Evaluating VANET Routing in Urban Environments

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***Abstract*—Vehicular Ad-hoc Networks (VANETs) are a class of Mobile Ad-hoc Networks (MANETs) incorporated into moving vehicles. Nodes communicate with both and infrastructure to provide Intelligent Transportation Systems (ITS) for the purpose of improving safety and comfort. Efficient and adaptive routing protocols are essential for achieving reliable and scalable network performance. However, routing in VANETs is challenging due to the high-speed movement of vehicles, which results in frequent network topology changes. This paper provides an in-depth evaluation of three well-known MANET routing protocols, AODV, OLSR and GPSR, in VANET with urban environment setup. We compare their performance using three metrics: drop burst length (DBL), delay and delivery ratio (PDR). The simulations are carried out using NS2 and SUMO simulators platforms, with scenarios configured to reflect real-world conditions. The results show that OLSR is able to achieve a shorter DBL and demonstrates higher PDR performance comparing to AODV and GPSR under low network load. However, with GPSR, the network shows more stable PDR under medium and high network load. In term of delay it is outperformed by GPSR, which delivers packets with the shortest delay.**

***Keywords*—VANETs, Routing, AODV, OLSR, GPSR.**

I. INTRODUCTION

In the last few years, VANETS have become an key research topic due to increasing demand for technology to make roads safer and manage traffic, alongside the possibilities for in-car entertainment and communication. VANETS represent a class of Mobile ad hoc networks (MANETS) where nodes (vehicles) rapidly come into and out of communication range. Vehicles in VANETS act as routers, sending, receiving and forwarding packets between each other to provide Intelligent Transportation Systems (ITS) that help avoid congestion on and to provide safer roads. Vehicles establish wireless communication with other vehicles (V2V) and with fixed Road Side Units (RSUs) (V2I). RSUs take part in both the wireless and wired networks and provide connectivity to the Internet [1]. Network topology in VANETs changes frequently, but the changes are sometimes predictable with vehicle velocity partly constrained by roads, traffic congestion, driver behaviour and traffic signals. The challenges for urban VANETs also include signal interference and blocking by buildings. Communication links exist between vehicles for only short-lived times. which affects the performance of VANET applications.

VANET performance is partly governed by the routing protocol that determines how packets are forward from node to node. VANETs usually employ traditional MANET routing protocols such as Optimized Link State Routing protocol (OLSR), Ad hoc on Demand Distance Vector Routing (AODV) and Greedy Perimeter Stateless Routing (GPSR). These protocols belong to three different classes (reactive, proactive and position-aware) and they perform well in multi-hop wireless ad-hoc networks. However, the rapid network topology change and the affects of signal attenuation means that established paths do not stay valid for long and the recomputation of the path affects the application traffic performance.

In this paper we evaluate three different routing protocols (OLSR, GPSR, AODV) in a VANET urban environment. We measure the performance of the protocols through the perceived performance of the applications being delivered by the network. As well as the traditional metrics of delay and packet delivery ratio (PDR), we examine the distribution of drop burst lengths (DBL). This provides with a better indication as to the effects of performance the QoS of real-time traffic.

II. BACKGROUND AND RELATED WORK

Routing protocols in VANET are categorised into two main classes of position-based and topology-based protocols. A separate classification is into reactive (on-demand) and proactive (table-driven). Topology-based protocols use link state information in the network to deliver packets to their destinations, While position based protocols utilise geographical position of the intermediate nodes[2]. In reactive routing protocols (e.g. AODV[3]), a path is established when it is needed. This allows nodes to communicate with each other and maintain routes in use. This reduces the amount of network overhead that caused by broadcasting routing information. The proactive technique (e.g. OLSR [4]) determines routes to all nodes in the network in advance by store these routes in one or several routing tables, hence, routes to all nodes always available whenever they needed. Nodes in a topology based update their routing tables periodically in order to discover all routes by exchanging routing messages. As a result, the route update process causes large network overhead. Position-based routing protocols (e.g. GPSR[5]) utilise geographical information for each node in topology to make all routing decisions, thus, each node needs to announce its position, to do that, each node periodically broadcast small packets called beacons contain geographical information of the node. Increase node velocity lead to inaccurate position information

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and high topology changing rate could cause route disconnect. Furthermore, position-based protocols work well in dense networks. However, they fail in sparse networks due to some regions without nodes (voids).

For simulation to be effective to evaluate the performance of a network it must be configured to be representative of reality. Factors that increase simulation realism in the case of VANETS are the application network traffic model, the mobility model, the network traffic model and a model of the impact of an urban area obstacles on radio signals. One or more of these is often neglected, consequently, results are less likely to be truly representative.

Rani et al.[6] used only V2V network topology. While the authors in [7] used a heterogeneous network model, they propose the vehicle node density parameter to improve the performance of the AODV routing protocol and OLSR routing protocol under two different scenarios; however, they do so in the absence of a realistic MAC protocol and fading propagation model for VANETs environment, 802.11g standard was configured and 1440B as a packet payload. In [8], the authors employed various numbers of nodes up to 120 nodes moving within the real map of US census Bureau, they consider a realistic fading model that reflects the impact of obstacles on radio signal and IEEE 802.11p was configured. However, only light network load has been taken into account and the network traffic was picked up randomly and do not represent a VANET application. Similar works also neglect the affects of representative network traffic [9], [10]. Furthermore, the authors present the performance evaluation of AODV, OLSR and DYMO routing protocols [11], they configured Two Ray Ground as a propagation model, which is a simple propagation model and do not reflect the impact of an urban environment on wireless signal. A paper by Haerri et al. [12] emphasis on artificial mobility map only and they miss many factors that they have a direct influence on the network performance such as propagation model and VANET application traffic.

Moreover, the majority of the previously mentioned evaluation studies used traditional metrics to measure network performance with different routing protocols such as average end-to-end delay and average packet loss. All these metrics do not fully reflect actual network performance; they measure averages sometimes losing vital information in the calculation.To overcome these issues, we used Drop Burst Length (DBL). This measures the probability of drop a consecutive number of packets in each connection. Real time traffic is more susceptible to burst drops so this metric provides a better indication of performance.

In this paper three routing protocols have been selected as a representative of reactive, proactive and geographic base routing, which are AODV, OLSR and GPSR respectively. They are evaluated through simulation. Our work considers these protocols in a realistic urban environment with two mobility models: an artificial map (Manhattan map) and real world map (part of the London congestion zone).

III. SIMULATION SETUP

To ensure some realism in our simulation we consider the following factors:

a) The network traffic model: the sorts of traffic patterns that applications will put onto the network. Table I presents typical application requirements. In our simulation we employ $10\,\mathrm{s}$ flows of 100 packets. Each simulation is for a fixed length of time with the total number of flows varying from 200 (low) to 1000 (high).

b) The communication model: we employ 801.11p as the MAC layer.

c) Network device topology: We consider each vehicle to be part of the network and for there to be a set of fixed wireless roadside units also forwarding traffic.

d) The vehicle traffic model: we use SUMO (Simulation of Urban MObility (SUMO) framework [13]) on a simple Manhattan squares map and one based on the London congestion zone (Fig. 1). 100 vehicles move at speeds up to $20\,\mathrm{m/s}$, with 13 fixed roadside units.

e) Propagation model: We employ the Nakagami propagation model which has the ability to simulate fading in the wireless channel, using parameters $(m_0, m_1, m_2 = 1.0, use\_nakagami\_dist\_ = false, \gamma_0, \gamma_1, \gamma_2 = 2.0$ and $d_{0\gamma}, d_{1\gamma} = 200, 500$ respectively) [14].

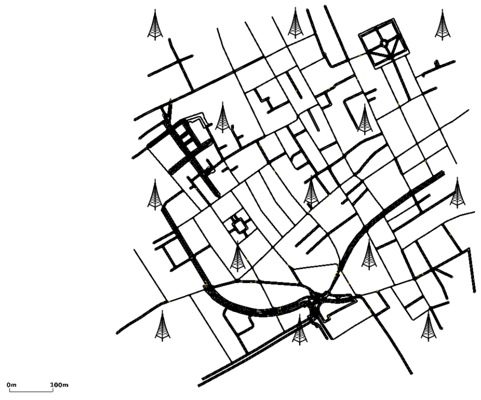


Fig. 1. Part of the London congestion zone with RSUs in SUMO.

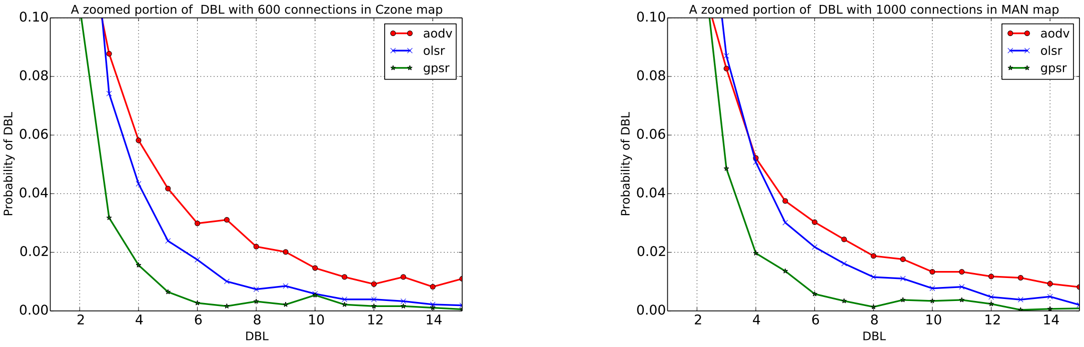
IV. RESULTS, DISCUSSION AND CONCLUSIONS

We analyse network performance using DBL, PDR, C2C delay, all described in section I. Simulations were undertaken with increasing numbers of traffic flows (connections), each flow 100 packets at 10pps, on each map. Each run was performed five times with random source and destination selections for each flow.

Fig. 2 and 3 show the DBL for two loads. We observe the performance of the selected routing protocols (AODV, OLSR and GPSR) is similar on the both maps.

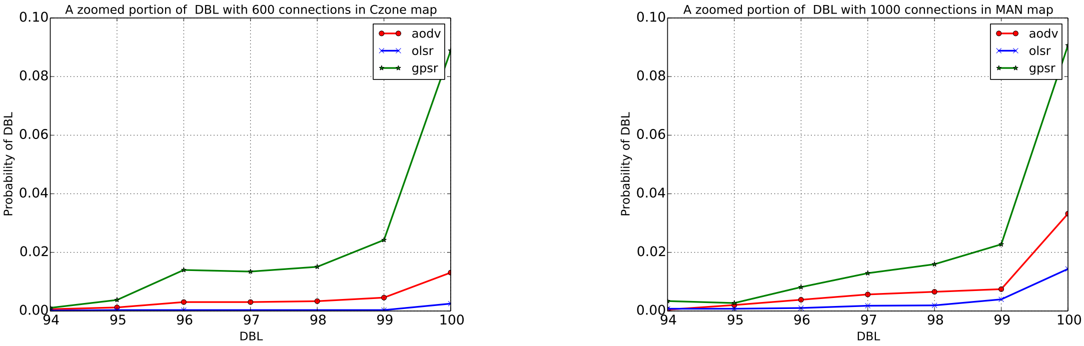
Each protocol shows different performance:

- GPSR achieves the shortest C2C delay because it considers the closest neighbour that has a route to destination. Fig. 4 illustrates CDF of C2C delay in low and high loads.



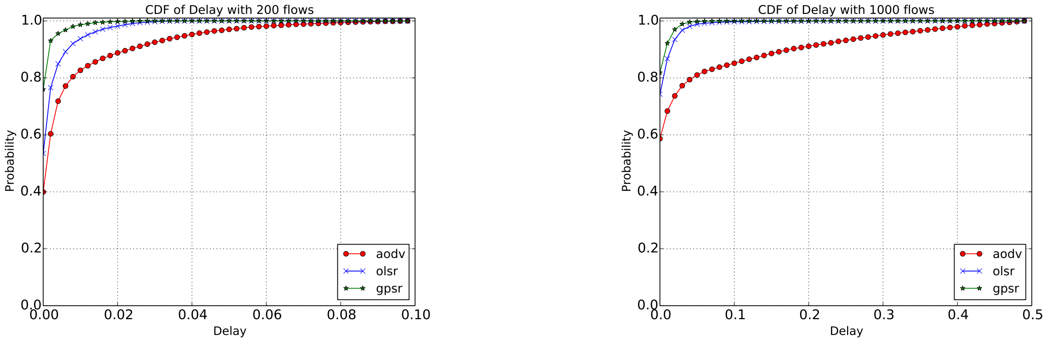
(a) (b)

Fig. 2. Short Drop Burst of AODV, OLSR and GPSR with 600 and 1000 connections (A zoomed portion).



(a) (b)

Fig. 3. Long Drop Burst of AODV, OLSR and GPSR with 600 and 1000 connections (A zoomed portion).



(a) (b)

Fig. 4. CDF of delay for both protocols under light and high network loads.

- With AODV packets take longer to be delivered under different network load on both maps. These longer delays are due to its route initialisation mechanism, it takes time to set-up a route to destination (sending a RREQ and waiting for a RREP). This leads to packets being queued and dropped before transmission and the probability of dropping consecutive packets with AODV increases along the simulation.
- OLSR provides a route to a destination immediately, and source node with GPSR already has the closest neighbour that has a route to destination, this can give an advantage for those protocols over AODV in terms of delay and DBL, especially at the start of the connection.
- Using DBL we observe that long packet burst drops are avoided. This is because OLSR recovers a broken route quickly when a failure is detected.
- GPSR shows a worse performance in term of DBL. The probability of dropping the entire flow is much higher compared with AODV and OLSR, see Fig. 3.
- OLSR outperforms AODV & GPSR in terms of DBL and PDR under low network load. However, as load increases, the performance reduces as the drop ratio on MAC layer

TABLE I. Some examples of VANET applications requirements[15]. [SC=Saftey Critical, CRS=Cooperative Road Safety, TM=Traffic Management, CM=Commercial, CO=Connection-oriented,CL=Connection-less,LW=Light-weight,HW=Heavy-weight(IP)]

Application	**Category**	**Conn. mode**	**Allowable latency (ms)**	**Minimum message freq. (Hz)**	**Transport protocol**	**Packet Format**
Braking Warning	SC	V2X	100	10	CL	LW
Emergency vehicle warning	SC	V2X	100	10	CL	LW
Roadwork warning	CRS	I2V	100	2	CL	LW
Weather condition	CRS	V2V	500	2	CO	HW
Intersection management	TM	I2V	500	2	CL	LW
Time to traffic light change	TM	I2V	100	1–10	CL	LW
Electronic commerce	CM	I2V	500	1	CO	HW
Media downloading	CM	I2V	500	1	CO	HW

TABLE II. Drop ratio on both MAC and Network layers

AODV	Manhattan			Czone		
	Delivered	Dropped		Delivered	Dropped	
Load	%	NR	MAC	%	NR	MAC
200	57	63	36	63	67	33
400	30	74	25	37	76	24
600	22	80	20	27	79	20
800	19	82	17	24	83	16
1000	17	84	15	20	84	15
OLSR	Manhattan			Czone		
	Delivered	Dropped		Delivered	Dropped	
Load	%	NR	MAC	%	NR	MAC
200	67	18	82	67	18	81
400	53	16	84	59	13	86
600	39	31	69	44	21	79
800	31	41	59	32	36	64
1000	27	48	52	27	44	55
GPSR	Manhattan			Czone		
	Delivered	Dropped		Delivered	Dropped	
Load	%	NR	MAC	%	NR	MAC
200	53	60	40	44	50	50
400	45	40	59	41	33	67
600	42	37	63	36	28	71
800	42	32	68	31	21	79
1000	39	32	68	31	23	77

increases

- With AODV, the poor performance of the network is due to unavailability of routes to the next hop (NR), so drop ratio increases on network (routing) layer as shown in the Table II. AODV failed to calculate paths from source to destination under high network load as a consequence of incapability of handling the growth in routes demanding.
- Despite the weakness with GPSR performance in terms of PDR under low network load, it shows a stable performance under medium and high network load compared with AODV and OLSR, the reasons behind inefficiency with GPSR are due to MAC gets busy alongside increase network load and failure in providing routes to destinations because of mobility pattern.

Our results indicate that the variation of the selected urban maps have little influence the performance network traffic for these simulations.

Using our performance metric (DBL) we find OLSR outperforms AODV and GPSR. With OLSR packet drops more commonly due to a busy MAC layer with AODV the failure to establish a path to the destination. With GPSR the network experiences a stable performance and the delay is the shortest among other protocols.

While no protocols provide all the requirements of a safety critical system we have established a mechanism for measurement and a path for future research on hybrid active/location aware protocols.

REFERENCES

[1] S. Zeadally, R. Hunt, Y.-S. Chen, A. Irwin, and A. Hassan, "Vehicular ad hoc networks (VANETS): status, results, andchallenges," *Telecommun. Syst.*, vol. 50, no. 4, pp. 217–241, dec 2010.

[2] F. Cunha, L. Villas, A. Boukerche, G. Maia, A. Viana, R. A. F. Mini, and A. A. F. Loureiro, "Data Communication in VANETs: Survey, Applications and Challenges," *Ad Hoc Networks*, pp. 1–12, 2016.

[3] C. Perkins and E. Royer, "Ad-hoc on-demand distance vector routing," in *Proc. WMCSA'99. Second IEEE Work. Mob. Comput. Syst. Appl.*, no. 3, 2009, pp. 90–100.

[4] P. Jacquet, P. Muhlethaler, T. Clausen, A. Laouiti, A. Qayyum, and L. Viennot, "Optimized link state routing protocol for ad hoc networks," in *Multi Top. Conf. 2001. IEEE INMIC 2001. Technol. 21st Century. Proceedings. IEEE Int.* Ieee, 2001, pp. 62–68.

[5] B. Karp and H. T. Kung, "Gpsr," *Proc. 6th Annu. Int. Conf. Mob. Comput. Netw. - MobiCom '00*, pp. 243–254, 2000.

[6] P. Rani, N. Sharma, and P. K. Singh, "Performance comparison of VANET routing protocols," in *7th Int. Conf. Wirel. Commun. Netw. Mob. Comput. WiCOM 2011*, 2011, pp. 1–4.

[7] J. Zuo, Y. Wang, Y. Liu, and Y. Zhang, "Performance evaluation of routing protocol in VANET with vehicle-node density," in *2010 6th Int. Conf. Wirel. Commun. Netw. Mob. Comput. WiCOM*, 2010.

[8] I. Khan and A. Qayyum, "Performance evaluation of AODV and OLSR in highly fading Vehicular Ad hoc Network environments," in *INMIC 2009 - 2009 IEEE 13th Int. Multitopic Conf.*, 2009, pp. 1–5.

[9] R. Bala and C. R. Krishna, "Scenario based performance analysis of AODV and GPSR routing protocols in a VANET," *Proc. - 2015 IEEE Int. Conf. Comput. Intell. Commun. Technol. CICT 2015*, pp. 432–437, 2015.

[10] E. Spaho, M. Ikeda, L. Barolli, and F. Xhafa, "Performance comparison of OLSR and AODV protocols in a VANET crossroad scenario," *Lect. Notes Electr. Eng.*, vol. 253 LNEE, pp. 37–45, 2013.

[11] E. Spaho, L. Barolli, G. Mino, F. Xhafa, V. Kolici, and R. Miho, "Performance Evaluation of AODV, OLSR and DYMO Protocols for Vehicular Networks Using CAVENET," in *2010 13th Int. Conf. Network-Based Inf. Syst.*, 2010, pp. 527–534.

[12] C. Haerri, J. and Filali, F. and Bonnet, "Performance comparison of AODV and OLSR in VANETs urban environments under realistic mobility patterns," in *Proc. 5th IFIP Mediterr. Ad-Hoc Netw. Work.*, no. i, 2006, pp. 14–17.

[13] M. Behrisch, L. Bieker, J. Erdmann, and D. Krajzewicz, "SUMO - Simulation of Urban MObility - an Overview," *Proc. 3rd Int. Conf. Adv. Syst. Simul.*, no. c, pp. 63–68, 2011.

[14] M. Nakagami, "The m-distribution - A General Formula of Intensity Distribution of Rapid Fading," *Stat. Methods Radio Wave Propag.*, pp. 3–36, 1960.

[15] D. O. T. Hs, "Vehicle Safety Communications Project Task 3 Final Report," Tech. Rep. March, 2005.