Performance Study for Impact of Mobility Model and Position Update Interval in Geographic Routing

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Abstract— Geographic routing has attracted many researchers with no need for routing table to forward packet in mobile ad hoc networks. Previously, some literatures have mentioned how to improve the performance via simulation results. However, they didn't address the impact of various mobility models and beacon interval, which is used to maintain recent position information for nodes. In this paper, we introduce well-known geographic routing protocol called as GPSR and conduct simulation to identify the impact of these parameters. Even though GPSR shows acceptable performance in most cases, sometimes its performance becomes worse than what we expect.

Index Terms— Geographic routing, mobility model, mobile ad hoc networks

I. INTRODUCTION

Mobile ad hoc network has been proposed to solve the problems of infrastructure networks such as long deployment time, high cost for installation and dependency of exiting network. In this kind of network, a node is able to communicate by wireless medium and move anywhere freely whenever it wishes. Node movement naturally brings dynamic topology so that links between nodes are connected and disconnected unpredictably and continuously. Moreover, dynamic topology requires that networks should be operated in a self-organizing way that each mobile node acts as not only a host but also a router. Thus, this kind of network is called the multihop network. There are some examples of possible uses of ad hoc network, including sharing information by business associates during a meeting, soldiers communicating with each other on the battlefield, and emergent operation after earthquake.

Outstanding features mentioned above imply that typical network protocol is not suitable for mobile ad hoc networks because they are not designed for dealing with unexpected dynamic topology efficiently. Also, a host in mobile ad hoc networks has limited resource in terms of computing, memory, and battery. These features are not considered in typical protocol too. In order to meet this requirement, many researches [3-5] have been conducted to establish and maintain the path under dynamic topology. In their approaches, mobile nodes need to maintain some neighbors' table in their transition range and then establish routing dynamically among themselves and to the others.

Different from above approach, a new technology called geographic routing has been introduced in mobile ad hoc networks. The basic assumption of this approach is that the nodes in ad hoc network can get the geographic information by themselves since the cost of including this specific equipment becomes cheaper and cheaper. Due to the help of this equipment, nodes can make simple routing decisions based on the local geographic position of nodes so it does not need to maintain routing table in geographic routing. It means that a node does not need to keep changing in topology. Example protocols include GPSR (Greedy Perimeter Stateless Routing) [1] and LAR (Location Aided Routing) [2].

However, these approaches are not ideal protocols so that additional scheme is required to improve performance. To achieve this, simulations are usually used to identify the comparative results in most literatures. But, as far as the authors know, there is no previous paper to address the impact of mobility model and position update interval now. More detailed, most simulations were conducted under a well-known mobility model, which is called the random waypoint model. In addition, the impact of control message acting on updating nodes' position information has not been analyzed.

In this paper, we evaluate geographic routing protocol under various mobility models by varying position update interval. We choose GPSR because it gets good reputation through well defined forwarding

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algorithm and structure. Also, heavy traffic scenarios are included to see whether GPSR can deal with traffic load well.

The reminder of this paper is organized as follows. We describe the motivation of this paper in Introduction. In section II, there is the overview of GPSR and related works are presented. The performance results are analyzed and explained in section III. Finally, conclusion and further works are presented.

II. OVERVIEW OF GPSR

In this section, we describe the basic procedure of GPSR and some research efforts to improve the performance of GPSR.

A. Basic Principle of GPSR

Whenever a source has a data to send, it needs to know the position of the destination in GPSR. The routing decision at each node is based on the destination's position which is already contained in the packet. Every forward node just needs to choose one neighbor most near to the destination to forward the packets. Then the packet will be directly sent to the destination.

This algorithm was proposed by Brad Karp and H. T. Kung. This method contains two important parts: the first part is greedy forwarding and the second is perimeter forwarding.

Firstly, greedy forwarding means that a forward node can make a greedy choice for choosing the packets' next hop. To implement this function, every node in the network mast maintains its neighbour table which contains the position information of their neighbours. And the neighbour table needs to be updated in the period of time which is called beacon time in the GPSR. By referring these tables, every packet will be forwarded until the packet arrives at the destination. In greedy forwarding procedure, each node should choose one node that is the nearest from its neighbour until the destination is reached. The nearest one means that the direct distance between the chosen nodes and the destination has the smallest value. This packet-sending procedure is called the Greedy forwarding. For example in Figure 1, radio range of node A is denoted by the circle around. In addition, the arc with radius equal to the distance between A and D is shown as the dashed arc about node D. Node A forwards the packet to B, that is because the distance between B and D is less than that between D and any of A's other neighbours. The greedy forwarding process will repeat until the packet reaches D.

Secondly, perimeter forwarding is mentioned as another outstanding feature of GPSR. When the packet is being forwarded there are always some nodes that cannot find out the next hop which can satisfy the greedy forwarding's condition. May be there is a void area in front of that node, and in that area there is no node that has a shorter distance than that one. Then in this case the packet will be forwarded to the destination around the void area. Forwarding the cycle according to the right hand rule amounts to crossing around the void area, especially for the nodes which are closer to the destination than the one that has a void area in front of it. After the packet reaches that node, the greedy forward will come back. We call the sequence of edges traversing by the right hand rule a perimeter. For example in Figure 2, there is a void area in front of node A, which has a longer distance than any other nodes. Then in this case the packet will be forwarded to the destination around the voids. So the traversing cycle is A→B→D→F→H→G→E→C →A by the right hand rule amounts to crossing around the void area.

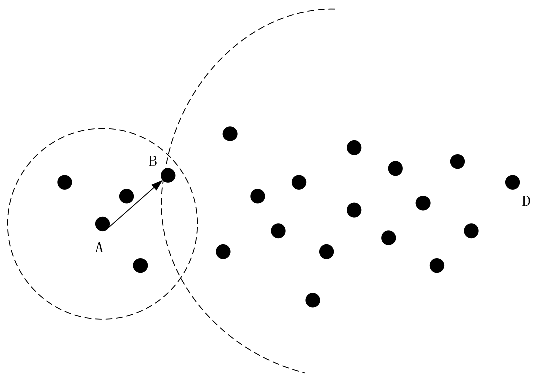

Fig. 1 example of greedy forwarding

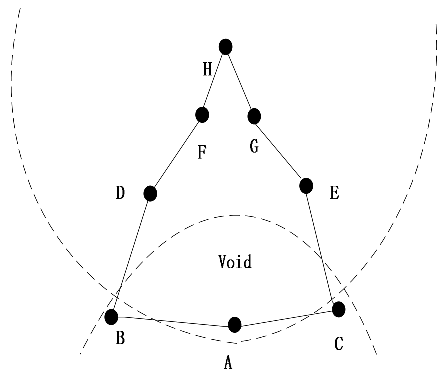

Fig. 2 example of perimeter forwarding

B. Research efforts to improve GPSR

Recently, some researchers have been conducted to improve performance of GPSR. Their goals are to complement GPSR by implementing movement prediction so as to choose the better next hop. We briefly describe their contributions.

DGRP (Directional Greedy routing protocol) [6] works based on greedy routing protocol. It uses the location, speed and direction of their neighbours to select the most appropriate next forwarding node. DGRP gets the position, speed and direction information of its neighbour nodes from each beacon packet so that we can predict the position of its neighbour nodes.

GBSR (Greedy Border Superiority Routing) [7] consists of two modes like GPSR algorithm; one is greedy mode and the other is recovery mode. In the recovery mode, it is not efficient to forward backward in short distance through planarized links in the vehicular network scenarios. The best way to recover from the local maximum is to make the packet reach a conversion point as fast as possible.

Greedy Perimeter Stateless Routing with Movement Awareness (GPSR-MA)[8] uses the speed and direction of movement to extend the set of parameters. If we get the movement direction and speed, every node is able to update location coordinates of its neighbours in time. Other schemes to improve GPSR include [9-10].

III. PERFORMANCE EVALUATION

A. Simulation Environment

The performance of GPSR is evaluated through ns-2.27 by using the Liuke's GPSR code. Our results are directly got from the simulation trace file, without any modification. For simulations, ns2 defaults the simulation model, which is used by node to choose the destination at a random way and make the velocity uniformly in the map. In simulations, the default value of some parameters is IEEE 802.11 for the MAC protocol. In addition, 250 meters is for the sending range. The simulation lasts 300 seconds. There is one packet being transmitted per second. The territory of this map in scenario is 300 meters for width and 1500 meters for height. Other environment parameters are explained according to the specific simulation scenario.

B. General Simulation Scenarios of GPSR

Since the code of GPSR that comes from Liuke is used in this simulation, general simulation scenarios follow the steps below. At the beginning of our simulation, each node should setup its neighbor table to save its neighbors' position information. And, all nodes in the network should broadcast their current position in a period of time since a location database to update packets for destinations' position is not implemented. After receiving this GPSR packet, a node updates the neighbor tables. After the system finishing the starting, the procedure of sending data packets will start. The data packets are delivered to the destination by greedy forwarding. The perimeter mode works in special case.

C. Simulation Results : Increasing sending rate

Fig. 3 shows that when the packet-sending rate increases, how many packets are delivered successfully by GPSR for varying beacon interval, which is defined as B. The nodes' velocity value in this scenario is set to 10 m/s. The increasing packet-sending rate shows that the network load becomes heavier. And the decreasing beacon interval indicates that the neighbor table is updated more frequently. Data packet delivering represents the range of how many packets are successfully delivered.

We can see the highest data packet delivery ratio when the beacon interval is set to 2.5s. The main reason for this result is that the frequent neighbor table plays an important role in successful packet delivery. If the neighbor table updating happens more frequently than the nodes' position changing, a node can keep the exact position information. So the node can forward packet more exactly to the destination. It implies that the higher packet delivery ratio is observed when beacon time is short in GPSR.

However, it is required to note that not all scenarios on graph show good performances. This can be explained by two features. First, a node cannot update neighbor table in time when neighbor nodes moves out of transmission range. So, it is better to set the update interval for neighbor table less than maximum beacon interval. Otherwise, some packet losses are not evitable in GPSR. Second, if the destination node's position is not updated in time for the source node, the source node will still send packet to the old position of destination. This packet is transmitted towards old position and discarded by other nodes due to no more available next hop.

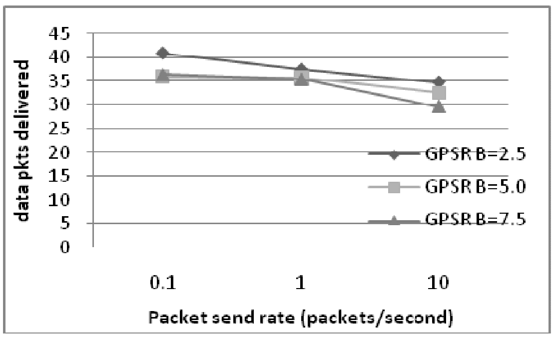

Fig. 3 Packet delivery success ratio as functions of varying packet sending rate and GPSR beacon intervals.

Figure 4 shows how much delay is taken for GPSR packets under the same scenarios as Fig. 2. We can find out that the beacon interval shows the shortest delay when the scenarios are with 2.5s. Also, the same patterns are observed with different sending rates because of the relationship between neighbor table updating interval and beacon interval. If neighbor table is updated more frequently than position information, delay will become shorter because packet is transmitted along the optimal path by greedy forwarding. Otherwise, additional delay is caused by delivery along the longer hops.

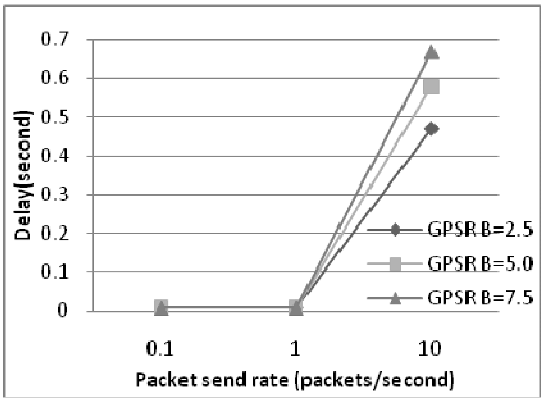

Fig. 4 Packet delay as functions of varying packet sending rate and GPSR beacon intervals.

D. Simulation Results : Freeway Mobility Model

Different from previous evaluation, we conduct simulations under the different mobility models, freeway and Manhattan model. In this part of simulation, 10 connections are randomly established while the other parameters for this simulation remain the same as previous scenario. For simulation, performances with different beacon time in GPSR are measured under different mobility models.

Firstly, freeway model is modeled in [11] and proposes this model to emulate the nodes' movement on a freeway. This model can be used in exchanging traffic status or tracking a vehicle on a freeway. There are several freeways on the map and each one has lanes in both directions. We use different velocity values to evaluate the GPSR with different beacon time in this mobility model.

From Figure 5 we can see that the different GPSR beacon intervals don't show similar pattern for increasing velocity. When the beacon time value is 7.5, it shows a higher rate of success than the others. That is because the congestion happens when the beacon time becomes shorter. When the beacon time decreases, the updating for neighbor table will occur more frequently. Moreover, the traffic loads in the whole network also increase. Thus, the network is not allowed to accommodate traffic any more. Absolutely, the line for beacon time in 7.5 is illustrated higher than others due to the congestion that the velocity increases in this scene.

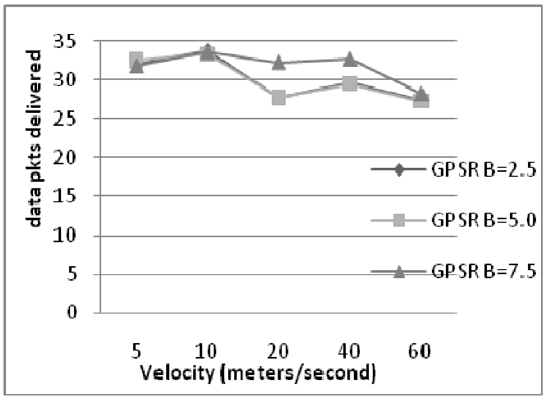

Fig. 5 Packet delivery success ratio as functions of varying GPSR beacon and velocity under freeway model

Fig 6 shows the packet delay for GPSR packets with varying buffer sizes under freeway model. We can see that a different GPSR beacon interval shows the similar pattern for increasing buffer size. In this scenario, I set the packet-sending rate as 10 packets per second and the velocity of nodes as 60 meters per second.

We can see that there is an obvious difference between beginning and end. The main reason for this result is due to the increasing of buffer size. If the buffer size becomes larger, a node can deal with more packets. And the packet waiting for deal time also gets longer. So the delay value becomes higher. But it does not mean more packets will be better. Sometimes, if the delay value gets too large, the packets will have no meaning.

In addition, in Fig 6, we can get another reason for why does not the packet delivery success ratio act well in this paper. Because when the buffer is full filled, there will be no more new packet that could be inserted into the buffer for dealing. Then the new packet will be dropped, until the buffer empties some places for the new packets after some of them have been already deleted. So the packets which have been dropped in this case cannot arrive at the destination. Then the packet delivery success ratio doesn't act very well.

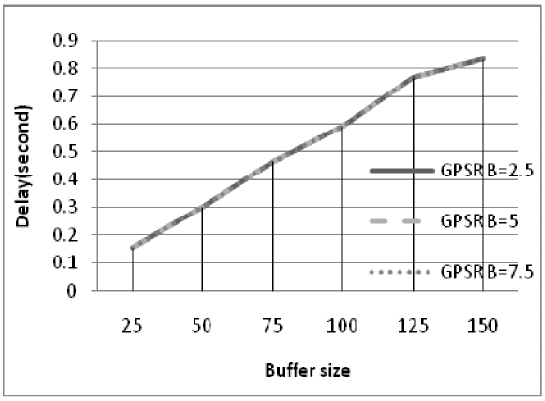

Fig. 6 Packet delay as functions of varying buffer size and GPSR beacon intervals under freeway model

E. Simulation Results : Manhattan Mobility Model

The Manhattan mobility model is proposed to model movements in an urban area [12]. In the Manhattan model, the mobile node can move along the horizontal or vertical streets. And at an intersection of streets, the mobile node can turn left, right or go straight. Increasing number of street means there would be more complicate movements of the nodes in the network. The streets are combined with the horizontal and vertical streets. Nodes in the network can move at a fixed speed in the random way, but still have to go along the streets. For this simulation, we adapt the same simulation parameter and expect the average value of velocity would be 20 m/sec.

And we can find out an interesting result from the Fig. 7, that GPSR with beacon time 2.5 outperforms other cases when the number of streets increases. The main reason is that the shorter beacon interval a node has, the more frequent update occurs. But, as indicated in previous simulation results, congestion is trade-off caused by short beacon time.

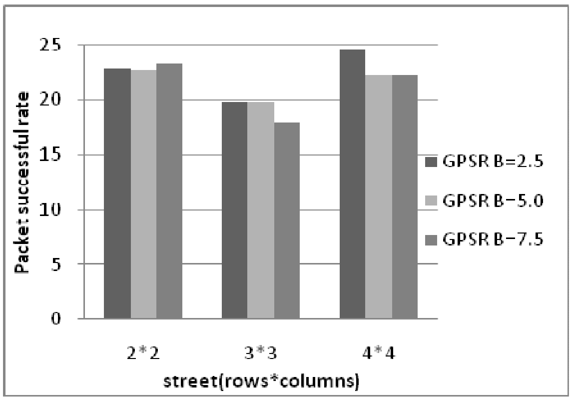

Fig. 7 Packet Delivery Success Ratio as functions of varying beacon intervals and the number of streets in Manhattan model

Fig. 8 shows the packet delay for GPSR packets with varying buffer sizes under Manhattan model. We can see that different GPSR beacon intervals show little differences on increasing buffer size. In this scenario, I set the packet-sending rate as 10 packets per second and the velocity of nodes as 20. When we increase the buffer size, the delay is also increased. The reason of this scenario is the same as the former one.

We can see that delay is still the highest when the beacon interval is set to 2.5s. The main reason for this result is that the frequent neighbor table updates. If the neighbor table updating happens more frequent, the whole network will accommodate more packets. So the node's buffer is always full filled. It implies that higher delay is observed when beacon time is short in GPSR.

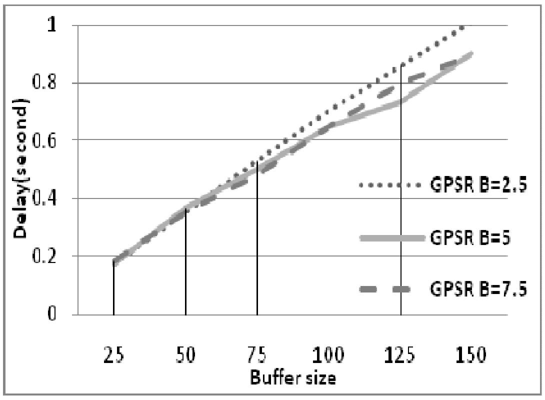

Fig. 8 Packet delay as functions of varying beacon intervals and the number of streets in Manhattan model

F. Simulation Results : Traffic Flows

To evaluate the performance of GPSR, we introduce 10 connections with varying speeds. To identify the differences, two groups are introduced. One is 10 connections with light traffic load while the others suffer from heavy traffic, which leads to a congestion quickly by increasing sending rate.

We can see that GPSR works very well in Fig. 9 no matter the simulation environments. However, another feature mentioned in Fig. 9 is that the successful packet rate is rapidly decreasing when the speed is increasing especially at the beginning. The point is that there is quite a big difference between beginning and end. But, the difference between them gets smaller and smaller. This feature implies that GPSR works very well in highly dynamic networks rather than lower ones.

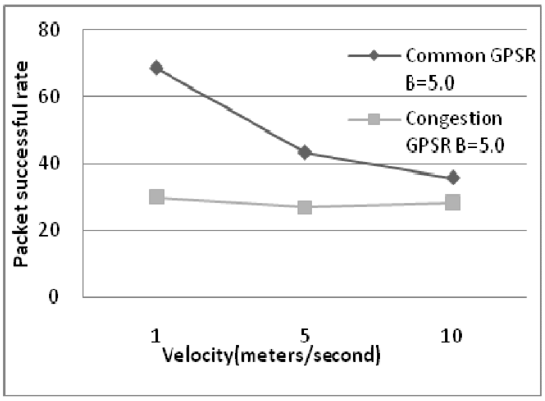

Fig. 9 Packet delivery success ratio as functions of varying velocity and traffic load

The increasing connection number means that how many data flows are established at the simulation. One connection is made by one source node and one destination node. Moreover, source and destination are always the same even though connection number increases.

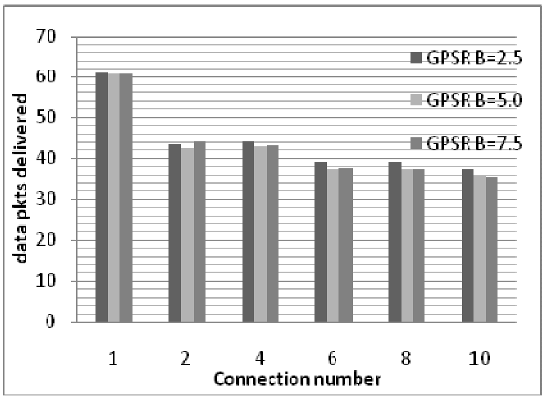

Fig. 10 Packet delivery success ratio as a function of connection numbers

Fig. 10 exhibits the packet delivery success ratio as a function of connection number. As we expect, traffic load in the whole network also increases when connection number increases. Delay shows the similar pattern because congestion greatly affects two measurable parameters, packet delivery and congestion.

G. Discussion

In this section, we analyze the simulation results. We identify two important factors to operate GPSR in mobile ad hoc networks. One is for beacon time. Beacon time is closely related to renewed position information. So, even though short beacon time is strongly desirable, however, it causes heavy traffic loads, which can prevent data packet from being transmitted along the optimal path. If the congestion is adjusted by GPSR according to network environment, this is not on problem. But, GPSR is not capable of avoiding heavy congestion.

Related to congestion, second problem is greedy forwarding, which is the major principle of forwarding in GPSR. Greedy forwarding can seek the next hop in optimal way at each node, the same node is always chosen without regarding to congestion or other parameters. So, low packet delivery ratio and long delay are not evitable in GPRS. These pheromones are easily observed when the nodes' velocity is set as a low speed. In less dynamic networks, the same node is chosen more frequently since it is likely for a node to stay near the neighbouring nodes for long time.

Another analysis for mobility model is summarized as follows. Even though two additional models are introduced in this simulation, performance is not greatly affected by these models. Rather, it shows acceptable performance in freeway model where vehicles move fast and follow their direction for a long time. It means that frequent position changing is not acceptable in GPSR.

IV. CONCLUSION AND FURTHER WORKS

Although geographic routing protocol has the strength in mobile ad hoc networks rather than topology based on general protocol in terms of mobility, some flaws have been recently reported and mentioned in previous works. However, they didn't mention the performance of GPSR as beacon time, mobility model, and traffic load. In this paper, simulations are conducted and analyzed. Through analysis, we found that the important weakness, no congestion control, was ignored in GPSR.

Related to this work, congestion control scheme is going to be developed. Also, the schemes that can improve the packet delivery ratio are under considerations. In addition, extensions to support real-time communication will be made in GPSR.

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REFERENCES

[1] Brad N. Karp and H. T. Kung, “GPSR: Greedy Perimeter Stateless Routing for Wireless Networks,” In Proceedings of MobiCom, pp. 243 - 254, August 2000.

[2] Y-.B. Ko, and N. H. Vaidya, “Location-aided routing (LAR) in mobile ad hoc networks,” In Proceedings of Mobicom, pp. 66-75, 1998.

[3] Changling Liu, and Jorg Laiser, “A Survey of Mobile Ad Hoc network Routing Protocol,” University of Ulm Tech. Report Series, Nr. 2003-08, October 2005.

[4] D. B. Maltz, D. B. Johnson, Y. Hu, and J. Jetcheva, “A performance comparison of multi-hop wireless ad hoc network routing protocols,” In Proceedings of MobiCom, August 1998.

[5] D. B. Maltz, and D. B. Johnson, “The effects of on-demand behavior in routing protocols for multihop wireless ad hoc networks,” IEEE Journal on Selected Areas in Communications, Vol. 17, No. 8, pp. 1439–1453, August 1999.

[6] R. Kumar, and S. V. Rao, “Directional Greedy Routing Protocol (DGRP) in mobile Ad-hoc Network. Information Technology,” in Proceedings of ICIT, pp 183 – 188, December 2008.

[7] Yu. Sukdea, Hoon Choi, Gihwan Cho, “A new recovery method for greedy routing protocols in high mobile vehicular communications,” in Proceedings of Vehicular Electronics and Safety, pp. 45 – 50, September 2008.

[8] Fabrizio Granelli, Giulia Boato, Dzmitry Kliazovich, and Gianni Vernazza, “Enhanced GPSR Routing in Multi-Hop Vehicular Communications through Movement Awareness, “IEEE Communications Letters, Vol. 11, pp. 781-783, 2007.

[9] C. Lochert, M. Mauve, and H. Fubler, “Geographic Routing in City Scenarios,” Mobile Computing and Communications Review, Vol. 9 No. 1, pp.69-72, 2004.

[10] K. C. Lee, J. Haerri, U. Lee, and M. Gerla, “Enhanced Perimeter Routing for Geographic Forwarding Protocols in Urban Vehicular Scenarios,” in Proceedings of Globecom, pp.1-10, November 2007.

[11] F. Bai, N. Sadagopan, and A. Helmy, “Important: a framework to systematically analyze the impact of mobility on performance of routing protocols for adhoc networks,” In Proceedings of INFOCOM, 2003.

[12] Biao Zhou, Kaixin Xu, and Mario Gerla, “Group swarm mobility models for ad hoc network scenarios using virtual tracks,” in Proceedings of MILCOM, October 2004.

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