Mechanisms for Enhancing the Performance of Routing Protocols in VANETs

Christos Bouras, Vaggelis Kapoulas, Nikos Stathopoulos
Computer Technology Institute and Press "Diophantus", Patras, Greece
Computer Engineering and Informatics Department, University of Patras, Greece
bouras@cti.gr, kapoulas@cti.gr, stathopou@ceid.upatras.gr

Apostolos Gkamas
University Ecclesiastical Academy of Vellas
Ioannina, Greece
gkamas@aeavellas.gr

ABSTRACT
Vehicular Ad Hoc Networks (VANETs) are considered as a special case of Mobile Ad Hoc Networks (MANETs) and are recently gaining a great attention from the research community. Routing in VANETs has to adapt to special characteristics such as high speed and road pattern movement as well as high linkage break probability. In an urban setting the problem becomes more difficult as the existence of buildings blocks the wireless signal and hinders communication, resulting in only few nodes with increased connectivity (mostly in the intersections) that can act as true routing nodes rather than just forwarding nodes. In this paper, we compare the performance of GPCR (Greedy Perimeter Coordinator Routing), GPSR (Greedy Perimeter Stateless Routing) as well as the modified GPSR (GPSR-M) routing protocols. GPSR-M is an enhancement for the GPSR protocol that focuses on routing a message to an intermediate vehicle moving in the line of movement of the final destination, as soon as possible. Based on the performance evaluation we propose enhancements to GPSR-M in order to improve performance.

Keywords
VANETs; MANETs; Routing Protocols; Applications

1. INTRODUCTION
Vehicular Ad Hoc Networks (VANETs) ([1], [2], [3], [4]) are a special class of Mobile Ad Hoc Networks (MANETs) with unique characteristics. Similar to MANETs, VANETs are an autonomous and self-configured wireless network that allows communications without any dependency on infrastructures or a central coordinator. Any vehicle can be an active node in a VANET if equipped with wireless transceivers. Most nodes in a VANET are continuously moving with a wide range of speeds and directions in the same way as a vehicle moves in a roadway or an urban area.

PE-WASUN'16, November 13-17, 2016, Malta, Malta
 ISBN 978-1-4503-4505-7/16/11…$15.00
DOI: http://dx.doi.org/10.1145/2989293.2989294

The main problem that VANETs face, is that the continuous and rapid movement of the nodes, leads to significant changes in the topology of the network, rendering routing a difficult task. The links between the nodes are maintained for a very small amount of time, so classic MANET routing protocols are not efficient in terms of usage and performance. The moving rates in a VANET are in the general case higher than that in a typical MANET but more predictable for nodes traveling on the same direction. This means that nodes in a VANET, moving towards the same direction in a roadway maintain similar speeds and thus longer radio communication periods of time than those moving in opposite directions. Another unique characteristic of VANETs is their challenging surrounding environment that contains blocks of buildings, roadways that limit the possible node movements and roadside infrastructures that may provide Internet access points along with a rich variety of services and applications.

VANETs are known to be used in specialized tasks, such as in military and in emergency services, in order to provide communication support. However, commodity vehicles that take advantage of the VANETs to exchange information have emerged. Efficient and precise routing protocols have to be designed in order to optimize the functionality of VANETs is imposed., since the complexity of urban areas, does not allow existing routing protocols to operate efficiently.

GPSR (Greedy Perimeter Stateless Routing) [5], is a responsive and efficient routing protocol for mobile, wireless networks. Unlike established routing algorithms before it, which use graph-theoretic notions of shortest paths and transitive reachability to find routes, GPSR exploits the correspondence between geographic position and connectivity in a wireless network, by using the positions of nodes to make packet forwarding decisions. GPSR uses greedy forwarding to forward packets to nodes that are always progressively closer to the destination. In regions of the network where such a greedy path does not exist (i.e., the only path requires that one move temporarily farther away from the destination), GPSR recovers by forwarding in perimeter mode, in which a packet traverses successively closer faces of a planar subgraph of the full radio network connectivity graph, until reaching a node closer to the destination, where greedy forwarding resumes. In GPSR every node periodically broadcasts a beacon message to all its neighbors containing the id and position of the node. If any node does not receive any beacon message from a neighbor for a specific period, then GPSR router concludes that the neighbor has failed or it is out of range, and deletes the neighbor from its table. In a city scenario greedy forwarding is often restricted because direct communications between nodes may not exist due to obstacles such as buildings and trees.

The authors in [6] eliminated graph planarization in GPCR. It consists of two procedures: a restricted greedy forwarding procedure and a repair strategy which is based on the real world topology of streets and junctions and hence does not require a graph planarization process. GPCR is a position-based routing protocol that uses greedy algorithms to forward packet based on a pre-selected path which has been designed to deal with the challenges of city scenarios. No global or external information like static map is required in GPCR.

The modified GPSR (GPSR-M) [7] is an enhancement for the GPSR protocol that focuses on routing a message to an intermediate vehicle moving in the line of movement of the final destination, as soon as possible. That is to say, the packets follow a route that leads to the destination's road and is vertical to it. Because of the intense and high speed mobility in VANETs, the GPSR forwarding process may not be always efficient. Choosing as next hop the neighbor node with the least distance from the destination may easily lead to recovery state as the link may break due to opposite directions or great speed difference between the next hop and the destination. GPSR-M enhancement is applied on the greedy forwarding process during the best next hop calculation. The modified process handles not only the positions of the routers but also the speed, direction and link quality. The speed and direction is sent as a velocity vector attached in the HELLO messages of the modified GPSR. The destination's position and velocity is added in the packet header in order to be available at the intermediate nodes. The position and velocity for every node is obtained from a location service that in the real world could be the GPS. For link quality assignment, every packet is tagged with an SNR value at the physical layer. This SNR packet tag is extracted at the routing layer during the HELLO messages reception. The position, velocity and SNR information is stored in the neighbor table of every node and then is included in the next hop weight calculation.

The work presented in this paper illustrates an efficiency comparison among the state-of-the-art routing protocols that focus their main interest in Urban Areas, and further exploitation of real-world routing simulation scenario is going to be proposed, as well. More specifically, we compare the performance of Greedy Perimeter Coordinator Routing (GPCR), Greedy Perimeter Stateless Routing (GPSR), GPSR as well as the modified GPSR (GPSR-M) routing protocols. We use simulations to compare the performance of GPCR vs GPSR vs. GPSR-M, in an urban setting, including the effect that buildings have in blocking the wireless signals. Based on this performance evaluation, we propose a further enhancement to the routing mechanism called GPSR-N (GPSR-New) that focuses on routing a message to an intermediate vehicle moving in the line of movement of the final destination, as soon as possible, because transmission to the destination from there should be quite easy. This tends to solve the problem of finding suitable intersections as early as possible, whereas the other protocols do not consider this and the message may arrive close to the destination but with no vehicle in the close intersections to facilitate the final delivery. This enhancement requires information on the destination's coordinates and direction, but this information is already used by GPSR.

The main benefits of our proposal are better performance of the network with reduced delays and improved throughput. Please note that the network performance of a VANET in an urban setting is seriously hindered by the existence of buildings that block the wireless signal and allow communication mostly along the lanes of the roads. Thus any improvement in the performance of the VANET is very important.

The rest of this paper is organized as following: Section 2 presents the simulation based performance evaluation of GPCR, GPSR and GPSR-M. Section 3 proposes a further enhancement to the routing mechanism based on the performance evaluation. Finally, the last section concludes the paper and presents the future work.

2. ROUTING PROTOCOLS PERFORMANCE EVALUATION

For the evaluation of the routing protocols, we conducted experiments on Network Simulator 3 (NS-3) [8]. The nodes are placed on a Manhattan grid, whose size varies. The grid has 3x3, 4x4 and 5x5 blocks in each scenario. The sides of each block are 150 meters long, while the roads are 20 meters wide. In order to observe the performance of the protocols, we conduct experiments where the density of the network varies. We define as density the average number of nodes that move in each road segment that is created by the grid. Because the scenarios are based on a Manhattan grid, in Table 1 the number of vehicles per km for each case. We run scenarios for densities 2-6. The mobility scenario was created using BonnMotion [8], where the nodes are set to move with an average speed of 11 m/s, and move randomly inside the grid. In all these experiments, 100 packets are sent from a randomly selected node to another every 0.1 seconds, where each packet's size is 256 bytes. Due to the random topologies that are created, we conducted 10 experiments for each grid-density pair, and calculated the average values for Packet Delivery Ratio (PDR) and End-to-End delay.

Table 1. Density equivalences

Density	Vehicles/km
2	13.3
3	20
4	26.6
5	33.3
6	40

Figure 1 shows End to End delay in the 3x3 blocks scenario. It is obvious that GPSR-M compared to GPSR and GPCR provides smaller end-to-end delay in most node densities. In low densities, GPSR-M does not perform well, mostly because the sparse network does not offer the desired connectivity in order to help the protocol function properly.

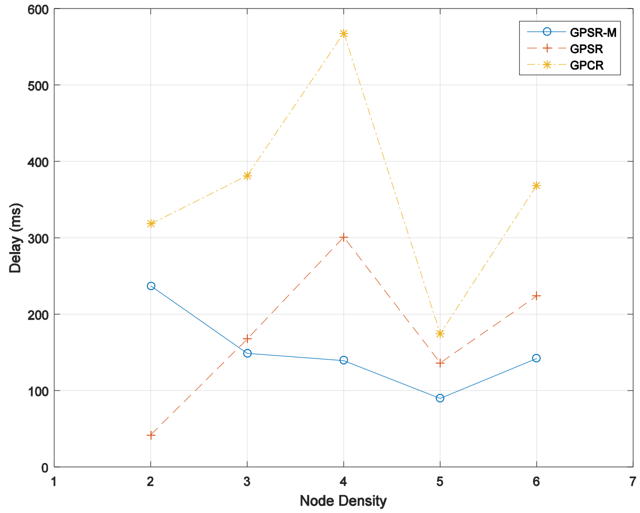

Figure 1. End-to-end delay in the 3x3 blocks scenario

Figure 2 shows Packet Delivery Ratio in the 3x3 blocks scenario. It is shown that GPSR provides better performance both in PDR and end-to-end delay comparing with GPCR. GPCR does not perform well on urban scenarios such as the one described in the experiments.

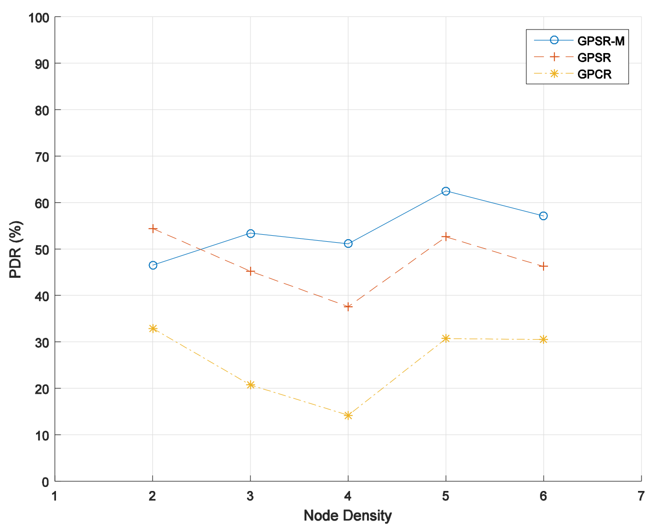

Figure 2. PDR in the 3x3 blocks scenario

Figure 3 shows end-to-end delay in the 4x4 blocks scenario and. Based on the figures, GPSR-M provides the best average performance – in terms of end-to-end delay – comparing with GPCR and GPSR in 4*4 grids.

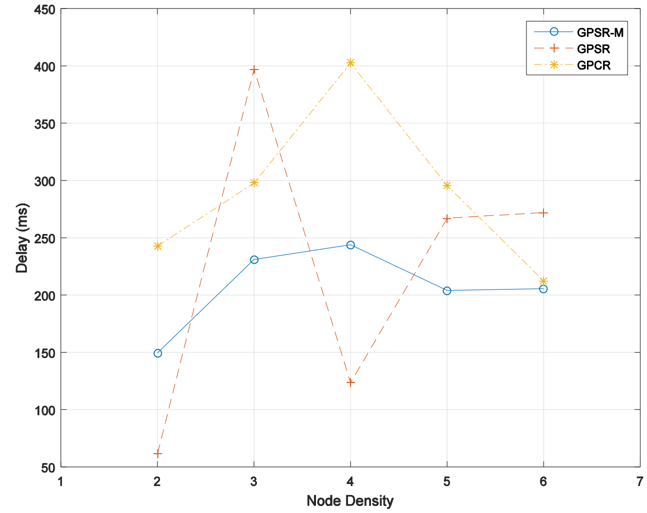

Figure 3. End-to-end delay in the 4x4 blocks scenario

Figure 4 shows PDR in a 4x4 grid. In terms of packet delivery ratio, GPSR-M provides better performance comparing with the two other routing protocols. In addition, GPSR comparing with GPCR provides better performance in terms of PDR and in terms of end-to-end delay GPRS and GPCR provide equal performance and for some Node Density GPRS is better than GPCR and for some other Node Density the opposite.

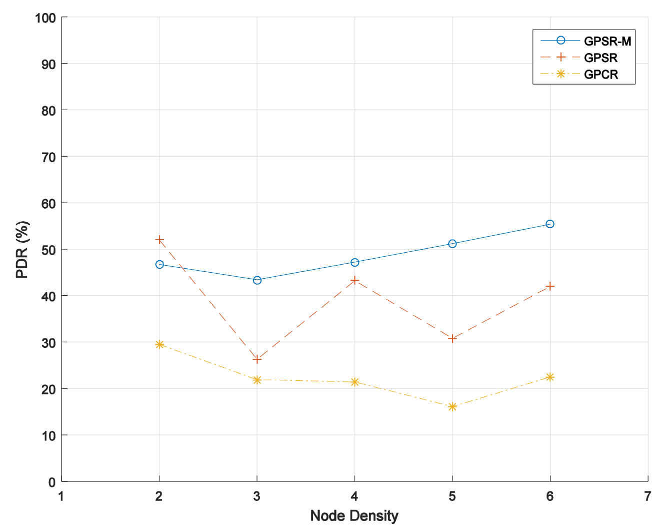

Figure 4. PDR in the 4x4 blocks scenario

Figure 5 shows end-to-end delay in the 5x5 blocks scenario. GPSR manages to keep end-to-end delay lower than the other two protocols in the majority of the cases.

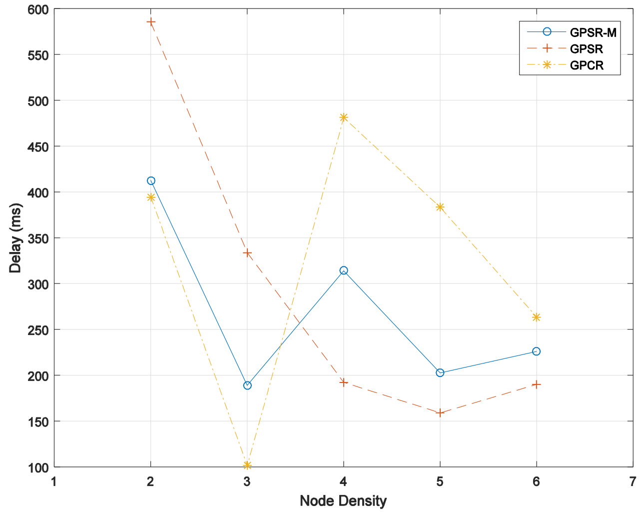

Figure 5. End-to-end delay in the 5x5 blocks scenario

Figure 6 shows PDR in the 5x5 blocks scenario. GPSR-M achieves almost the double performance and the highest of the 3 protocols. GPRC is the worst of the three protocols in term of PDR.

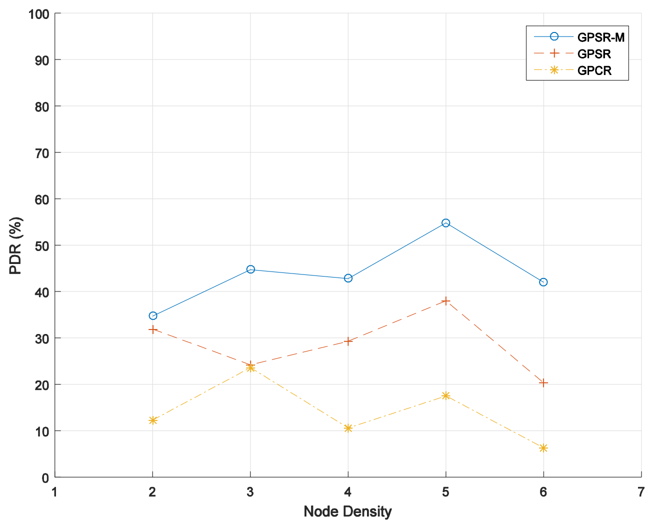

Figure 6. PDR in the 5x5 blocks scenario

Based on the above simulations it is clear that none of the above routing protocol provides clearly the best performance in all the simulation scenarios and all evaluation parameters. In most cases GPSR-M provides better performance in terms of both PDR and end-to-end delay but in some case either GPSR or GPCR provide better performance either on end-to-end delay or PDR. For this reason, in the next section we propose some enhancement to GPSR-M in order to improve its performance.

3. PROPOSED ENHANCEMENT: MODIFIED GPSR

In order to improve performance, we propose a routing mechanism that focuses more to the destination's main coordinate. We named this new algorithm GPSR-N. The main idea is that our algorithm tries not to find the final destination but the coordinate, instead. In other words, the main process of our routing algorithms gives more interest to the search of that coordinate, because after the search process the routing to the destination is inevitable. In that way, vehicles try to route between the urban junctions in order to find the destination's coordinate. In other words, junctions use vehicle-to-vehicle routing in order not to find the final destination but every possible route that reaches the destination's coordinate. The main problem that worries us, is the best junction selection. As a consequence, we have to define some further cases.

i. If the packet is orientated in the same coordinate with the final destination: then the problem is very easy, because the final routing is trivial.

ii. If the packet is orientated to a vertical coordinate with the destination's coordinate, the packet is routed to that coordinate until finding destination's coordinate.

ii.a. If the vehicle exceeds that coordinate, because it may not find nodes in the junction, it selects to turn back through junctions, which have the best node density.

ii.b. If the packet finally reaches the destination's, act according to i.

iii. If the packet is orientated in a parallel to the destination's coordinate, the vehicle searches for the best node density junction, which may has better possibility to reach a vertical coordinate, and act according to ii.

iv. If the packet is not able to route in the coordinate direction, a coordinate is selected randomly and a search for the best node density junction to route the packet takes place, as described above.

The following pseudocode presents the proposed routing mechanism in detail:

```
do{
    if(is_same(packet_sent_coordinate, dest_coordinate)){
        route(packet_sent, final_destination);
        packet_received=TRUE;
    }else{
        if(check_is_vertical(packet_sent_coordinate,dest_coordinate) == "OK"){
            while(packet_sent_coordinate!=dest_coordinate) {
                packet_sent_coordinate = next_in_directon_coordinate();
                if (check_limits(packet_sent_coordinate)) break;
            }
            if(is_same(packet_sent_coordinate, dest_coordinate)){
                route(packet_sent, final_destination);
                packet_received=TRUE;
            }else{
                if(check_rec_density(dest_coordinate) == "OK"){
                    packet_sent_coordinate=dest_coordinate;
                    transmit(packet_sent, packet_sent_coordinate);
                }else{
                    broadcast_msg(coordinate_chosen, coordinate_left, coordinate_right);
                    if(coordinate_chosen == 0){
                        packet_sent_coordinate=random_dest();
                        transmit(packet_sent, packet_sent_coordinate);
                    }else{
                        packet_sent_coordinate = coordinate_chosen;
                        transmit(packet_sent, packet_sent_coordinate);
                    }
                }
            }
        }else{
            if(check_rec_density(dest_coordinate) == "OK"){
                packet_sent_coordinate=dest_coordinate;
                transmit(packet_sent, packet_sent_coordinate);
            }else{
```

```
                broadcast_msg(coordinate_chosen, coordinate_left, coordinate_right);
                if(coordinate_chosen == 0){
                    packet_sent_coordinate=random_dest();
                    transmit(packet_sent, packet_sent_coordinate);
                }else{
                    packet_sent_coordinate = coordinate_chosen;
                    transmit(packet_sent, packet_sent_coordinate);
                }
            }
        }
    }
}while(packet_received==TRUE);
```

The proposed algorithm was also tested in NS-3 testbed, using the same scenarios that were used for the previous measurements. Figures 7, Figure 11 and Figure 15 show the end-to-end delay of all the evaluated protocols in different grid sizes, Figures 8, 12 and 16 show the end-to-end delay standard deviation of all the evaluated protocols in different grid sizes. Also the PDR and its standard deviation for each test case is displayed at Figures 9, 13 and 17 and Figure 10, Figure 14 and Figure 18.

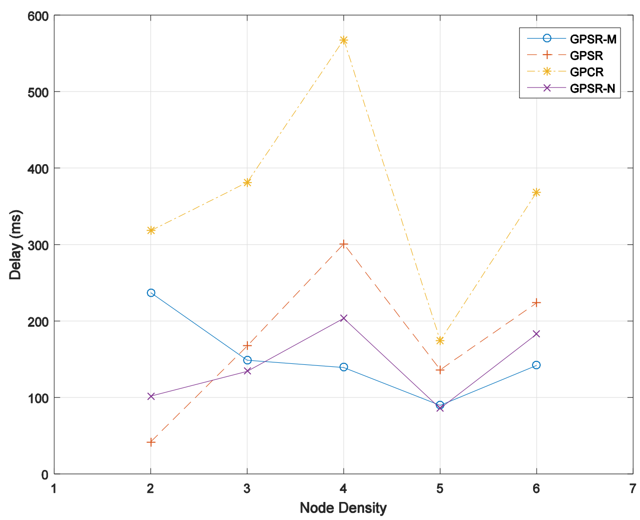

Figure 7. End-to-end delay in 3x3 grid using the proposed algorithm

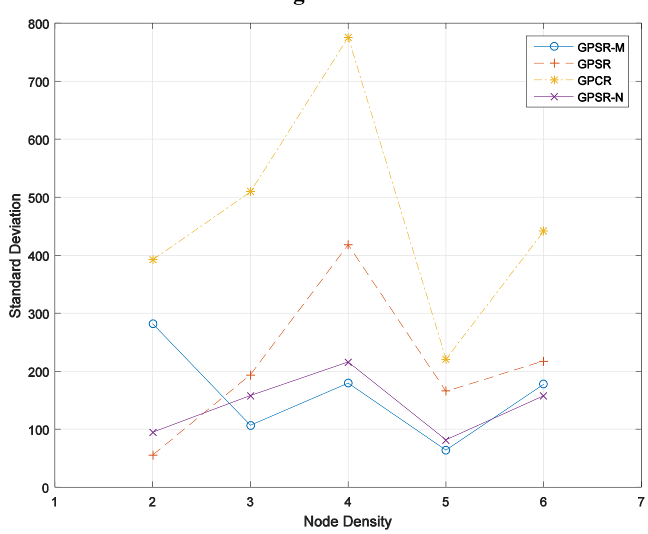

Figure 8. End-to-end delay standard deviation in 3x3 grid using the proposed algorithm

During the execution of the 3x3 grid, each packet reaches to a node that is located close the destination's coordinate after 1 step at most. Using the proposed mechanism, the source node sends the packet to a node that is close to the destination, thus making routing to the final destination a trivial task.

The results show that the proposed mechanism's end-to-end delay is similar to GPSR-M's which has the best performance of the 3 studied protocols. Moreover, the proposed GPRS-N protocol provides similar performance than GPRS-M in terms of end-to-end delay standard deviation.

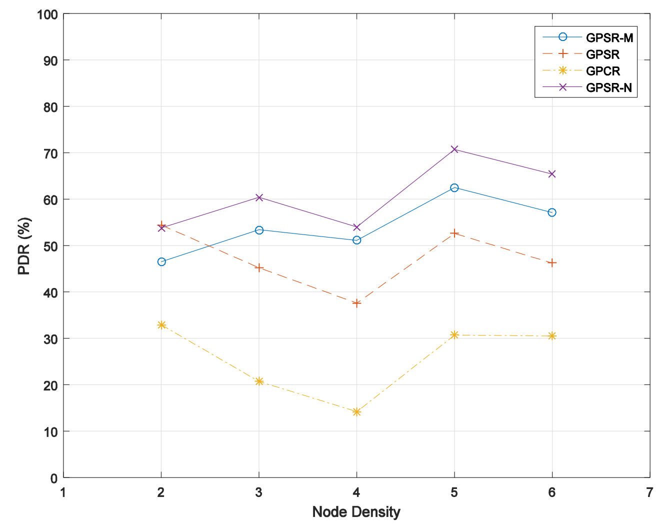

Figure 9. PDR in 3x3 grid using the proposed algorithm

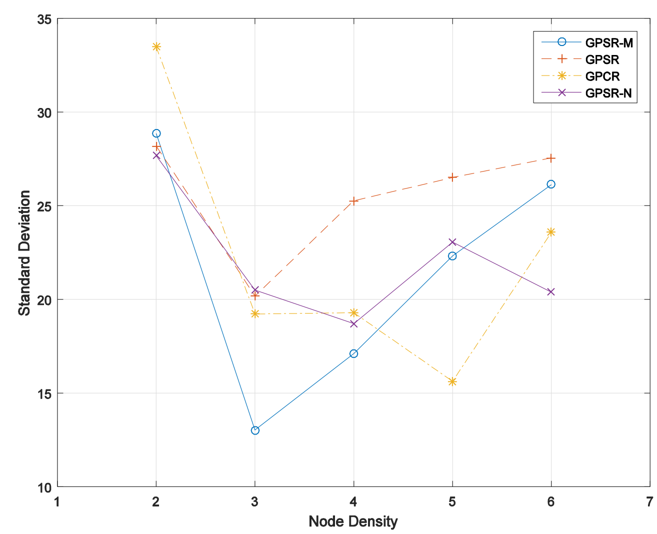

Figure 10. PDR standard deviation in 3x3 grid using the proposed algorithm

In terms of PDR, it manages to achieve a higher ratio, since in our proposal, most important decision factor is to forward the packet close to destination's vicinity using paths that are vertical to its movement direction. However, given the scenarios that were produced during the experiments, it managed to be more stable than GPSR-M only in the highest density case. For very sparse topologies, the protocol cannot guarantee better results than the GPSR-M protocol, even though the average PDR is higher.

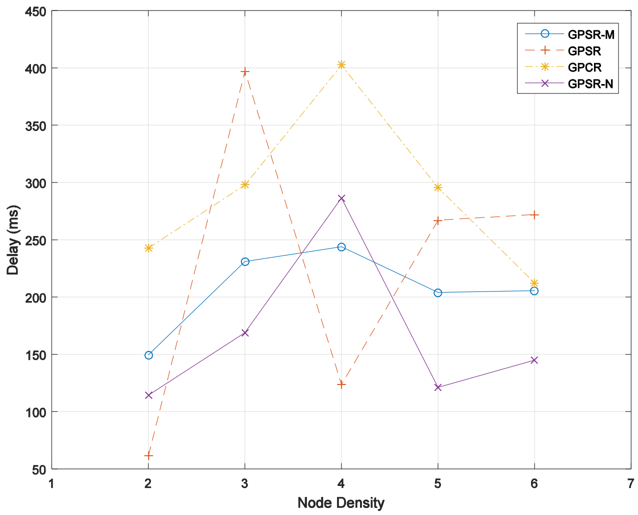

Figure 11. End-to-end delay in 4x4 grid using the proposed algorithm

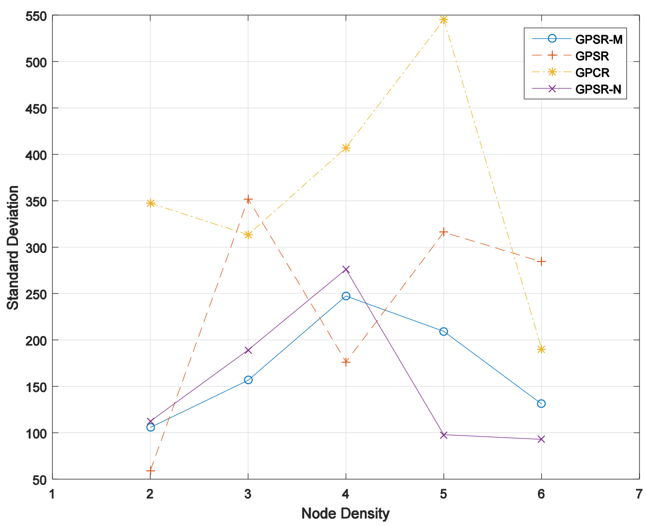

Figure 12. End-to-end delay standard deviation in 4x4 grid using the proposed algorithm

In the 4x4 grid experiments, the mechanism achieves even lower end-to-end delay than GPSR-M in comparison with the 3x3 grid case. The urge of the mechanism to reach the destination's coordinate, leads to less intermediate hops than the other protocols, where routing is decided using different criteria. In addition, the proposed GPRS-N protocol provides better performance than GPRS-M in high node density scenarios in terms of end-to-end delay standard deviation. For sparse topologies, where network connectivity is crucial, GPSR-M displays slightly better performance in the worst cases. This fact can be justified by the fact that GPSR-M targets intersections in the fashion of the classic GPSR, so the chances that a route is found are greater, but the route length might be longer. As a result, end-to-end delay is increased. On the other hand, GPSR-N uses intersections in order for the packet to enter a road that eventually leads to the destination's vicinity, so in spare topologies, there is a high chance that no such connection can be found, and the protocol will fall to GPSR's recovery mode.

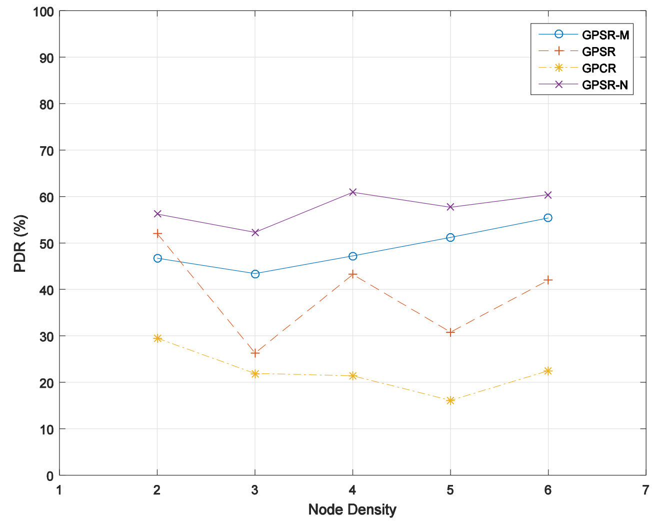

Figure 13. PDR in 4x4 grid using the proposed algorithm

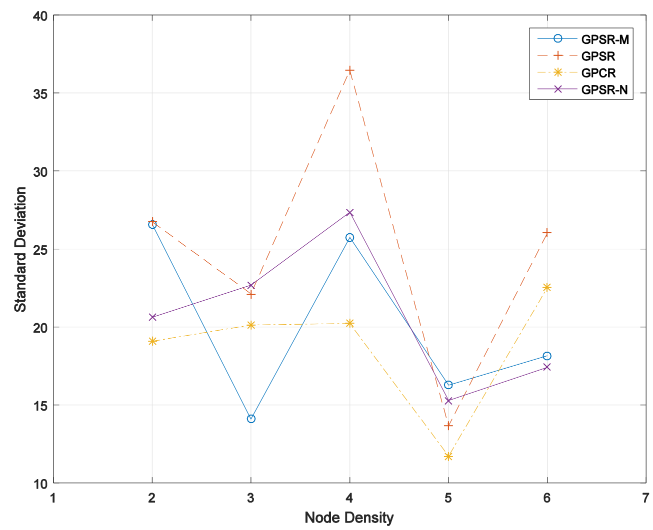

Figure 14. PDR standard deviation in 4x4 grid using the proposed algorithm

For the same reason, PDR in GPSR-N is higher than the other protocols'. The location-based routing scheme increases the possibility of establishing a successful route to the final destination of the packet. Moreover, the proposed protocol is more stable in denser environments as standard deviation is lower than the rest of the protocols. In the worst case scenarios that were tested in the experiments, it manages to deliver more packets successfully to the destination.

Additionally, from 5x5 experiments we can claim that the proposed mechanism is more stable than the others. This fact can be confirmed by comparing the standard deviation of the end-to-end delay and PDR, where the standard deviation is clearly lesser than the corresponding in GPSR-M.

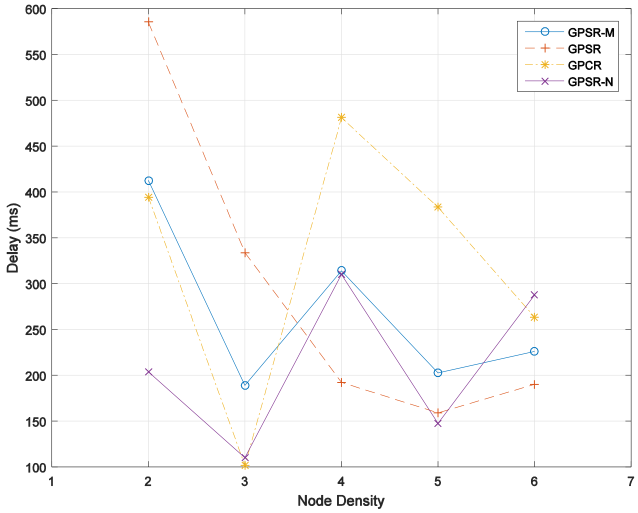

Figure 15. End-to-end delay in 5x5 grid using the proposed algorithm

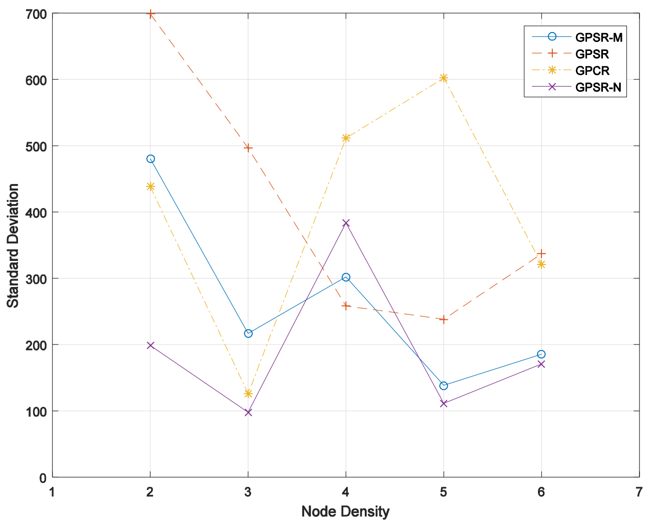

Figure 16. End-to-end delay standard deviation in 5x5 grid using the proposed algorithm

In the 5x5 grid experiments, GPSR-N performs much better in comparison with the other protocols. As the grid size grows, forwarding the packets by preferring intersections as GPSR-M does leads to larger paths, thus delaying the delivery of the packet. On the other hand, GPSR-N manages to cover large distances with less hops, decreasing delay significantly. From Figure Figure 16, we can see that the results of the experiments are more stable using GPSR-N. In contrast with corresponding results in the 4x4 grid, the proposed extension manages to surpass GPSR-M even in sparser topologies. So, it can be deducted that as the area of the network increases, GPSR-N is faster that GPSR-M, while in smaller areas, GPSR-M has the upper hand in the worst case scenario. In terms of PDR, the proposed protocol is better than the rest, while its results are not far away from the calculated average.

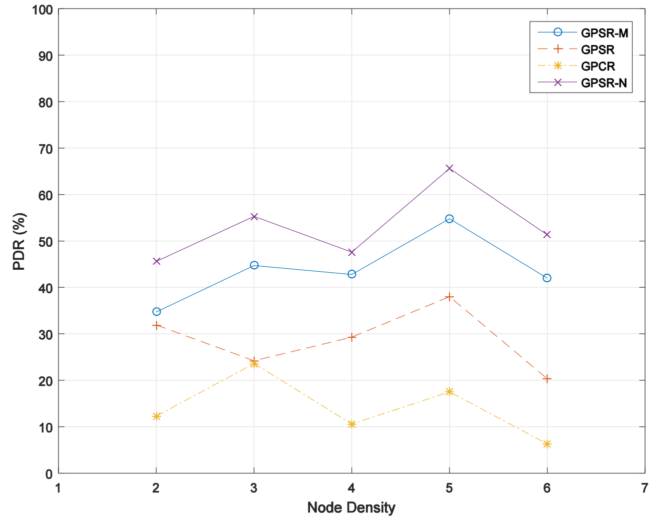

Figure 17. PDR in 5x5 grid using the proposed algorithm

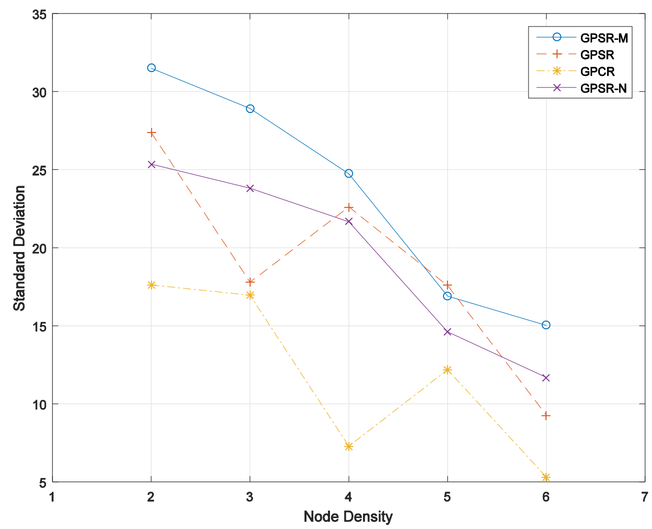

Figure 18. PDR standard deviation in 5x5 grid using the proposed algorithm

The results show that, the proposed GPSR-N has a much better performance and stability in comparison with the ones aforementioned in this paper. The urge to transit the packets close to a zone where the destination moves, avoids the risk that the packet may be lost in an intersection where no node exists a certain time. Also, the improved utilization of location and movement parameters, have made it possible for the protocol to transfer the packet to the destination with a higher probability in comparison with the other evaluated protocols. From the end-to-end delay point of view, our proposal is almost always better than the rest of the protocols, while in the cases that it does not excel, the difference from the best protocol is very low. From the PDR point of view, the proposed protocol GPSR-N provides in all cases improved performance. It is significant that, GPRS-N compared to the classic GPSR protocol, has managed to increase PDR up to 100% and achieve lower end-to-end delay derivation. The increased PDR performance is very important because lead to increased data transmission rates and better end user experience.

4. CONCLUSIONS AND FUTURE WORK

In this paper, we compare the performance of GPCR, GPSR as well as the modified GPSR (GPSR-M) routing protocols. GPSR-M is an enhancement for the GPSR protocol that focuses on routing a message to an intermediate vehicle moving in the line of movement of the final destination, as soon as possible. Based on the performance evaluation we propose enchantments to GPSR-M in order to improve performance. We propose a new mechanism, called GPSR-N, which is based on choosing the node that has an advantageous position and can relay the packet towards the coordinate of the final destination. Performance evaluation shows that in most cases our proposal provides better performance in comparison with the other three evaluated protocols. It achieves visibly higher PDR and slightly better end-to-end delay. Finally, based on the experiment results, we can claim that our proposal is characterized by higher stability that the others.

Our future work includes the further performance evaluation of the proposed enchantments to GPSR-M through simulation, and especially in larger grids, in order to confirm the performance improvement of the proposed enchantments to GPSR-M and reach conclusions regarding alternative approaches on VANETs ad hoc routing.

5. REFERENCES

[1] Maan F. and Mazhar N. 2011. MANET routing protocols vs mobility models: A performance evaluation. In *2011 Third International Conference on Ubiquitous and Future Networks (ICUFN)*. Dalian, 15-17 June 2011.

[2] Kakarla J., Sathya S. S., Laxmiand G. B. and Babu B. R. 2011. A Survey on Routing Protocols and its Issues in VANET. *International Journal of Computer Applications.* Vol. 28, no. 4, pp. 38-44. August 2011

[3] Rakesh K. and Mayank D. 2011. A Comparative Study of Various Routing Protocols in VANET. In *International Journal of Computer Science Issues (IJCSI).* Vol. 8, no. 4, p. 643. July 2011.

[4] Lee K. C., Lee U. and Gerla M. 2010. Survey of Routing Protocols in Vehicular Ad Hoc Networks. In *Advances in Vehicular Ad-Hoc Networks: Developments and Challenges*. Hershey, PA. IGI Global, 2010. pp. 149-170.

[5] Karp B. and Kung H. T. 2000. GPSR: Greedy Perimeter Stateless Routing for Wireless Networks. In *The 6th Annual International Conference on Mobile Computing and Networking (MobiCom '00)*. Boston, Massachusetts, USA. August 6-11, 2000.

[6] Lochert C., Mauve M., Fussler H. and Hartenstein H. 2005. Geographic Routing in City Scenarios. In *ACM SIGMOBILE Mobile Computing and Communications Review.* Vol. 9, no. 1, pp. 69-72. January 2005.

[7] Bouras C., Kapoulas V. and Tsanai E. 2015. A GPSR Enhancement Mechanism for Routing in VANETs. In *The 13th International Conference on Wired & Wireless Internet Communications (WWIC'2015)*. Malaga, Spain. May 25-27, 2015.

[8] Fonseca A., Camoes A. and Vazao T. 2012. Geographical Routing Implementation in Ns3. In *The 5th International ICST Conference on Simulation Tools and Techniques (SIMUTOOLS '12)*. Desenzano del Garda, Italy. March 19 - 23, 2012.

[9] Aschenbruck N., Ernst R., Gerhards-Padilla E. and Schwamborn M. 2010. BonnMotion: A Mobility Scenario Generation and Analysis Tool. In *The 3rd International ICST Conference on Simulation Tools and Techniques (SIMUTools '10)*. Torremolinos, Malaga, Spain. March 16 - 18, 2010.