A New Performance Efficient Trend of Delivery Mechanism Applied to DTN Routing Protocols in VANETs

Joao Goncalves Filho,
Joaquim Celestino Jr.
Computer Networks and Security Laboratory (LARCES)
State University of Ceara (UECE)
Fortaleza, Brazil
{joao.goncalves, celestino}@larces.uece.br

Ahmed Patel
Software Technology & Management Research Center
Faculty of Information Science & Technology
Universiti Kebangsaan Malaysia (UKM)
Bangi, Sengalor, Malaysia
whinchat2010@gmail.com

***Abstract*—There are major challenges in establishing effective communications between nodes in vehicular ad hoc networks (VANETs) that are subject to disconnections, hinder end-to-end source and target connection. Another problem arises when VANETs are sparse, whereby communication between vehicles occurs after long periods of time causing delays. In these environments, traditional routing protocols proposed for VANETs suffer holding continuous connection and performance problems. To overcome these problems, Delay Tolerant Networks (DTN) for Interplanetary Networks (IPN) routing protocols, which encourages applications to use a minimized number of round trips are considered suitable alternatives. They are designed for storing and forwarding messages when nodes can find other nodes to maintain end-to-end connections. In our previous work, we proposed a routing protocol VDTN-ToD based on DTN which uses a metric Trend of Delivery (ToD) scheme to assist in its routing and forwarding decisions. In our current work, we use this metric in order to provide better performance for DTN routing protocols Spray-And-Wait and PROPHET in VANETs. The results show that the inclusion of ToD in VANETs allows significant performance improvements and it can also be used in many other routing protocols to overcome performance issues.**

***Keywords*-VANET; DTN; SUMO; ToD; NS-3.**

I. INTRODUCTION

The TCP/IP architecture is largely robust to deal with infrastructure networks, where a disconnection is improbable and the end-to-end path between two source/destination nodes hardly broken. This feature changes in a Mobile Ad Hoc Network (MANET) environment, where nodes are mobile and are operating in relative disconnected mode. In such conditions the TCP has its performance degraded [1]. Such a problem gets even harder when we imagine a scenario where the network is sparse and the nodes cannot mount and continuously retain an end-to-end route, which is what also happens in VANETs.

In VANETs with these problematic conditions the use of DTN architecture [2] (primarily designed for IPN routing protocols which can withstand huge delays, connections disruptions and minimizes the number of roundtrips response confirmation) is considered and proposed as a suitable alternative. DTN is also applicable in all other types of mobile networks such as cellular and wireless sensor networks. In these scenarios it is necessary to develop new protocols which know how to take advantage of the DTN paradigm. Particularly, the so-called Store-carry and Forward with random or controlled movement of mobile nodes called ferries are looked for. This allows the preamble information for connecting and routing to be in a single packet as a complete data packet, which permits the node to retain for a long time until delivery to the next participating node is successful.

Some DTN protocols are: Spray-And-Wait [3], PROPHET [4] Epidemic [5] and MaxProp [6]. However, they do not consider the specific restrictions of VANETs. Some protocols for VANETs that have been proposed based on the technique DTN are: VDTN-ToD [7], FFRDV [8], VADD [9], and GeOpps [10].

In our previous work [7], we proposed a routing protocol VDTN-ToD which uses a metric called Trend of Delivery (ToD) mechanism to assist in its routing and forwarding decisions. In this our current work, the ToD is inserted in Spray-And-Wait, MaxProp and PROPHET protocols; thus they take into account features that are specific to VANETs. The results show a considerable improvement in their performance in a VANET environment. For this, all protocols were developed for simulation in Network Simulator 3 (NS3) [11], in this article the comparisons are based on Spray-And-Wait and PROPHET protocols.

The other sections in this paper are organized as follows: Section 2 presents related work, Section 3 describes the theoretical basis with a brief overview of DTN, its architecture and routing as well as the ToD mechanism. Section 4 describes how the ToD has been incorporated into Spray-And-Wait and PROPHET protocols. Section 5 shows and describes the scenarios used together with the results from our work. Finally, in Section 6, we conclude the work and present some suggestions for future research work.

II. RELATED WORK

A VANET environment has characteristics that hinder the existence of an end-to-end path between source and destination; therefore, DTN routing protocols have been designed for

 ISBN: 978-1-61208-360-5

vehicular scenarios, some are reported below.

The VDTN-ToD [7] uses the metric Trend of Delivery (ToD) to assist in routing decisions to allow a particular network node to decide when it is best to keep, forward or copy a packet, taking into account improvements in the delivery rates and decrease in the message delays. The VDTN-ToD also uses a scheme of *disclosure* and *maintenance* of *location messages* based on the concept of *Adaptive Coverage Detection* (ACD), which takes into account the transmission range, to reduce the number of update messages with their location details given by the nodes.

Yu and Ko [8] proposed the VANET/DTN protocol called Fastest-Ferry Routing in DTN-enabled Vehicular Ad Hoc Networks (FFRDV). It works specifically in motor-highway scenarios. It divides the highway into blocks and within them it decides to which vehicle as a relay node it will forward the packet, based on the vehicle speed. The ToD that we incorporated into the DTN routing protocols in our work reported in this paper also uses the speed factor to assist in the routing decisions, but we go one step further taking into account the angle between the vehicle and the distance to the target node.

Zhao and Cao in [9] proposed the protocol Vehicle-Assisted Data Delivery in Vehicular Ad Hoc Networks (VADD) that uses a digital map to obtain the maximum speed, the vehicle density and intersection places. Based on this information, it uses a metric called expected delay for delivery to make routing decisions when one arrives at an intersection/junction. When it is not at an intersection it typically works like Greedy Perimeter Stateless Routing (GPSR) [12]. The VADD does not perform packet replication, but forwarding, and furthermore the target nodes are fixed in the proposed application. In our proposed scheme in the ToD protocols reported in this paper, we go one step further to ensure knowing each target's geolocation of the vehicle nodes, which are e evaluated on their mobility.

Another VANET/DTN protocol that uses metrics for its routing decisions is the Geographical Opportunistic Routing for Vehicular Networks (GeOpps) [10], which is obtained with the aid of a navigation system that makes a node to know the routes of its neighbors in it vicinity range. Since the navigation system indicates which way the neighbors will take (based on their source-to-destination route selection), suggest that GeOpps may achieve more optimum routing than in other protocols with ToD. However, this scheme may expose user security and privacy that could be used by criminals and other agencies for the wrong reasons. Protocols with ToD have the advantage of requiring less information from the VANET environment. Another proposal GeoSpray [13], which is a combination of GeOpps with Spray-And-Wait extends .

In our research work reported in this paper, the ToD mechanism has been incorporated in the Spray-And-Wait and PROPHET protocols to determine and compare their respective performances in a VANET environment.

III. Theoretical Basis

A. Delay Tolerant Networks

Initially in the 90s, IPN project was developed aimed to define the architecture for land interoperability internet with an interplanetary one. It was reported that the solutions used in IPN could also work for terrestrial networks that faced problems of disconnections and disruptions [14].

The DTN architecture uses the strategy called Store-carry and Forward, in which the first packet as a package is fully received at an intermediate node, then it stores the packet and carry (forward) it until it reaches its target destination.

The packet may be stored for hours or even days, depending on the life time set for the packet. This functionality is placed in a new layer called Layer Bundle [15], which is located below the application layer and above the transport layer.

The DTN applications generate messages of different size called bundles and they are processed, stored and forwarded in DTN nodes.

B. DTN Routing

The traditional routing protocols for networks on Earth assume that they establish an optimum end-to-end path between source and target according to some metric, such as number of nodal hops. In DTN, the concept is to establish a journey so that the bundle reaches its target by taking the maximum advantage of possible contacts (opportunity to send data) that occur with the nodes to maximize the delivery rate as quickly as possible, because there is no guarantee that a particular bundle enroute through the network will reach its destination. The protocol also has to manage the use of storage space of nodes, since in some schemes, such as epidemic routing, it can quickly fill the buffers of these devices. Another important metric is the delay metric to ensure that the protocol can deliver bundles to the target as fast as possible.

C. Trend of Delivery (ToD) Mechanism

The value of ToD is achieved through the use of fuzzy logic from soft computing that seeks to discover through the mobility of nodes how good that node is to forward or copy a packet. The ToD is based on three variables: direction ($\omega_{i,d}$), distance ($\Psi_{i,d}$) and speed ($\tau_{i,d}$), where i is the node with the message and d is the final destination of the message.

The direction indicates how close the direction from i to d is, thus a θ angle formed between the direction vector $\overrightarrow{u}$ indicating the direction of vector i and facing the recipient $\overrightarrow{v}$ is calculated, so the angle between them indicates how good or bad the value ($\omega_{i,d}$) is. The associated values are *great*, *good*, *bad* and *awful*.

For distance, four values are considered: *very close*, *close*, *far* and *very far*; each of them is achieved by the value of the transmission range of the vehicles as nodes.

In the case of the speed, four values are considered: *low*, *medium* and *high*, which indicates how fast the vehicle as a node travelling.

With the values of the variables ($\omega_{i,d}$), ($\Psi_{i,d}$) and ($\tau_{i,d}$), the value of ToD is set in seven parameter values: *maximum*

 ISBN: 978-1-61208-360-5

(MA), *great* (GR), *very good* (VG), *good* (GO), *bad* (BA), *very bad* (VB) and *awful* (AW).

IV. ToD Applied to Protocols

A. ToD Applied to Spray-And-Wait

The idea used to implement ToD in the Spray-And-Wait protocol to limit the number L of copies, thus the ToD is applied to assist to choose the L copies; whereas in Spray-And-Wait, these copies are spread to the first neighbors found in their immediate vicinity. The pseudo-code below shows how the decision is made:

```
/*
* Consider j as being the best
* neighbor of i, ie neighbor with
* best ToD for the bundle m chosen
* ALPHA 0.05
*/
if (node is source && L(i) > 1) {
    L(i) = L(i) / 2;
    L(j) = L(i);
    i copies the bundle m to j;
}
else if (val(ToD (i, m)) + ALPHA
  <= val(ToD(j, m))) {
    if ([(Tod(j, m)] is subset of
            [Maximum, Great, Very Good]) {
        i forwards the bundle m to j;
    }
    else if (L(i) > 1) {
        L(i) = L(i) / 2;
        i copies the bundle m to j;
    }
    else {
        i keeps the bundle m;
    }
}
else {
    i keeps the bundle m;
}
```

It can be observed that before making decisions based on ToD, we check whether the node i is the source node, in which case it always copies directly to j (where the bundle is still L $>$ 1). This decision is taken due to the possibility of having fixed source nodes in some VANET scenarios. In which case, whenever it has the opportunity it spreads the bundle to its best neighbor. We also see in the pseudo code that routing decisions are different when compared to VDTN-ToD. Since the α constant indicates the minimum difference that j must have to node i. This decision is made in order to have the best selection of neighbors, since they may show values even greater of ToDs. When the ToD node j is greater than the node i with a difference greater than or equal to alpha another check is performed, which examines whether j has a ToD that is subset of [Maximum, Great, Very Good]. When this occurs, the bundle is transferred to j, since it has a high chance of finding the destination, thus avoiding spreading unnecessary copies in the network. Moreover, the bundles are transferred even when L = 1, allowing the spread to take place successfully. If the ToD of j is not a subset of [Maximum, Great, Very Good], the bundle is copied, dividing the number of copies with the two nodes. In any other case the bundle is maintained at node i.

When a node contacts another node, each one has a list of bundles and must choose the order in which bundles should be sent, thus three mechanisms were chosen. The first works with First in First out (FIFO), in the second approach, the sequence is established based on the value of L, so the first bundles are those with the highest values of L, aiming to prioritize those bundles that were less spread. The third mechanism is the same as that used in VDTN-ToD; in this case, the bundle selection is based on its ToD.

For this work we evaluated the behavior of 4 versions for Spray-And-Wait, as follows: **Spray-And-Wait** original version using FIFO, **Spray-And-Wait V1** original version using queue approach based in the number of copies of L, **TrendOfSpray** version with trend of delivery using the same approach queue V1 and **TrendOfSpray 2** version with trend of delivery using the same approach as VDTN-ToD queue.

B. ToD Applied to PROPHET

PROPHET has its own routing strategy which is based on nodal encounter history. Hence, we applied the ToD strategy associated with the PROPHET strategy. Two approaches called PROPHETorToD and PROPHET+ToD were created.

The first works by performing an “or” between the two strategies when a bundle (chosen from the top of the queue) is ready for forwarding when it meets the sending conditions of the PROPHET protocol. If the protocol does not authorize the sending, then it goes to the strategy based on VDTN-ToD. This approach is shown in the pseudo code below:

```
/* Given the bundle m, that i
 * need to send to the destination
 * d and i have a set of n neighbors
 * P(k, d) -> Probability of node k
 * find the node d
 */

    best_neighbor =
        neighbor_with_best((P(k, d));

    if ( P(best_neighbor, d) >
            P(i, d)) {
         i copies the bundle to
          the best_neighbor;
    }
    else {
         i transfers the bundle queue
          to strategy of VDTN-ToD;
    }
```

In the second approach, the first bundle is always chosen; thus seeking the neighbor j that adds the greater delivery probability value added to ToD according to the pseudo-code below:

```
/* Given the bundle m, that i
 * need to send to the destination
 * d and i have a set of n neighbors
 */
```

```
for each k that is a neighbor of i
  j = neighbor with highest sum
    of ToD(k, m) + P(k, d)

sum_j = val(ToD(j, m)) + P(j, d);
sum_i = val(ToD(i, m)) + P(i, d);

if (sum_j > sum_i) {
    i forwards the bundle m to j;
}
else if (val(ToD(j, m)) >= val(ToD(i, m))
  || P(j, d) >= P(i, d)) {
    i copies the bundle m to j;
}
else {
    i keeps the bundle m;
}
```

V. Experiments and Results

A. Scenarios Description

For the experiments, two scenarios developed in Simulation of Urban Mobility (SUMO) [16] were prepared and the behavior of the protocols in two different scenario applications in a VANET environment was evaluated as follows.

1) Scenario 1: The first scenario is shown in Figure 1. This simpler scenario was used to evaluate a type of VANET application in which there are five nodes exchanging messages among them in the form a chats between vehicles or files exchanges.

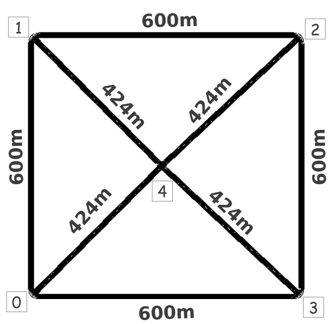

Fig. 1. Scenario 1 of simulation

TABLE I. Scenario 1 Configurations

Parameter	Configuration
Simulated Environment Area	600 x 600 m^2
Transmission Range	300 m
Maximum Speed of Nodes (Varies depending on the vehicle)	(10, 15, 20 and 25) m/s
Propagation Model	Nakagami
Model Mobility	carFollowing-Krauss (SUMO Default)
Size of Bundles	(512, 1024, 2048, 5096) bytes
Number of Generated Bundles	244
Simulation Time	300 seconds
Bundle Lifetime	200 seconds
Amount of simulations for each scenario	33
Confidence Interval	95%

All vehicles are randomly generated at the scenario edges and move randomly throughout the simulation period. The value of L for Spray-And-Wait is according to Equation 1

$$L = (N * 0.1) + 1 \tag{1}$$

where N is the number of network nodes, whose value is approximately 10% as suggested in [3]. For PROPHET values are PINIT = 0.5, γ = 0.98 and β = 0.25. Other details of the scenario are shown in Table I.

2) Scenario 2: Scenario 2 is similar to the one proposed in the previous work [7], as shown in Figure 2. In this scenario,

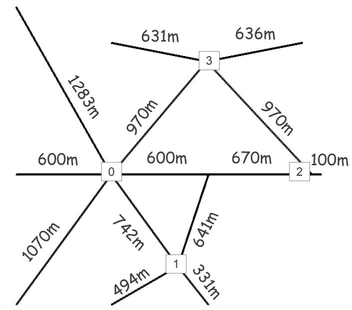

Fig. 2. Scenario 2 of simulation

application 4 points (0, 1, 2, 3), which are fixed DTN regions that exchange data with each other using vehicles as a data mules, is as reported in our previous work [7] (Figure 3).

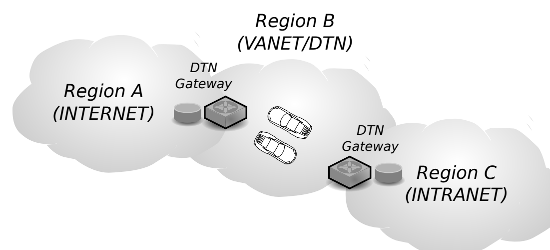

Fig. 3. Communication between remote regions

We reused this application to evaluate the protocols proposed in this work. Another detail concerning this scenario is the similarly to scenario 1: the vehicles are generated at the edges of the map and move throughout it during the simulation. Moreover, all the tracks have four lanes (two each direction).

Other information of the scenario is described in Table II.

TABLE II. Scenario 2 Configurations

Parameter	Configuration
Simulated Environment Area	1970 x 1750 m^2
Transmission Range	300 m
Maximum Speed of Nodes (Varies depending on the vehicle)	(10, 15, 20, 25) m/s
Propagation Model	Nakagami
Model Mobility	carFollowing-Krauss (Padro do SUMO)
Size of Bundles	(512, 1024, 2048, 5096) bytes
Number of Generated Bundles	471
Simulation Time	500 seconds
Bundle Lifetime	200 seconds
Amount of simulations for each scenario	33
Confidence Interval	95%

B. Metrics

Several studies suggest which metrics should be used to evaluate the performance of a DTN routing protocol. The three metrics are suggested, Delivery Rate, Average Delay, and Overhead [7] [17]. The calculations of these metrics are the same as reported in our previous work [7].

C. Analysis of ToD applied to Spray-and-Wait

We begin the analysis with the first scenario, where the VANET environment is also simpler.

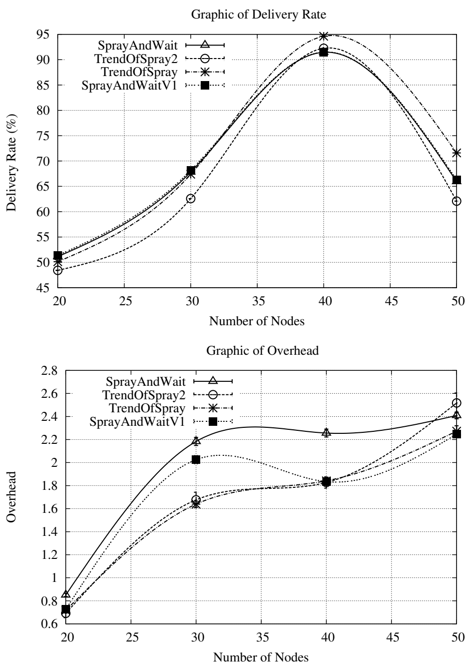

Fig. 4. *Spray-And-Wait* - Graphics of delivery rate and overhead for scenario 1

By evaluating the results in Figure 4, it can be observed that there was a slight improvement over TrendOfSpray when there was an increase in the number of vehicles, it achieved greater delivery rates, and thus keeping the overhead low. Only in once instance it achievd lower improvment to V1. Figure 5 shows a lower average delay for TrendOfSpray in all cases. These results come from a better choice of L copies that are spread associated with the strategy of the queue based on the value of L. Hence, the overhead is more controlled, since a bundle is only spread to a neighbor with a higher ToD. The bundles with these smart copies of information, tend to reach the destination faster, thus keeping the average delay lower.

According to the results (Figures 6 and 7), it can be observed that both TrendOfSprays had delivery rates below the two versions of the Spray-And-Wait. This is due to the scenario being more complex, where the guarantee that a bundle reach its target is very low. In the case of the two TrendOfSpray approaches, several bundles are retained because the neighbor does not have a higher ToD, but it is possible that it finds its target late, since the environment is much more sparse, allowing the protocol to spread more copies speedily, hence the possibility of finding the target is greater. So, in this case the delivery rate versions of Spray-And-Wait

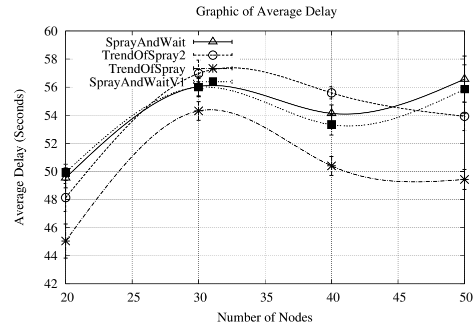

Fig. 5. *Spray-And-Wait* - Graphic of average delay for scenario 1

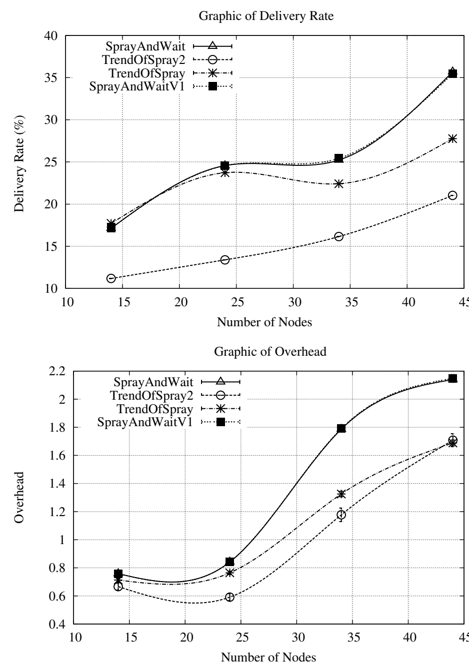

Fig. 6. *Spray-And-Wait* - Graphics of delivery rate and overhead for scenario 2

are higher, becasue they only retain bundles when L = 1. The low overhead of TrendOfSpray approaches are reflections of bundles that are retained. Regarding the average delay, the versions of TrendOfSpray showed higher values, since they take longer to spread the bundles to network.

The TrendOfSpray (version 1) provides better results for scenario 1, keeping good delivery rates, low overhead, as well as achieving shorter delay than the two versions of Spray-And-Wait. However, in scenario 2, it did not achieve better results due to the bundles not spreading widely. A possible improvement could be to try to calibrate a better value for α; for instance, it can be 0, making the bundles to achieve more spreading in the network.

D. Analysis of ToD applied to PROPHET

From the analysis, it is important to know that PROPHET suffer more difficulties in a VANET environment of scenario

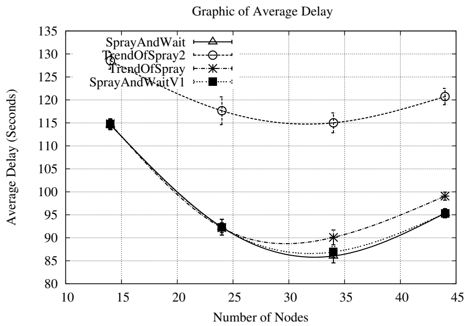

Fig. 7. *Spray-And-Wait* - Graphic of average delay for scenario 2

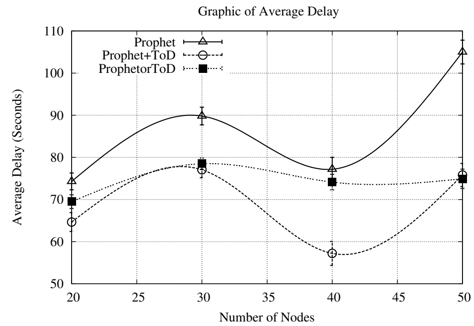

Fig. 9. PROPHET - Graphic of average delay for scenario 1

2, because it depends on a history of reencounters [7], since the bundles are forwarded only when there are reencounters or when the transitivity case occurs. This is made more difficult because both source and target nodes are fixed.

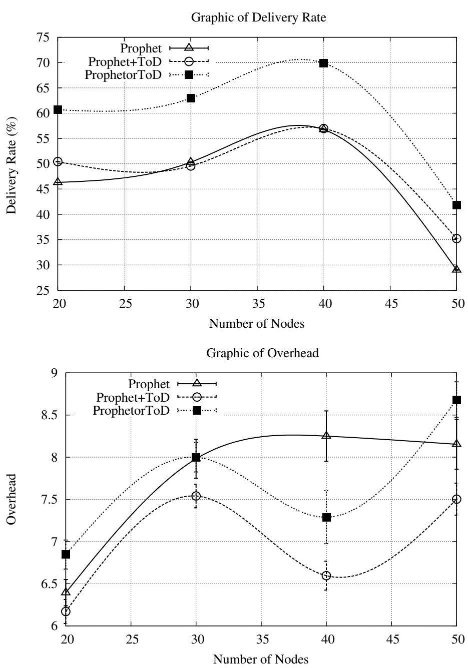

Fig. 8. PROPHET - Graphics of delivery rate and overhead for scenario 1

By observing Figure 8, it can be noticed that PROPHETorToD achieves superior delivery rates than others, with the variable overhead in relation to PROPHET (sometimes gaining, sometimes losing). The gain was due to greater probability to spread the bundles, allowing PROPHETorToD to spread the copies even if the metric PROPHET did not authorize it. in this case, with VDTN-ToD approving, with this the overhead was well controlled. For the case of PROPHET+ToD, it kept a delivery rate similarly to PROPHET, but with much lower overhead. This is due to PROPHET+ToD uses two metrics to better help their routing decisions. From Figure 9 it can be seen that compared to average delay, the PROPHET+ToD and PROPHETorToD showed a better performance since more bundles are spread using the two metrics ToD and delivery predictable. So, on the average, the bundle arrives at their target faster with greater regularity.

Observing the results shown in Figure 10, the PROPHET achieves much lower performance. In this scenario, both PROPHET and PROPHETorToD retain more bundles, making the PROPHET+ToD to achive a higher delivery rate. In the case of PROPHETorToD, it suffers from the problem of the bundles being retained longer in fixed source node (since in this case it retains the bundles due to PROPHET and VTDN-ToD not authorizing forwarding or copying), which hinders the possibility of the bundle arriving speedily at its target. With more retained bundles, the PROPHETorToD and PROPHET have lower overheads.

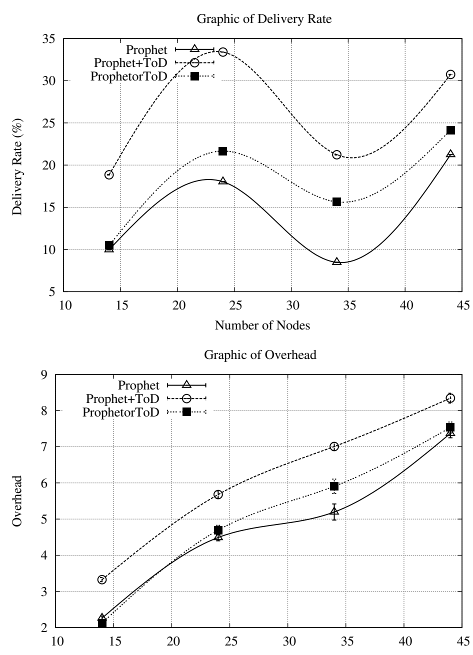

Fig. 10. PROPHET - Graphics of delivery rate and overhead for scenario 2

Referring to Figure 11, it can be seen that all of these

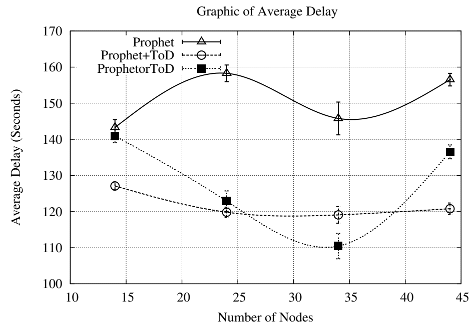

Fig. 11. PROPHET - Graphic of average delay for scenario 2

conditions of scenario 2 the PROPHET+ToD achieve a better value for average delay, since the bundles spread faster.

VI. Conclusion and Future Work

The proposed mechanism, called ToD, has succeeded in improving the performance of traditional DTN algorithms when they are applied in VANET environment. This mechanism has been also tested with the MaxProp routing protocol, and it will be reported in another follow-up paper.

The Spray-And-Wait and PROPHET protocols, using the ToD, had a significant improvement in the evaluated metrics. In the case of Spray-And-Wait, this result was expected, since it does not use any criteria for the scattering of bundles. For PROPHET, the ToD expanded the possibility of spreading the bundles, which was depended solely on historical encounters.

As future work, we consider implementing VADD and GeOpps protocols in NS3, incorporating the ToD mechanism and compare them to VDTN-ToD to perform more comprehensive evaluation.

References

[1] Z. Fu, X. Meng, and S. Lu, "How bad TCP can perform in mobile ad hoc networks," in *Computers and Communications, 2002. Proceedings. ISCC 2002. Seventh International Symposium on*. IEEE, 2002, pp. 298–303.

[2] K. Fall, "A delay-tolerant network architecture for challenged internets," in *Proceedings of the 2003 conference on Applications, technologies, architectures, and protocols for computer communications*. ACM, 2003, pp. 27–34.

[3] 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.

[4] A. Lindgren, A. Doria, and O. Schelén, "Probabilistic routing in intermittently connected networks," *ACM SIGMOBILE Mobile Computing and Communications Review*, vol. 7, no. 3, pp. 19–20, 2003.

[5] A. Vahdat, D. Becker *et al.*, "Epidemic routing for partially connected ad hoc networks," Technical Report CS-200006, Duke University, Tech. Rep., 2000.

[6] J. Burgess, B. Gallagher, D. Jensen, and B. N. Levine, "MaxProp: Routing for vehicle-based disruption-tolerant networks." in *INFOCOM*, vol. 6, 2006, pp. 1–11.

[7] A. S. de Sousa Vieira, J. Gonçalves Filho, J. Celestino Júnior, and A. Patel, "VDTN-ToD: Routing protocol vanet/dtn based on trend of delivery," in *AICT 2013, The Ninth Advanced International Conference on Telecommunications*, 2013, pp. 135–141.

[8] D. Yu and Y. Ko, "FFRDV: fastest-ferry routing in dtn-enabled vehicular ad hoc networks," in *Advanced Communication Technology, 2009. ICACT 2009. 11th International Conference on*, vol. 2. IEEE, 2009, pp. 1410–1414.

[9] J. Zhao and G. Cao, "VADD: Vehicle-assisted data delivery in vehicular," *Vehicular Technology, IEEE Transactions on*, vol. 57, no. 3, pp. 1910–1922, 2008.

[10] I. Leontiadis and C. Mascolo, "GeOpps: Geographical opportunistic routing for vehicular networks," in *World of Wireless, Mobile and Multimedia Networks, 2007. WoWMoM 2007. IEEE International Symposium on a*. IEEE, 2007, pp. 1–6.

[11] "Network Simulator 3," access date: 28 June. 2014. [Online]. Available: www.nsnam.org

[12] B. Karp and H.-T. 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.

[13] V. N. Soares, J. J. Rodrigues, and F. Farahmand, "GeoSpray: A geographic routing protocol for vehicular delay-tolerant networks," *Information Fusion*, 2011.

[14] C. T. de Oliveira, M. D. Moreira, M. G. Rubinstein, L. H. M. Costa, and O. C. M. Duarte, "Redes tolerantes a atrasos e desconexoes," *SBRC Simpósio Brasilieiro de Redes de Computadores e Sistemas Distribuıdos*, 2007.

[15] K. Scott and S. Burleigh, "Bundle protocol specification," 2007.

[16] 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.

[17] Y. Cao and Z. Sun, "Routing in delay/disruption tolerant networks: A taxonomy, survey and challenges," *Communications Surveys & Tutorials, IEEE*, vol. 15, no. 2, pp. 654–677, 2013.

 ISBN: 978-1-61208-360-5