VDTN-ToD: Routing Protocol VANET/DTN Based on Trend of Delivery

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***Abstract*—Providing access to the Internet or other network services to remote regions with low population density is quite complicated, since telecommunications companies may be unwilling to invest in a communications infrastructure in these locations. A possible solution to this problem is using Vehicular Ad-hoc Networks (VANET) with Delay Tolerant Networks (DTN) architecture in order to provide Internet access and other services to these regions. This is quite a challenging task because it is really difficult to predict when vehicular nodes will be in contact with each other and how long it will remain connected. In this paper , we are proposing a unique VANET/DTN routing strategy based on a new metric called Trend of Delivery (ToD). The results have shown that our proposition had better performance than other classical DTN protocols when applied to VANET. We used the Network Simulator 3 (ns-3) to implement classical DTN protocols as: Epidemic, Prophet and Spray-and-Wait in order to compare with our proposition. The simulation shows a good performance of the proposed strategy, maintaining good delivery rate while keeping overhead low, unlike purely epidemic strategy, where the overhead increases uncontrollably.**

Keywords-VANET; DTN; Routing Protocol; Fuzzy Logic; ns-3; Trend of Delivery;

I. INTRODUCTION

DTNs are a special class of networks that allow communication between regions with strong connectivity constraints, propagation delays and high error rates. In these regions, there is no way to use reliable communication and routing protocols or common standards for wireless networks as has been shown by Sadagopan et al. [1].

To overcome these constraints, the RFC4838 [2] propose that the DTN architecture can store persistent messages in a new network layer named the bundle layer until the node connectivity could be restored. This layer can provide communication between heterogeneous networks operating at different transmission media.

In the environment where we want to provide communication between the distant regions using the VANET/DTN, the Epidemic protocol [20] may achieve a high delivery rate, but its overhead is too high. The Spray-And-Wait [22] keeps overhead low, but its delivery rate may not be practical, because it controls flooding by reducing the number of copies to be made. However it does not use any smart strategy to know when it is appropriate to copy. The PROPHET [21] may have performance issues if there is no reencounters, since it is based on historical encounters.

In our paper, we propose a new VANET/DTN routing strategy, based on a new metric called the Trend of Delivery, which was created especially for this work by using fuzzy logic, in order to assist in the routing task. We also consider other recommendations proposed by Cabrera et al. [3] (the transmission range assumption, use of stale information, and an objective function in trajectory-based routing) for the development of our DTN routing protocol in order to satisfy operating constraints in a real environment. This protocol has been named the Vehicular Delay Tolerant Network - Trend of Delivery (VDTN-TD).

Bromage et al. [28] proposed a DTN routing framework based on epidemic behavior and mobility history of the nodes called the Trajectory-Assisted Routing (TAROT). In this work, the TAROT nodes only will be infected, in other words, they will receive a copy of the message, if their mobility pattern takes them closer to the destination. According to [28], when the protocol succeeds in combining intelligently replication and forwarding the messages, this leads to a reduction of overhead. Similarly to the TAROT, VDTN-TD reduces the overhead by using an intelligent forwarding strategy.

The remainder of this paper is organized as follows: Section II describes the related works. Section III covers the theoretical foundation, with a quick overview of VANET, DTN and DTN routing. The Section IV describes how ToD is calculed, also it presents VDTN-TD, the routing protocol proposed. The Section V shows the experiments and resultsobtained through simulations in ns-3. Finally, Section VI includes an outlook to future works and the conclusion.

II. RELATED WORK

DTNs are recurrent themes in the literature [3-7]. Many routing protocols have been proposed and they can be classified according to their operations [7]. Franck et al. [8] presented the attributes and requirements for VANET's operation and described how DTN can help to overcome the problems caused by high disconnection in a vehicular network. For this purpose, many tests were performed using nodes with and without vehicular DTN activated in different network conditions. The authors concluded that purely a VANET node has a high rate of packet loss and that even in a scenario with VANET/DTN packet loss is encountered due to routing loops in isolated clusters. This paper uses the combined

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VANET/DTN to overcome disconnection problems inherent in vehicular networks.

Cheng et al. [9] proposed a DTN routing protocol called hybrid GeoDTN+Nav that explored the details of vehicular mobility and navigation systems on-board to carry the messages. According to the authors, the protocol outperforms protocols Greedy Perimeter Stateless Routing [10] and Greedy Perimeter Coordinator Routing [11] by comparing the rates of message delivery.

Besides the VDTN-ToD uses this mobility information, it also uses fuzzy logic [12] to identify mobility patterns and then decide when it is appropriate to: copy, forward or stay with the message.

III. THEORETICAL FOUNDATION

A. Vehicular Ad-hoc Networks

VANETs are a subclass of mobile ad hoc networks that emerged due to the advancement in technology for transmitting wireless networks. One of the main factors that boosted its development was the need to improve safety and traffic efficiency through communication between vehicles. Although similar to a Mobile Ad-hoc Network (MANET), a VANET has specific characteristics that the protocols, developed for MANET, are not suitable for operation in VANETs [13].

In a VANET, two categories of applications can be developed. One is focused on safety and the other should provide comfort to passengers. The first category contributes to improving the efficiency of vehicular traffic and to decrease risk situations such as sending alert messages when an accident occurs. However, the second category's focus is to make the entire trip enjoyable for the passengers. This can be achieved through applications that provide access to the Internet such as, chat with passengers of other vehicles, radios online, games, restaurants or other information relevant to the comfort of the trip [14].

B. Delay Tolerant Networks

DTN is architected by the group Delay Tolerant Network Research Group (DTNRG), a part of the Internet Research Task Force (IRTF), that enables the operation of networks operating in environments with intermittent connectivity and high delays.

In the design of the DTN architecture the following requirements have been proposed: reliable delivery, security services and flexible framework for identification of late binding. In order to attend these requirements, the architecture has included a bundle layer operating above the transport layer, where the packet of this layer is called bundle, permitting the DTN to support intercommunication among heterogeneous networks through the DTN gateways.

The DTN architecture was defined in 2007 by RFC 4838 [2] together with the specifications of the bundle protocol by RFC 5050 [15]. Later, in 2010 and 2011, they were defined in RFCs 6255 [16] and 6257 [17].

In this paper, we aim to establish communication between remote regions, in the sparse environment, using vehicles as data mules [29], as can be seen in Figure 2. A region in the context of DTN, as illustrated in Figure 2, represents a communication network that comprises one or more nodes interconnected via protocols that are exclusive to their communication needs. The DTN is designed to enable communication between different regions through the DTN gateway, using the bundle layer that is able to provide such communication, through specific protocol stacks to each region as shown in Figure 1.

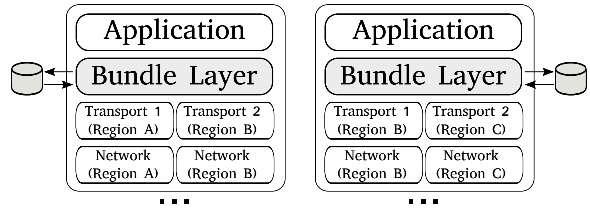

Fig. 1. Example of DTN gateways with protocol stacks specific for different regions

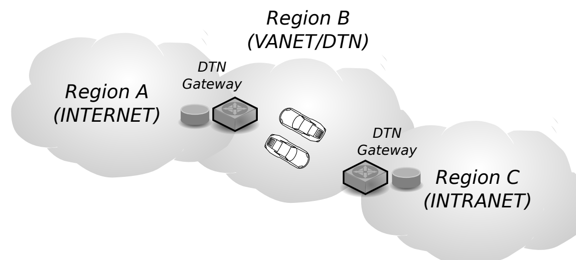

Fig. 2. Communication between remote regions

C. DTN Routing

A route (journey) in DTN is a sequence of communication opportunities, foreseen or unforeseen without guarantee of stability. At each contact, the message can be forwarded, copied or retained. Accordingly, the main goal of a DTN routing protocol is to increase the probability of message delivery while it aims to reduce the end-to-end delay. In challenging environments which the DTN operates, traditional routing protocols like Optimized Link State Routing Protocol (OLSR) and Ad hoc On-Demand Distance Vector Routing (AODV) do not work properly [4]. Therefore, several specific DTN protocols were proposed.

IV. ROUTING PROTOCOL VDTN-TOD

A. Trend of Delivery

Trend of Delivery is based on fuzzy logic that serves to evaluate how the mobility of nodes contributes to the delivery of a message to a fixed destination node. The ToD is composed by three linguistic variables (explained below) that are very important to the decision process, the sense ($\omega_{i,d}$), the distance ($\psi_{i,d}$) and the speed ($\tau_{i,d}$), where i denotes the node with the custody of the message and d is a border gateway of any destination region. Vehicles that possess the custody of messages must decide if the transfer will be effectuated based on these three metrics.

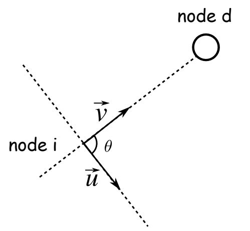

Fig. 3. Representation of the angle between the vector direction of the node and the desired direction vector

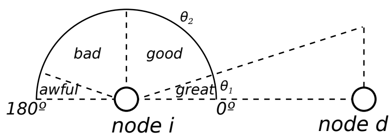

Fig. 4. Representation of categories $great$, $good$, bad and $awful$ for the variable linguistic sense

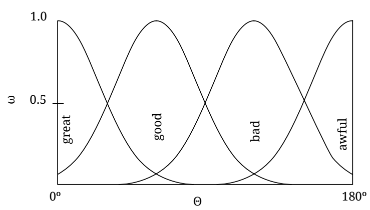

Fig. 5. Categories of variable linguistic sense

1) Sense (ω): The sense is calculated by the node that stores the message when cross with another vehicle. Its value is calculated as a function of the angle Θ formed between the direction vector $\vec{u}$ and the vector turned to the destination node $\vec{v}$, as can be seen in Figure 3. To identify the degree of importance of Θ on the approximation or departure of a node with respect to the destination, in Figure 4, we define the ranges of possible values of Θ. We propose four categories for the sense variable, based on the nebulous identification: $great$, $good$, bad and $awful$. We identify four angles associated with different categories of the sense variable in the range [0°, 180°]. We consider the same range of values for the $great$ and $awful$ classes as also to $good$ and bad classes. It is important to point out that the values of Θ_1 and Θ_2, shown in 4, are defined as a function of distance from the node i to the node d and transmission range (R). Values greater than 180° and less than or equal to 360° can be converted easily to values between 0 and 180 degrees using equation 1.

$$F(x) = 360 - x \quad (1)$$

Where x is Θ_1 or Θ_2. The ranges of the categories of ω (Figure 5) are dynamically defined as a function of the distance from node i to node d and R, this is necessary because when i reaches d the angle Θ_1 (Figure 4) gradually increases. The values of the intervals are defined according to Table I. Note that $\theta_1 + \theta_2 = 90°$.

2) Distance (ψ): For the distance linguistic variable we define four categories, namely: $very\ close$, $close$, far and

TABLE I
THE INTERVALS OF VARIABLE LINGUISTIC SENSE

	left	center	right
$\propto_{great}(x)$	$-\Theta_1$	$0°$	Θ_1
$\propto_{good}(x)$	Θ_1	$\frac{90°-\theta_1}{2}$	$90°$
$\propto_{bad}(x)$	$90°$	$\frac{180°-\theta_1}{2}$	$180° - \theta_1$
$\propto_{awful}(x)$	$180° - \theta_1$	$180°$	$180° + \theta_1$

$very\ far$. The pertinence functions of each variable are defined as follows:

- $very\ close$: $x < R$; $close$: $R < x \leq 2.R$;
- far: $2.R < x \leq 3.R$; $very\ far$: $x > 3.R$

Where R is the value of the transmission range and x is the distance from a node i to the destination.

3) Speed (τ): The velocity used refers to decomposed velocity for the node i ($v_{i,x}$) as the speed that indicates if the vehicle approaches or moves away from the destination. It is calculated according to equation 2.

$$v_{i,x} = v_i.cos(\theta) \quad (2)$$

For the speed linguistic variable we define three categories: low, $medium$ and $high$.

TABLE II
FUZZY RULES FOR SETTING THE TREND OF DELIVERY

		Distance											
		Very Close			Close			Far			Very far		
		Speed			Speed			Velocity			Speed		
		High	Medium	Low	High	Medium	Low	High	Medium	Low	High	Medium	Low
Sense	Great	MA	MA	MA	GR	GR	VG	VG	VG	GO	GO	BA	BA
	Good	MA	MA	MA	VG	VG	GO	GO	GO	BA	GO	BA	BA
	Bad	MA	MA	MA	BA	BA	GO	VB	VB	BA	VB	VB	VB
	Awful	MA	MA	MA	VB	BA	BA	AW	VB	VB	AW	AW	AW

These three linguistic variables $\omega_{i,d}$, $\psi_{i,d}$, $\tau_{i,d}$ are used together in order to infer the ToD using defuzzification by generating a value between 0 and 1. Furthermore, ToD is classified by seven categories: $maximum$ (MA), $great$ (GR), $very\ good$ (VG), $good$ (GO), bad (BA), $very\ bad$ (VB) and $awful$ (AW) as depicted in Table II. The ToD is considered as a maximum when the distance from a node to the destination is smaller than the transmission range.

B. Features and Operation of VDTN-ToD

The protocol VDTN-ToD uses a dissemination scheme and maintenance messages based on the location technique, Adaptive Detection Coverage, proposed by Harri et al. [18]. Each node sends a message to disseminate positioning (m_p) when travels a portion of its transmission radius. In VDTN-ToD, besides sending a message in the same way, the protocol checks in advance if it is really necessary to send a new message positioning taking into account the last positioning message sent. With the present position and speed of the vehicle. It is easy to predict the time at which a new positioning message (mp) must be sent, considering an average

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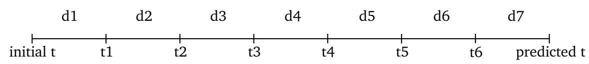

Fig. 6. Intervals of time checking to verify the need to send a new positioning message

speed of the vehicle and the transmission range. The interval between the instant of sending the initial message and the instant expected is divided into seven equal parts as shown in Figure 6.

After each interval t_i, the real position of the neighbouring vehicle (P_r) is compared to the predicted position (P_p), i.e., if the absolute difference between P_r and P_p is greater than a constant ϵ (epsilon), a new message is sent to all vehicles in the neighborhood. The m_p consists of the following fields:

- **Position-** position vector;
- **Velocity-** velocity vector;
- **Sending Time-** time sending of the message;

When a node i receives a m_p of a node j it adds a new entry in its routing table and calculates the time that both remained in contact. If during that time, node i does not receive another updated positioning message from j, node j is removed from the routing table i.

The VDTN-ToD protocol periodically checks the routing table in order to identify when a route has expired. This verification cycle is called the cycle of protocol (cp). At the beginning of each cp, the VDTN-ToD calculates the expected ToD of its neighbours for the next cycle, as well as their intended ToD, so the decision making by the protocol can be based on a configuration of the future network.

When the two nodes i and j get contact with each other and the first one has custody of a message, it compares its ToD with the one of the node j to decide which routing strategy should be used. In this sense, the strategy may be:

1) Read: $ToD(i, m)$ Trend of Delivery of the node i with the message m
2) If ($(ToD(i, m) = \{great,\ very\ good$ or $good\})$ and $(ToD(j, m) = \{great,\ very\ good$ or $good\})$ and $(ToD(i, m) \leq ToD(j, m))$), then the vehicle i copies the message m to the vehicle j, thus the VDTN-TD is intended to increase the probability of message delivery.
3) If ($(ToD(i, m) = \{bad,\ very\ bad$ or $awful\})$ and $(ToD(j, m) = \{bad,\ very\ bad$ or $awful\})$ and $(ToD(i, m) \leq ToD(j, m))$), then the vehicle i transfers the custody of message m to the vehicle j in order to delay the remoteness of the message in relation to the destination without overloading the network with unnecessary copies of the message.
4) If ($ToD(i, m)$ and $ToD(j, m)$ are opposed, for example, $good$ and bad, then
   a) If ($ToD(i, m) < ToD(j, m)$ the vehicle i transfers the custody of message m to the vehicle j.
   b) If ($ToD(i, m) > ToD(j, m)$ i remains with the message m.

When i has more than one neighbour, for each message, the one that possess the greatest ToD will be chosen among all its neighbours. This is represented mathematically as follows:

$$y = max(ToD(j, m)_{\forall j \in J, \forall m \in M}) \tag{3}$$

Therefore, the $ToD(y, m)$ will be compared with the $ToD(i, m)$ in the decision making according to the protocol operations previously seen.

The buffer management is an important aspect when using DTN protocols. We propose to use the ToD in order to manage this problem. Here, the bundle that has a higher ToD has priority over other bundles to remain in the buffer when the drop is necessary. To know the order of which bundle in the queue has to be sent, it is first checked whether any of them is a direct link, in other words, whether the neighbouring node is the destination of the bundle, if not a such case, then the bundle that has a higher ToD will be chosen.

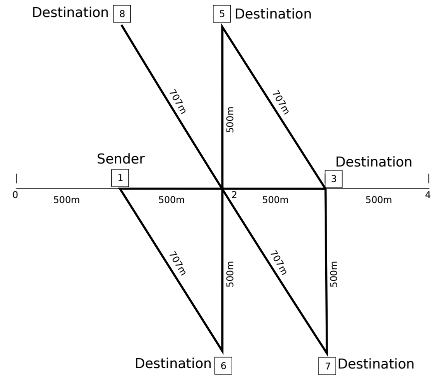

Fig. 7. Simulation scenario used in the experiments, The regions are places where are marked sender and destinations

TABLE III
ROUTING TABLE USED IN THE SIMULATION

Routes for Region 3	Routes for Regions 5, 6, 7 e 8
0-1-2-3-4	0-1-2-7
0-1-6-2-3-4	0-1-2-8
0-1-2-5-3-4	0-1-2-5
0-1-2-7-3-4	0-1-2-6
0-1-6-2-5-3-4	0-1-6-2-5

V. EXPERIMENTS AND RESULTS

A. Scenario Description

The scenario used in our experiments is shown in Figure 7. It has a fixed node (1) considered as a DTN Gateway which is responsible for sending bundles with pre-defined sizes and rates for destinations (3,5,6,7,8). This scenario was developed using the tool Simulation of Urban Mobility (SUMO) [19], where we created five routes that lead towards region 1 and five others that lead towards regions 5, 6, 7 and 8 (Table III) on the map. The thicker lines on the Figure 7 represent a road with two lanes opposed to each other where two vehicle nodes travel. The first vehicle follows the circular route 5-2-6-1-2-3-5 and the second one follows 6-2-5-3-2-1-6 throughout the simulation, other nodes randomly choose which noncircular routes of the Table III they will follow. During

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the generation of the bundles, the DTN sender node knows the geolocation of the gateway node of the destination regions and this information is loaded into the bundle, thus the ToD calculation can be performed during the decision making of the protocol.

TABLE IV
CONFIGURATION OF EXPERIMENTS

Parameter	Configuration
Simulated Environment Area	2.000 x 1.000 m^2
Transmission Range	300 m
Maximum Speed of Nodes	40 m/s (144 km/h)
Propagation Model	Nakagami
Model Mobility	carFollowing-Krauss (SUMO Default)
Size of Bundle	256, 512, 1024 and 2048 bytes each generating respectively 196, 119, 66, 27 bundles
Simulation Time	500 seconds
Flow Vehicles	50 (generate 15 nodes), 150 (generate 29 nodes) Vehicles per Hour (VpH)
Bundle Lifetime	200 seconds
DTN Routing Protocols	Epidemic, Prophet, Binary Spray-and-Wait and VDTN-ToD
Amount of simulations for each scenario	30
Confidence Interval	95%

The experiments were performed using the Network Simulator 3.13 as described in Table IV. We implemented the following classical DTN protocols: Epidemic [20], Probabilistic Routing Protocol using History of Encounters and Transitivity (PROPHET) [21] and Spray and Wait [22] in order to compare with our VDTN-ToD.

B. Metrics

For this work we use three metrics to evaluate and compare the performance of VDTN-ToD, they are the $Delivery\ Rate$, the $Overhead$ and the $Average\ Delay$. We assume B_g for bundles generated by the source during simulation, B_c for bundles copied, B_{ct} for bundles that are transfered by custody and B_r for bundles successfully received in destination.

The Delivery Rate is calculated taking into account the equation 4 which calculates how many bundles have reached the destination.

$$delivery\ rate = \frac{B_r}{B_g} \tag{4}$$

The overhead is calculated according to equation 5, which compares the copied and transmitted bundles with the received ones.

$$overhead = \frac{(B_c + B_{ct}) - B_r}{B_g} \tag{5}$$

The average delay denotes the average time spent by the bundles in order to travel between the source and the destination regions.

C. Analysis of Results

First, we analyze the $Delivery\ Rate$. This metric is important because it reflects how the protocols behave in different situations. In a challenging network as VANET, the main problems are related to low connectivity and packet loss. In this case, it is important that a DTN routing protocol adapted to VANET use a good strategy so as to not overly consume network resources in adverse situations and behaves well especially when transferring bundles of relatively large size.

In this context, the proposed protocol achieved good results in challenging scenarios, such as shown in Figure 8. In this

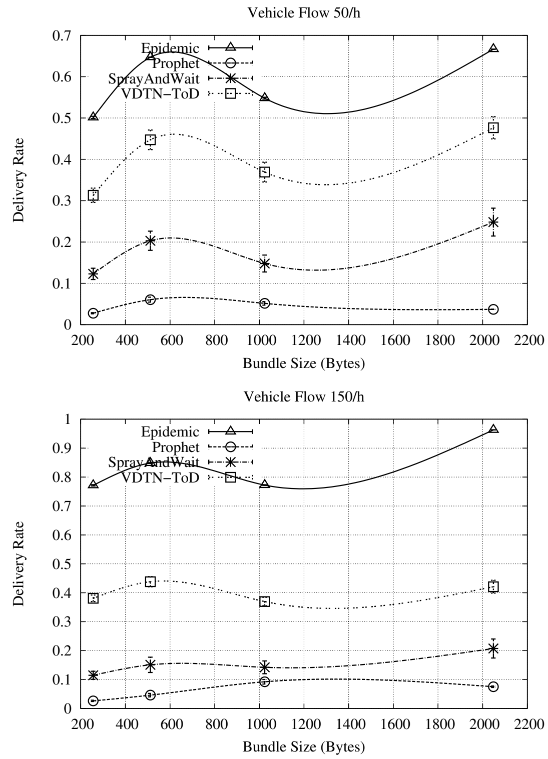

Fig. 8. Bundle Size x Delivery Rate - 50 and 150 VpH

scenario, the VDTN-ToD get a delivery rate between 30% and 50%, while the Spray-And-Wait and PROPHET stay with lower rates. In the case of the Spray-And-Wait, it do not use any mechanism to know when it should or should not spread a bundle, thus the possibility to achieve the destination is smaller than the VDTN-ToD. In the case of the PROPHET, there is a poor performance because it depended on the historical basis of the encounter, what it is difficult to build considering that in this scenario one vehicle can hardly meet another again.

We see in Figure 8 that the Epidemic protocol has the $Delivery\ Rate$ much higher than the VDTN-ToD, but as seen in Figure 9, the overhead caused by the Epidemic is extremely higher and it grows in an uncontrolled manner as the density of nodes increases, showing its low scalability. The second metric analyzed is $Overhead$. In Figure 9 we see that the overhead of VDTN-ToD is really low, becoming very close to the Spray-And-Wait (Despite its higher delivery rate). Note also that the VDTN-ToD in a more dense scenario (VpH 150) maintains the overhead close to the less dense scenario (VpH 50), unlike the Epidemic protocol that its overhead rapidly increase in a more dense scenario. We show that the VDTN-ToD can disseminate bundles efficiently to reach the destination without excessively overloading the network resources, i.e., it has a good delivery rate and is also scalable.

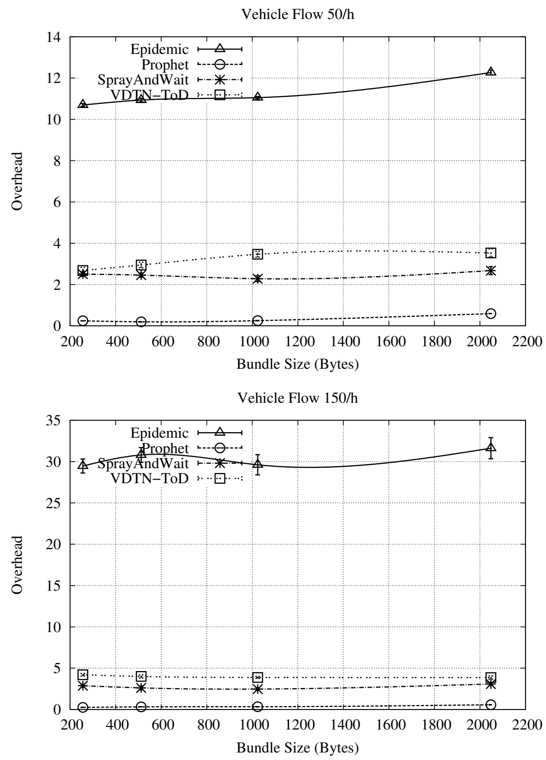

Fig. 9. Bundle Size x Overhead - 50 and 150 VpH

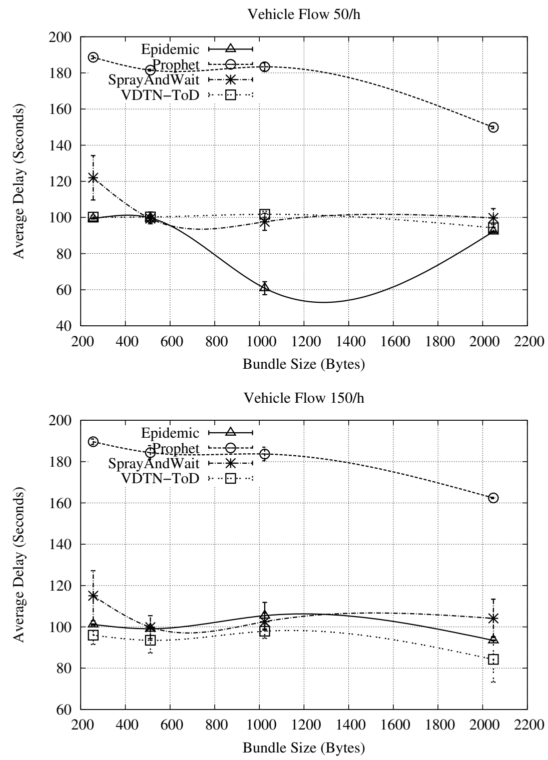

Fig. 10. Bundle Size x Average Delay - 50 and 150 VpH

The final one is the *Average Delay*. In Figure 10, in the less dense scenario (50 VpH), the Epidemic protocol achieves better results, since Epidemic node copies the bundles for all nodes that it comes in contact, the information spreads widely in this scenario, contributing to the bundle arriving quickly to the destination. When a node VDTN-ToD forward a message to a neighbouring node, the choice is aided by the proximity to the destination and speed of the neighbouring node, thereby, although a few copies, VDTN-ToD achieves better results as shown in the Figure 10 (150 VpH), where VDTN-ToD reaches a delay smaller than the Epidemic.

From our experimental results we conclude that VDTN-ToD has a good ability to adapt to the environment proposed due to its well-formulated decision making, ensuring smart forwards that cause low network overhead. This can be seen through its good delivery rate and low overhead.

VI. Conclusion and Future Works

One of the major simulation tools used to validate the DTN routing protocols is the Opportunistic Networking Environment (ONE). This simulator is used in several published studies [23] [24] [25], but there are situations where it is necessary to consider the propagation error of the messages that are inherent in wireless networks what is not provided by ONE. Differently, in this work, we use the simulator ns-3. We develop an environment capable of simulating a vehicle network together with the architecture of Delay Tolerant Networks using a module developed by Herbertsson [26]. Regarding the techniques used to create the protocol VDTN-ToD, becomes clear that we achieved great results, regarding good practices that should be employed in the development of protocols that must consider the characteristics and limitations of vehicular networks.

In general, the metric trend of delivery can be used for decision making in other DTN routing protocols. A future work is to incorporate the ToD mechanism in PROPHET and Spray-and-Wait in order to be used as a VDTN protocol. Furthermore, we will analyze the behavior of our protocol in a denser scenario, also we will evaluate perfomance when source and destination are mobile nodes. The classical DTN protocols and VDTN-ToD are available for downloading in [27].

References

[1] N. Sadagopan, F. Bai, B. Krishnamachari, and A. Helmy, “Paths: analysis of path duration statistics and their impact on reactive manet routing protocols,” in Proceedings of the 4th ACM international symposium on Mobile ad hoc networking & computing. ACM, 2003, pp. 245-256.

[2] V. Cerf et al. “Rfc 4838, delay-tolerant networking architecture,” IRTF DTN Research Group, 2007.

[3] V. Cabrera, F. Ros, and P. Ruiz, “Simulation-based study of common issues in vanet routing protocols,” in Vehicular Technology Conference, 2009. VTC Spring 2009. IEEE 69th. IEEE, 2009, pp. 1-5.

[4] T. Hossmann, T. Spyropoulos, and F. Legendre, “Know thy neighbor: Towards optimal mapping of contacts to social graphs for dtn routing,” in INFOCOM, 2010 Proceedings IEEE. IEEE, 2010, pp. 1-9.

[5] T. Spyropoulos, R. Rais, T. Turletti, K. Obraczka, and A. Vasilakos, “Routing for disruption tolerant networks: taxonomy and design,” Wireless networks, vol. 16, no. 8, 2010, pp. 2349-2370.

[6] E. de Oliveira, C. de Albuquerque, "Nectar: a dtn routing protocol based on neighborhood contact history," in Proceedings of the 2009 ACM symposium on Applied Computing. ACM, 2009, pp. 40-46.
[7] M. Liu, Y. Yang, and Z. Qin, "A survey of routing protocols and simulations in delay-tolerant networks," Wireless Algorithms, Systems, and Applications, 2011, pp. 243-253.
[8] L. Franck, F. Gil-Castineira, "Using delay tolerant networks for car2car communications," in Industrial Electronics, 2007. ISIE 2007. IEEE International Symposium on. IEEE, 2007, pp. 2573-2578.
[9] P. Cheng et al. "Geodtn+ nav: A hybrid geographic and dtn routing with navigation assistance in urban vehicular networks," in Proc. 1st Annual Intl. Symp. Vehicular Computing Systems, Dublin, Ireland, 2008.
[10] C. Lochert, M. Mauve, H. Füßler, and H. Hartenstein, "Geographic routing in city scenarios," ACM SIGMOBILE Mobile Computing and Communications Review, vol. 9, no. 1, 2005, pp. 69-72.
[11] B. Karp, H. Kung, "Gpsr: greedy perimeter stateless routing for wireless networks," in Proceedings of the 6th annual international conference on Mobile computing and networking. ACM, 2000, pp. 243-254.
[12] S. Sandri, C. Correa, "Lógica nebulosa," Escola de redes neurais: conselho nacional de redes neurais, vol. 5, 1999, pp. 73-90.
[13] M. Taha, Y. Hasan, "VANET-DSRC Protocol for Reliable Broadcasting of Life Safety Messages," in Proc. of the IEEE International Symposium on Signal Processing and Information Technology, 2007.
[14] H. Moustafa, Y. Zhang, Vehicular Networks: Techniques, Standards, and Applications. Auerbach Publications Boston, MA, USA, 2009.
[15] K. Scott, S. Burleigh et al., "Rfc 5050, bundle protocol specifications," IRTF DTN Research Group, 2007.
[16] M. Blanchet, "Delay-tolerant networking bundle protocol iana registries," 2011.
[17] S. Farrell, H. Weiss, S. Symington, and P. Lovell, "Bundle security protocol specification," 2011.
[18] J. Härri, C. Bonnet, and F. Filali, "Kinetic mobility management applied to vehicular ad hoc network protocols," Computer Communications, vol. 31, no. 12, 2008, pp. 2907-2924.
[19] D. Krajzewicz, G. Hertkorn, C. Rossel, and P. Wagner, "SUMO (Simulation of Urban MObility); An open-source traffic simulation," in 4th Middle East Symposium on Simulation and Modelling (MESM2002), 2002, pp. 183-187.
[20] A. Vahdat, D. Becker et al., "Epidemic routing for partially connected ad hoc networks," Technical Report CS-200006, Duke University, Tech. Rep., 2000.
[21] A. Lindgren, A. Doria, and O. Schelén, "Probabilistic routing in intermittently connected networks," ACM SIGMOBILE Mobile Computing and Communications Review, vol. 7, no. 3, 2003, pp. 19-20.
[22] T. Spyropoulos, K. Psounis, and C. Raghavendra, "Spray and wait: an efficient routing scheme for intermittently connected mobile networks," in Proceedings of the 2005 ACM SIGCOMM workshop on Delay-tolerant networking. ACM, 2005, pp. 252-259.
[23] V. Le, H. Scholten, and P. Havinga, "Towards opportunistic data dissemination in mobile phone sensor networks," in ICN 2012, The Eleventh International Conference on Networks, 2012, pp. 139-146.
[24] J. Whitbeck, Y. Lopez, J. Leguay, V. Conan, and M. De Amorim, "Push-and-track: Saving infrastructure bandwidth through opportunistic forwarding," Pervasive and Mobile Computing, 2012.
[25] N. Belblidia, M. De Amorim, L. MK Costa, J. Leguay, and V. Conan, "Part-whole dissemination of large multimedia contents in opportunistic networks," Computer Communications, 2012.
[26] F. Herbertsson, "Implementation of a delay-tolerant routing protocol in the network simulator ns-3," Ph.D. dissertation, Linköping, 2010.
[27] "Dtn routing protocols in ns-3," access date: 1 May. 2013. [Online]. Available: jeri.larces.uece.br/~joaogf/vanet/ns3Dtn.zip
[28] M. K. Bromage, J. T. Koshimoto, and K. Obraczka, "Tarot: trajectory-assisted routing for intermittently connected networks," in Proceedings of the 4th ACM workshop on Challenged networks. ACM, 2009, pp. 9-18.
[29] M. Jain and R. Patra, "Implementing delay tolerant networking," 2003.