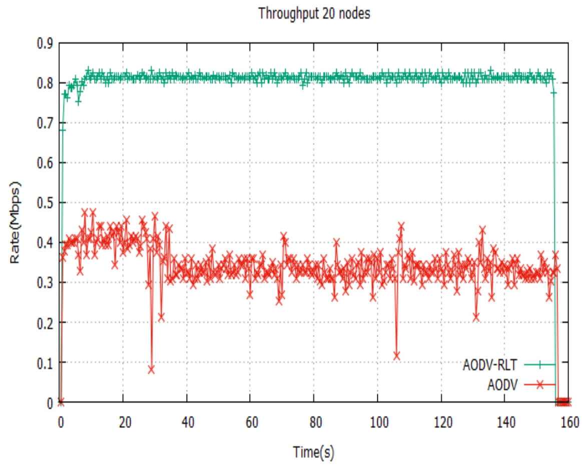
4.2 AODV-RLT Performance

As shown in Fig. 4-(a)-(b)-(c), ADOV-RLT keeps a stable throughput. The number of nodes as increases since the nodes' positions is pre-computed according to the RLT policy.

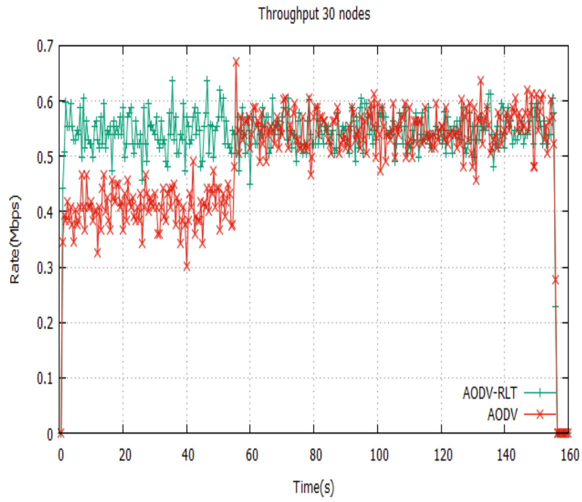


(a) –Network throughput – 10 nodes

The network throughput results demonstrate that AODV-RLTLT succeeds to keep a stable network throughput whereas AODV causes network degradation as the number of nodes increases especially at the beginning of the transmission. This confirms the effectiveness of the RLT policy operation within AODV-RLT to maintain thehe established route as long as possible.



(b) –Network throughput – 20 nodes

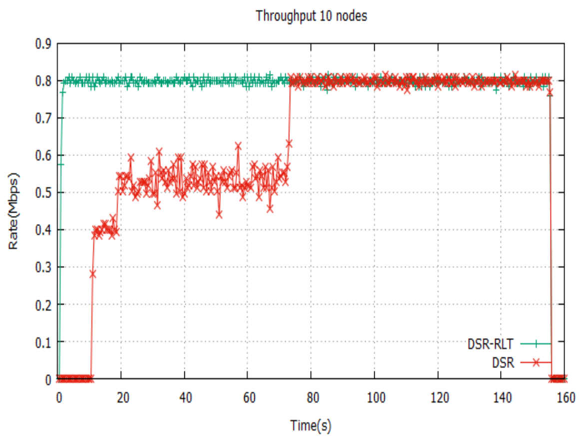


(c) –Network throughput – 30 nodes

Fig 4: Network throughput

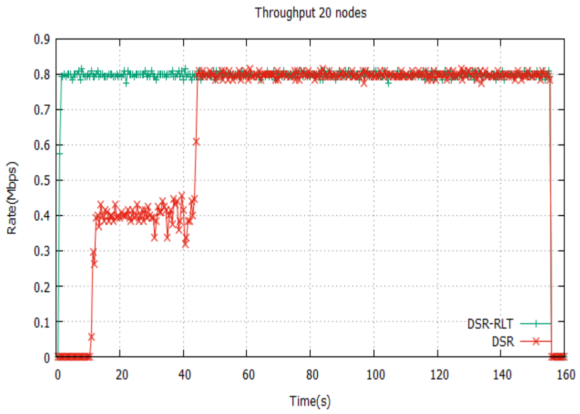
4.3 DSR-RLT Performance

As shown in Fig. 5-(a)-(b)-(c), DSR-RLT keeps also a stable throughput compared to DSR.

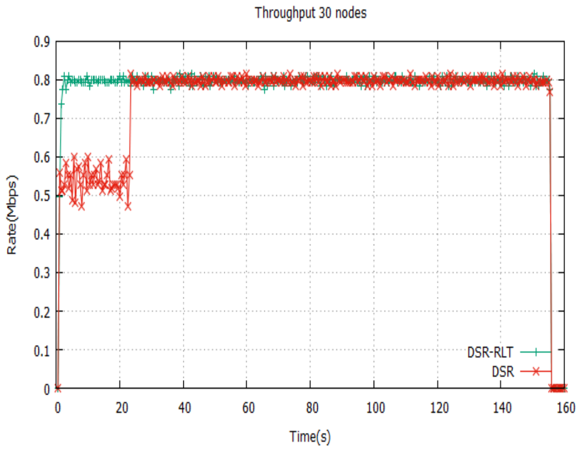


(a) –Network throughput – 10 nodes

The network throughput results demonstrate that DSR-RLT succeeds to keep a stable network throughput whereas DSR encounters difficulties when the simulation starts. Then the network throughput increases to reach the same level as DSR-RLT.



(b) –Network throughput – 20 nodes



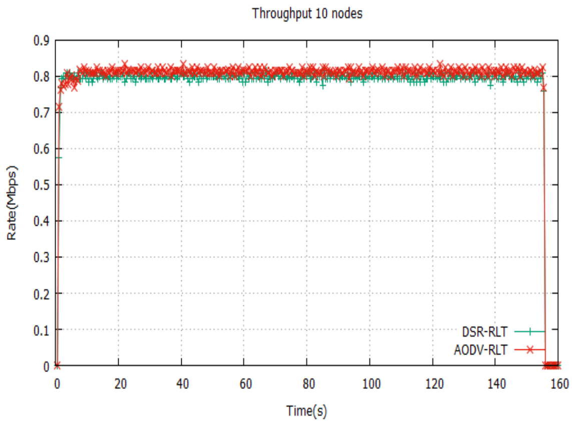
(c) –Network throughput – 30 nodes

Fig 5: Network throughput

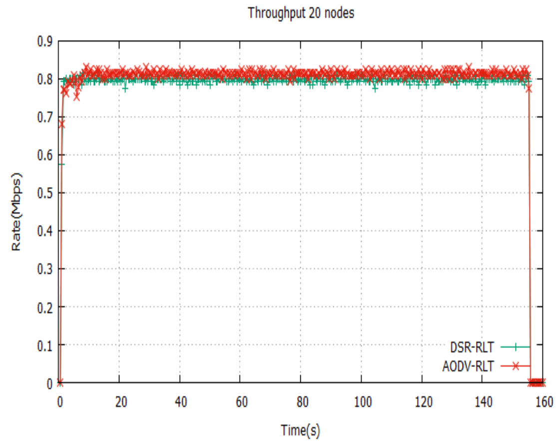
4.4 AODV-RLT vs DSR-RLT

The results demonstrate that the RLT policy enhance the establishment of route between the source and the destination in both AODV and DSR. Thus it is interesting to compare the two novel routing protocols.

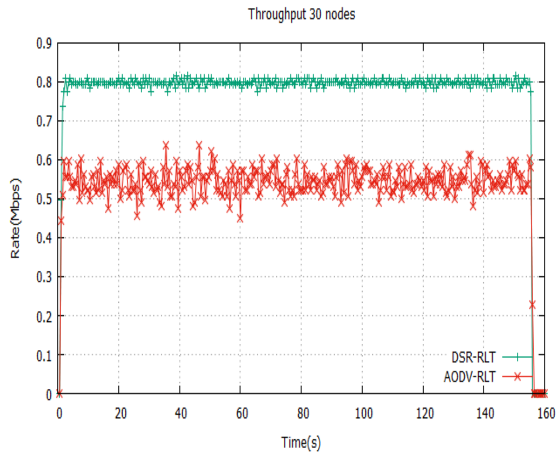
As shown in Fig. 6-(a)-(b)-(c), AODV-RLT and DSR-RLT offer almost the same flow rate with a slight increase for AODV-RLT in the case of 10 and 20 nodes. But with 30 nodes, DSR-RLT outperforms AODV-RLT. This noteworthy enhancement shows better performance of DSR-RLT in a realistic environment especially in a crowded highway.



(a) –Network throughput – 10 nodes



(b) –Network throughput – 20 nodes



(c) –Network throughput – 30 nodes

Fig 6: Network throughput

5. CONCLUSION AND FUTURE WORK

In this paper a preliminary evaluation of the AODV-RLT and DSR-RLT routing protocols for VANETs is presented. These protocols are improvements of the respective generic routing protocols using the Route Lifetime strategy and yield an increase in the lifetime of an established route between the source and the destination.

Performance results obtained with AODV-RLT show that it gives a more stable network throughput. Besides, it is well noticed that DSR-RLT gives better performance than AODV-RLT in a more realistic VANET environment. The VANET routing protocol comparative study presented in [16] has shown that the DSDV (Destination-Sequenced Distance Vector) routing protocol outperforms both AODV and DSR for the average throughput. In the light of this result, a next step will be to integrate the RLT policy to the DSDV routing protocol in order to adapt it to VANET context and to evaluate the three routing protocols i.e. AODV-RLT, DSR-RLT and DSDV-RLT by respect to the performance metrics: packet delivery ratio, average throughput and average end to end delay.

6. REFERENCES

[1] F. Li and Y. Wang. "Routing in vehicular ad hoc networks: A survey". IEEE Vehicular Technology Magazine, Vol. 2, pp.12–22, February 2008.

[2] B.N. Karp and H.T. Kung. "GPSR: Greedy Perimeter Stateless Routing for Wireless Networks". In Proc. MobiCom, Boston, MA, USA, pp. 243-254, August 2000.

[3] E.M. Royer and C.-K. Toh, "A Review of Current Routing Protocols for Ad-Hoc Mobile Wireless Networks". IEEE Personal Communications Magazine, Vol. 6, pp. 46-55, April 1999.

[4] F. Zhao and al."Comparison of analytical and measured performance results on network coding in IEEE 802.11 ad-hoc networks", International Symposium on Network Coding (NetCod), pp. 43-48, June 2012.

[5] D. Kumar, A. A. Kherani, E. Altman. "Route Life time based Interactive Routing in Intervehicle Mobile Ad Hoc Networks", Research Report, INRIA, France, September 2005.

[6] B. Ding, Z. Chen, Y. Wang and H. Yu, "An Improved AODV Routing Protocol for VANETs", 5th Int. Conf. on Wireless Communications, Networking and Signal Processing (WiCSP), pp. 1-5, November 2011.

[7] J. Ledy and al. "An Enhanced AODV Protocol for VANETs with Realistic Radio Propagation Model Validation", 9th Int. Conf. on Intelligent Transport Systems Telecommunications (ITST'09), pp. 398-402, October 2009.

[8] J. Ledy, A. -M. Poussard, R. Vauzelle , B. Hilt and H. Boeglen, "AODV enhancements in a realistic context", Int. Conf. on Wireless Communications in Unusual and Confined Areas (ICWCUCA), pp. 1-5, August 2012.

[9] A. Mor, "A Study of improved AODV routing protocol in VANET", Int. J. of Computer Applications & Information Technology, Vol. 2, January 2013.

[10] Aissani, M. ; Fenouche, M. ; Sadour, H. ; Mellouk, A., "Ant-DSR: Cache Maintenance Based Routing Protocol for Mobile Ad-Hoc Networks", The Third Advanced International Conference on Telecommunications (AICT 2007), May 13-19, 2007, Morne, Mauritius.

[11] Kumar. C. ; Kumar. G. ; Rani. P., "Efficient-dynamic source routing (E-DSR)", International Symposium on Communications and Information Technologies (ISCIT), 2-5 Oct. 2012, Gold Coast, Australia.

[12] Tambuwal, A.B. ; Noor, R.M. ; Michael, O, "Improvement of DSR routing protocol using TTL-based scheme in Mobile Ad Hoc Networks", IEEE International Conference on RFID-Technologies and Applications (RFID-TA), 4-5 September 2013 Johor Bahru, Malaysia.

[13] C. Perkins, E. Belding-Royer, S. Das, RFC 3561, " Ad hoc On-Demand Distance Vector (AODV) Routing", July 2003.

[14] D. Johnson, Y. Hu, D. Maltz, RFC 4728, "The Dynamic Source Routing Protocol (DSR) for Mobile Ad Hoc Networks for IPv4", February 2007.

[15] http://www.legipermis.com

[16] R. Mstafa, A. Alarabe, E. A. A. Odeh and M. Alshowkan, "Analysis of Routing Protocols over VANET", ASEE Northeast Section Conference, March 2013.