Location-Based Routing for Vehicular Ad-Hoc Networks

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1. INTRODUCTION

Communication between vehicles is likely to be one key area where mobile ad-hoc networks will be used in the near future. Currently there are several projects ([1, 3]) that investigate this application area, while car manufacturers and their suppliers aim at the development of products within the next few years. This raises the question what kind of routing algorithm is suited for communication between vehicles. Existing performance studies for various ad-hoc routing protocols do not use movement patterns which resemble the movement of cars and are thus not well suited to answer this question.

We have conducted an extensive simulation study based on realistic vehicle movement patterns. Our main aim was to investigate how a topology-based approach compares to a location-based routing scheme when applied to vehicular networks. As representatives we have chosen DSR [4] as a topology-based approach and GPSR [5] complemented with a simple location service as a location-based scheme. For a general discussion of topology-based and location-based ad-hoc routing please refer to [2] and [6].

Vehicular ad-hoc networks have several unique characteristics. The main challenge is the high speed with which nodes move in respect to each other. If oncoming traffic is included in the forwarding of packets, then relative speeds of 250 km/h to 300 km/h are common. This implies a very high rate of topology changes. Also it is not clear if one single partition spans sufficient distance to enable meaningful applications such as emergency warnings or vehicle-to-vehicle entertainment. On the other hand it is safe to assume that battery power is not an issue for vehicular ad-hoc networks. Location-based approaches further benefit from the fact that vehicles are aware of their geographical positions through the use of on-board navigation systems.

2. PRELIMINARY RESULTS

2.1 Real-World Movement Scenarios

Generating realistic vehicular movement patterns is a direction of research which is of fundamental interest to vehicle manufacturers, e.g., to determine how certain parts of a vehicle will last until they have to be replaced. As the vehicle movements are generated by a ‘pre-process’ and complexity is therefore a minor concern, we decided to use a *Driver Behavior Model* for the traffic simulation. Such a model not only takes the characteristics of the vehicles into account but it also includes a model of the driver’s behavior, like lane changing and passing decisions, traffic regulation and traffic sign considerations, or decreasing speed in curves, to name only a few. Driver Behavior Models are known to be highly accurate. As a simulator we used the well validated DaimlerChrysler-internal driver behavior simulation tool called FARSI. In particular FARSI simulations show realistic speeds, distances, and macroscopic properties like traffic flow and lane usage. Thus, FARSI guarantees that the vehicle movement patterns forming the basis of our experiments are as realistic as possible.

With FARSI we generated movement patters for (German) highway traffic as well as traffic within parts of Berlin. The key contribution of our work is to study these patterns and the behavior of the routing protocols analytically and by means of discrete simulation using the ns-2 network simulator. An example for an analytical graph of a highway scenario can be found in Figure 1. This figure displays the connectivity of the ad-hoc network depending on the radio range and whether or not to use oncoming traffic for the forwarding of packets.

An important observation of this analysis is the need to use oncoming traffic if the radio range is smaller than about 500 meters. This leads to high relative speeds and low topological stability.

2.2 Comparison of Routing Strategies

For the comparison of location-based and topology-based routing algorithms, we choose GPSR [5] (location) and DSR [4] (topology), since they are well known representatives of the respective classes. The comparison done in [5] unrealistically assumed that each node knows the position of each other node. Furthermore the movement patterns of the nodes were random and did not allow an assessment for vehicular ad-hoc networks.

We ported the original implementation of GPSR to ns-2.1b8a and extended it with a simple reactive location service (RLS), inspired by DSR route discovery: whenever the position of a node is required, the node looking for position information floods a request containing the ID of the node it is looking for. The request contains the ID and position of the requesting node. When a node receives a request with its own ID, it replies to the node looking for its position. In order to reduce the range of the flooding an expanding ring search is performed: the flooding starts with a range of 2 hops and is repeated with exponentially increasing range when no response is received during a certain time. For DSR we used the standard distribution which is part of ns-2. As MAC layer IEEE 802.11 was employed, while the communication partners were chosen such that there is always a valid path from the source to the destination.

Figure 2 shows the main results of the comparison: the rate of successfully delivered packets for DSR diminishes when the maximum communication distance becomes larger. This is caused by the fact the DSR needs to maintain a route from the sender to the receiver which becomes harder when the length of the route increases. The location-based approach stays close to the perfect

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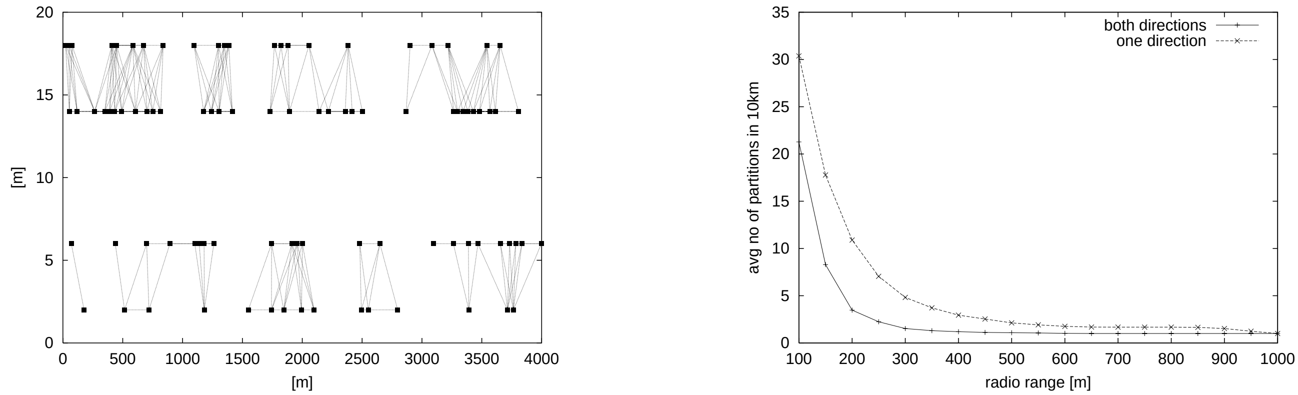

(a) Connectivity-snapshot ignoring oncoming traffic (b) Average number of partitions

Figure 1: Network partitioning in a highway scenario

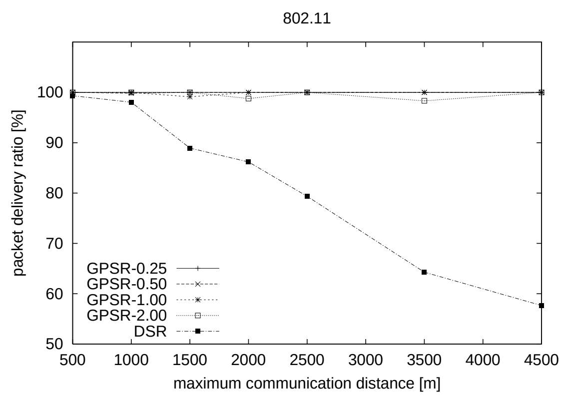

Figure 2: Packet Delivery Ratio of DSR and GPSR

packet delivery rate of 100% for all distances. This can be explained by the properties of location-based approaches: packet drops can occur only for one of the following three reasons: (1) if a local maximum is reached. This is extremely unlikely in our scenario. (2) If the information about the position of the local neighbors is inaccurate. Again this is very unlikely since the flooding of the location service in combination with piggy-backed beacons will provide nearly perfect information about the neighbors. (3) If the information about the position of the destination is inaccurate. This is also very rare, since the reply containing the position of the destination requires only minimal time to reach the sender, thus it is very accurate when the data packet is transmitted.

We are currently in the process of comparing the performance of both routing protocols in city environments. The generation of traffic patterns is complete and the obstacle modeling is also done. At this time simulations are underway.

3. CONCLUSIONS AND OUTLOOK

In this work we have shown that location-based routing is likely to be an appropriate scheme for routing in vehicular ad-hoc networks, at least for highway environments. The direct usage of existing topology-based mechanisms seems less appropriate. However, it may be possible to tune topology-based routing, e.g. by preferring routes over vehicles driving in the same direction. Currently we investigate city scenarios to allow a broader view on the suitability of the distinct routing approaches. In addition to the analytical and theoretical evaluation we are going to conduct experiments using a fleet of 10 DaimlerChrysler Smart-class vehicles. Although the multihop-capability of such a small network may not be highly representative, we still expect valuable insights by connecting theory and the real world.

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