An Efficient Vehicle-Heading Based Routing Protocol for VANET Networks

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Abstract— **Internetworking over Vehicle Ad-hoc Networks (VANETs) is getting increasing attention from all major car manufacturers. The design of effective vehicular communications poses a series of technical challenges. Guaranteeing a stable and reliable routing mechanism over VANETs is an important step towards the realization of effective vehicular communications.**

In current ad-hoc routing protocols, the control messages in reactive protocols and route update timers in proactive protocols are not used to anticipate link breakage. They solely indicate presence or absence of a route to a given node. Consequently, the route maintenance process at both protocol types is initiated only after a link breakage event takes place. This paper argues the use of information on vehicle headings to predict a possible link breakage event prior to its occurrence. Vehicles are grouped according to their velocity vectors. When a vehicle shifts to a different group and a route, involving the vehicle, is to be broken, the proposed protocol searches for a more stable and "more durable" route that includes vehicles from the same group. The proposed scheme is dubbed *Velocity-Heading based Routing Protocol (VHRP)*. Whilst the proposed scheme can be implemented on any existing routing protocol, the paper considers the case of VHRP over Destination-Sequenced Distance Vector (DSDV) routing protocol. The performance of the scheme is evaluated through computer simulations. Simulation results indicate that knowledge on the vehicles' heading adds major benefits to routing in terms of reducing the number of link breakage events and increasing the end-to-end throughput.

I. INTRODUCTION

Along with the exponential spread of small electronic devices and the increasing demand for full support of mobility, telecom operators are facing a major paradigm shift in the way they provide their services. Users should be no longer restricted to wired networks. They should be rather granted pervasive access to Internet services, regardless of time and space limitations. This has caused the emergence of different types of wireless networks.

There are two types of wireless networks: Infrastructure and ad hoc networks. The former represents most of today's wireless networks. It includes cellular phones and wireless LAN networks. In wireless infrastructure networks, Base Stations (BSs) manage the end-terminals that are roaming within their coverage areas. In general scenarios, the base stations are connected to the wired part of the network and communication with mobile users goes always via these BSs. Mobile Ad-hoc NETworks (MANETs) are deployed and managed independently of any pre-existing infrastructure. Indeed, in MANETS, mobile users communicate directly among each other with no central management unit. When a communication path can not be directly established between two end-users, it goes through multi-hops. In such a case, users in the middle of the path act as routers.

MANET networks have recently received particular attention at both industrial and academic levels. They are seen as an important component of next-generation networks. While MANETs were initially designed for militarily purposes, recent advances in wireless technologies, such as Personal Area Network (PAN) (e.g. Bluetooth 802.15.1, ZigBee) and wireless LAN (802.11), have brought new alternatives to the use of MANETS. They have enabled the support of a broad range of new commercial applications over MANETs. In addition to the aforementioned technologies, Short Range Communications (DSRC) have made Inter-Vehicular Communications (IVC) and Road-Vehicle Communications (RVC) possible in MANET networks. This has given birth to a new type of MANET networks known as Vehicular Ad-Hoc Networks (VANETs).

Over the past few years, VANETs have been gaining a great deal of momentum. Indeed, its increasing importance has been recognized by industrial corporations, government organizations, and the academic community. Federal Communications Commission (FCC) has allocated spectrum of IVC and similar applications (e.g. Wireless Access in Vehicle Environment, WAVE). Governments and prominent car manufacturers, such as Toyota, BMW, and Daimler-Chrysler have launched important projects for IVC communications. Advanced Driver Assistance Systems (ADASE2) [2], Crash Avoidance Metrics Partnership (CAMP) [3], Chauffeur in EU [4], CarTALK2000 [5], FleetNet [6], California Partners for Advanced Transit and Highways (California PATH) [7], DEMO 2000 by Japan Automobile Research Institute (JSK) are few notable examples for cooperative driving. These projects are a major step towards the realization of Intelligent Transport Services (ITS).

VANET networks are special cases of MANETs. They resemble to MANET networks in their rapidly and dynamically changing network topologies due to the fast motion of vehicles. However, unlike MANETs, the mobility of vehicles in VANETs is in general constrained by predefined roads.

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Vehicle velocities are also restricted according to speed limits, level of congestion in roads, and traffic control mechanisms (e.g. stop signs and traffic lights). Additionally, given the fact that future vehicles can be equipped with potentially longer transmission ranges, rechargeable source of energy, and extensive on-board storage capacities, processing power and storage efficiency are not an issue in VANETs as it is in MANET. From these features, VANETs are considered as an extremely flexible and relatively "easy-to-manage" network pattern of MANETs.

Along with the recent developments in the VANET field, a number of attractive applications, unique for the vehicular setting, have emerged. VANET applications include on-board active safety systems to assist drivers in avoiding collisions and to coordinate them at critical points such as intersections and highway entries. Safety systems may intelligently disseminate road information, such as incidents, real-time traffic congestion, high-speed tolling, or surface condition to vehicles in the vicinity of the subjected sites. This helps to avoid platoon vehicles and to accordingly improve the roads capacity. With such active safety systems, the number of car accidents and associated damage are expected to be largely decreased. In addition to the aforementioned safety applications, IVC communications can be used to provide comfort applications as well. The latter may include weather information, gas station or restaurant locations, mobile e-commerce, infotainment applications, and interactive communications such as Internet access, music downloads, and content delivery.

There are numerous research challenges that need to be addressed till a wide deployment of VANET networks becomes possible. One of the critical issues consists of the design of scalable routing algorithms that are robust to frequent path disruptions caused by vehicles mobility. Existing routing protocols, traditionally designed for MANET, do not make use of the unique characteristics of VANETs and are not suitable for Vehicle-to-Vehicle (V2V) communications over VANETs. Many interesting improvements can be obtained by adjusting these routing protocols to reflect the dynamically changing topology of VANETs while taking into account vehicles' movement information such as position, direction, speed, and digital mapping of roads. This challenging task underpins the research work outlined in this paper.

In this paper, we consider a general scenario where both IVC and RVC coexist. We consider a VANET network made of a number of hot spots dispersed over a geographical area. Vehicles can have a direct access to these hot spots or via other vehicles. The basic idea behind the paper is to use information on the velocity vector of vehicles to avoid route breakage and to accordingly add appropriate modifications to the used routing protocol. While the scheme can be implemented on any ad hoc routing protocol, the paper considers the case of Destination-Sequenced Distance Vector (DSDV) routing protocol [1]. Vehicles are grouped into a number of sets according to their moving directions. Communication paths are maintained between vehicles belonging to the same group. Along the connection path, if an intermediate routing node changes its direction and belongs to a different group, a link rupture may likely happen during the transmission time. Throughput may then degrade, had a new route been established without taking stability and quality of network links into account. To avoid link ruptures and to establish reliable routes, the routing algorithm dynamically searches for the most stable route that includes only hops from the same group. The proposed scheme is dubbed Vehicle-Heading based Routing Protocol (VHRP).

The remainder of this paper is structured as follows. Section II showcases the variety of research being conducted in VANETs and surveys the state-of-the-art in the field of MANET routing protocols. The design philosophy behind the proposed routing algorithm and its distinct features are described in Section III. Section IV evaluates the performance of the scheme. The paper concludes in Section V.

II. RELATED WORK

This section highlights major attempts in applying MANET routing protocols to VANET networks. First is a description of important MANET routing protocols. A large number of routing protocols have been recently proposed within the framework of the Internet Engineering Task Force (IETF) for executing routing in MANET networks. They can be all classified as either reactive, proactive, or hybrid [9].

In Reactive Routing Protocols (RRPs), route determination is invoked on a demand or need basis. Thus, if a node wishes to initiate communication with another host to which it has no route, a global-search procedure is employed. This route search operation is based on classical flooding-search algorithms. Indeed, a Route Request (RREQ) message is generated and flooded, sometimes in a limited way, to other nodes. When the RREQ message reaches either the destination or an intermediate node with a valid route entry to the destination, a Router Reply (RREP) message is sent back to the originator of the RREQ. A route is then set up between the source and the destination. Reactive protocols then passive until the established route becomes invalid or lost. Link breakage is reported to the source via a Route Error (RERR) message. Several protocols fall in this category. Notable examples are Ad hoc On-Demand Distance Vector (AODV) [10] and Dynamic Source Routing (DSR) [11]. Reactive protocols incur significant control traffic overhead and are preferred for dynamically changing environments where nodes have a few number of active routes [12]. The control traffic overhead can be partially solved by selective forwarding of control messages based on geographical location of the destination [13]. Whilst the control traffic overhead can be accordingly mitigated, the additional initial latency introduced by the route discovery procedure poses serious challenges for reactive protocols. For this reason, reactive protocols are seen inappropriate for time-critical applications such as Cooperative Collision Avoidance (CCA), an important application type for vehicular communications [14].

Proactive Routing Protocols (PRPs), the flip-side of reactive protocols, maintain and update information on routing between all nodes of a given network at all times. Route updates are periodically performed regardless of network load, bandwidth constraints, and network size. Routing information is stored in a variety of tables and is based on received control traffic. Generation of control messages and route calculation are themselves driven by the routing tables. The main characteristic of proactive protocols is that nodes maintain a constantly updated understanding of the network topology. Consequently, a route to any node in the network is always available regardless of whether it is needed or not. While periodic updates of routing tables result in substantial signaling overhead, immediate retrieval of routes overcomes the issue of the initial route establishment delay in case of reactive protocols. Some of the protocols that have achieved prominence in the proactive category include Optimized Link State Routing (OLSR) [15], Hazy Sighted Link State Routing (HSLSR) [16], Topology Broadcast based on Reverse Path Forwarding (TBRPF) [17], and Destination-Sequenced Distance Vector (DSDV) [1]. Compared to reactive approaches, proactive protocols are easier to implement and exhibit relative stability. Applying proactive protocols to a highly mobile environment, a storm of control messages is required to maintain an accurate view of the network topology. This intuitively results in a significant waste of the wireless scarce bandwidth. They are seen thus optimal for environments where mobility is relatively static. For a qualitative comparison between reactive and proactive schemes, the interested reader is referred to [19] [20].

Hybrid Routing Protocols (HRPs) combine both the proactive and reactive approaches. Zone Routing Protocol (ZRP) is a notable example [18]. ZRP divides the network topology into different zones. Routing within zones, "intra-zone routing", is performed by a proactive protocol. This yields no initial delay for routing among nodes from the same zone. On the other hand, to increase the system scalability, routing between zones, "inter-zone routing", is done by a reactive protocol. While the hybrid approaches present an efficient and scalable routing strategy for large scale environments, a number of key issues remain unsolved and their implementation has not accordingly gained that much popularity within the researchers' community.

Based on the above mentioned routing concepts, a set of routing protocols have been proposed for vehicular communications. While it is all but impossible to come up with a routing approach that can be suitable for all VANET applications and can efficiently handle all their inherent characteristics, attempts have been made to develop some routing protocols specifically designed for particular applications. For safety applications, a broadcast oriented packet forwarding mechanism with implicit acknowledgment is proposed for intra-platoon cooperative collision avoidance [22]. In [21], a swarming protocol based on gossip messages is proposed for content delivery in future vehicular networks. For the provision of comfort applications, a Segment-Oriented Data Abstraction and Dissemination (SODAD) is proposed [23]. SODAD is used to create a scalable decentralized information system by local distribution of the information in vehicular networks. CarNet proposes a scalable routing system that uses geographic forwarding and a scalable distributed location service to route packets from vehicle to vehicle without flooding the network [24]. To avoid link rupture during the data transmission, a Movement Prediction based Routing (MOPR) is proposed [25]. MOPR predicts future positions of vehicles and estimates the time needed for the transmission of data to decide whether a route is likely to be broken or not during the transmission time. The performance of the scheme depends largely on the prediction accuracy and the estimate of the transmission time that depends in turn on several factors such as network congestion status, driver's behavior, and the used transmission protocols.

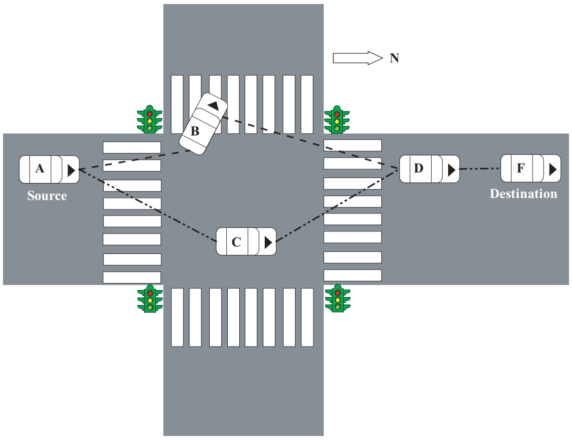


Fig. 1. Problem formulation: a link rupture event is more likely to occur between vehicles A, B, and D.

III. VEHICLE-HEADING BASED ROUTING PROTOCOL

This section describes the key design and distinct features that are incorporated in the proposed scheme. While VHRP can be implemented on any routing protocol, in this paper we chose DSDV. The reason behind this choice underlies beneath the relative simplicity and stability of the scheme. Our implementation of DSDV is based largely on the paper by Perkins et al [1]. Before delving into details of the scheme, we first formulate the problem via the following simple example. Fig. 1 depicts the scenario of five vehicles at an intersection where vehicle B is turning onto a new street and the other four vehicles are continuing straight on the same road. A connection is established between vehicles A and F. Communication is possible on two routes: one via vehicle B (route A-B-D-F) and the other via vehicle C (route A-C-D-F). As vehicle B is turning left and vehicle A is continuing straight, the former route is more likely to be ruptured after a certain time. Consequently, the selection of the latter router is a more appropriate choice and has tendency to add more stability and reliability to the communication path between the two vehicles (A and F). In the remainder of this section, we explain how such a selection can be possible using information on the velocity vector of vehicles.

In the proposed routing scheme, vehicles are grouped into four different groups based on their velocity vectors. In a Cartesian space, each group is characterized by one of the

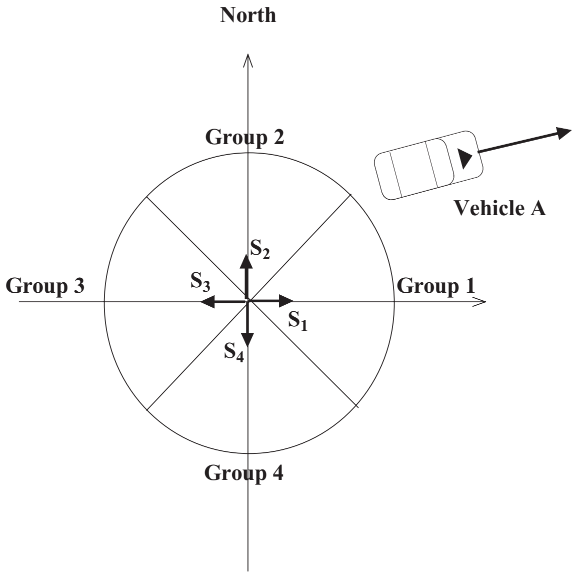


Fig. 2. Velocity vector based grouping of vehicles.

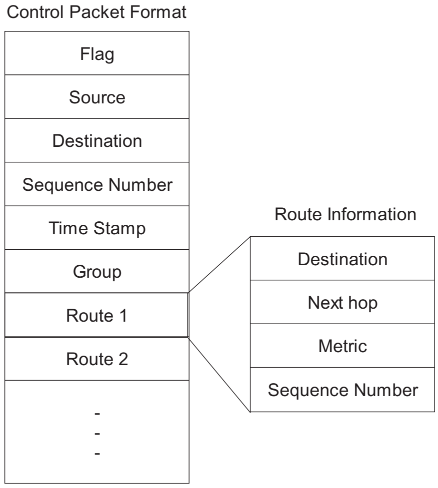


Fig. 3. Packet format of a route update message.

unit vectors, $S_1 = (1, 0)$, $S_2 = (0, 1)$, $S_3 = (-1, 0)$, $S_4 = (0, -1)$, as shown in Fig. 2. Vehicles are assumed to be equipped with Global Positioning Systems (GPSs) to detect their geographical location. Location detection is performed every 1s time interval. Let $V_A = (v_x, v_y)$ denote the Cartesian coordinates of the velocity vector of a given vehicle A. Using the velocity vector and unit vectors, the group of vehicle A can be decided as follows. Vehicle A belongs to Group N, if the dot product of its velocity vector and the unit vector S_N ($V_A \cdot S_N$) takes the maximum value (in Fig. 2, $N = 1$).

In ad hoc networks, routing is based on information contained in "route update" messages that are periodically exchanged among neighboring nodes. This information consists of the next hop address, routing metric, and sequence number for each destination address. In the proposed scheme, information on groups is included also in the control messages. Fig. 3 shows a simplified format of a route update packet. When a vehicle X receives a control message from another vehicle Y, it compares its group ID with that of the originating vehicle (Vehicle Y). If the two vehicles belong to two different groups, the link between the two vehicles is judged to be unstable. A penalty is then added to the routing metric between the two vehicles and routes are updated. In such a manner, added penalties can reflect the information of groups on the routing procedure. If the two vehicles belong to the same group, routing metrics are not modified and routing is performed according to the number of traversed hops as in the basic distributed Bellman-Ford routing algorithm.

To better explain the basic idea behind the use of metric penalties, we consider the same scenario of Fig. 1. Let β_{AB}, β_{BD}, β_{AC}, β_{CD} denote the routing metrics of links between vehicles A & B, B & D, A & C, and C & D, respectively. In case of no routing metric penalties, all routing metrics are equal to one. In such case, both routes ABD and ACD can be chosen for communication. However, if a penalty α_m is added to the routing metrics β_{AB} and β_{BD} ($\beta_{AB} = \beta_{BD} = 1 + \alpha_m$), the route ACD will be chosen. In this way, the proposed scheme guarantees stable routes for communication.

In the following, we explain how a vehicle updates its routes upon receiving a control packet. When a vehicle X receives a control packet P from a vehicle Y containing information on the routing metric and sequence number of its route to a destination A, vehicle X first checks if it has any route to destination A. If such a path does not exist, the route is then added to the routing table of vehicle X. If the route already exists, vehicle X has to update its route only if the sequence number and routing metric indicated in the control packet are smaller.

IV. PERFORMANCE EVALUATION

Having described the details of our scheme, we now direct our focus to evaluating its performance through computer simulations using Network Simulator (NS2) [26]. In addition to DSDV, TBRPF is used as a comparison term given the fact it is a proactive protocol. Fig. 4 shows the network topology used in the simulation. The scenario presented in the figure simulates a typical road situation with two intersections. Vehicles are moving along the main road while communicating with a hot spot located at Intersection 1. To simulate cases where vehicles change their headings, some vehicles turn onto a new street at Intersection 2. In the simulation, 30 vehicles are used and distance between adjacent vehicle is randomly chosen from a uniform distribution with Max and Min equal to $10m$ and $90m$, respectively. The road width is set to $3m$. Different scenarios are created by increasing the distance between the two intersections by $10m$ from $190m$ to $250m$. In the simulations, vehicles are constrained to roads in an urban area. Their average speeds are thus varied within the range of $[3m/s, 15m/s]$. To enable vehicles to travel a long enough distance, the simulation end time is varied in function of the speed of vehicles as shown in Table I. The transmission range of vehicles is set to $100m$. Vehicles use UDP to send data packets and their transmission rate is set to $1Mbps$. The packet size is set to $512\ bytes$. In the performance evaluation, end-to-end throughput and packet drops are used as quantifying

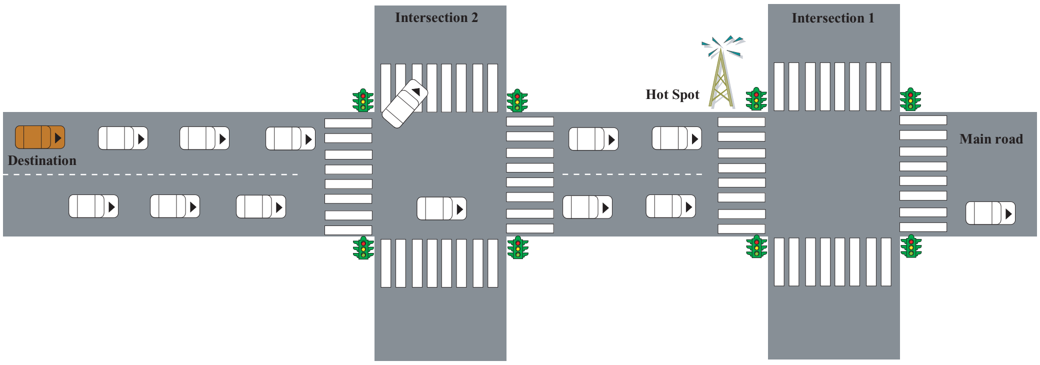


Fig. 4. Network topology.

TABLE I

SIMULATION END TIME FOR DIFFERENT VEHICLE SPEEDS.

Vehicle speed (m/s)	Simulation end time (s)
15	56
14	57
13	59
12	61
11	64
10	67
9	70
8	75
7	80
6	88
5	99
4	115
3	141

TABLE II

SIMULATION PARAMETERS AND RANGE OF VALUES.

Simulation parameters	Range of values
Distance between intersections	190 - 250m
Distance between adjacent vehicles	3m
Distance between Intersection 2 and initial position of the destination vehicle	400m
Number of vehicles	30
Road width	3m
Vehicle transmission range	100m
Vehicle transmission rate	1Mbps
Packet size	512 bytes
Simulation runs	175

parameters. The throughput measurement is made at a vehicle initially located at $400m$ from intersection 2. Packet drops are counted along the communication path between the hot spot and the destined vehicle. For each considered scenario, the simulation is run for 175 times. The presented results represent the average behavior of these simulation runs. Table II summarizes the parameters used for road traffic simulation.

To illustrate the better performance of the proposed scheme over TBRPF and DSDV in improving the end-to-end throughput, the following gain ratio is used:

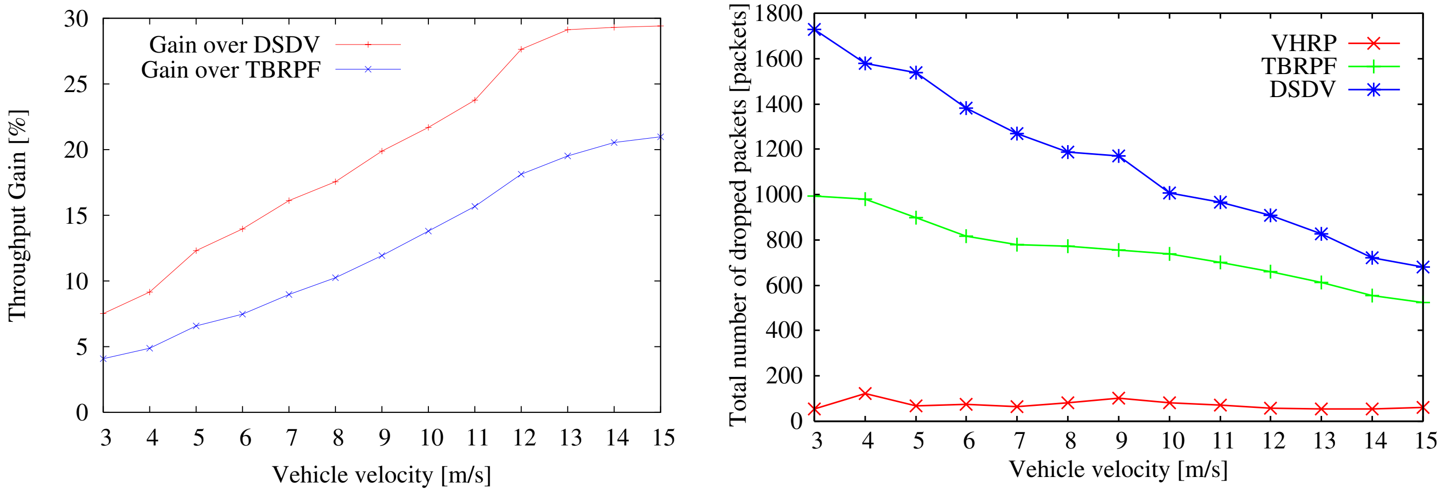
$$G = \frac{N_p - N_t}{N_t} \cdot 100 \qquad (1)$$

where N_p and N_t denotes the number of received packets in case of the proposed scheme and TBRPF (or DSDV), respectively. Fig. 5(a) shows the variation of the gain for different velocity speeds. The results are the average values of several simulation runs. The simulation results indicate that in case of a vehicular network with slow mobility (low speeds), the throughput improvement is not that significant and both protocols exhibit similar throughputs. However, as the vehicle speed increases, the proposed scheme exhibits better performance. The reason behind this performance underlies beneath the fact that in case of high speeds, the link breakage occurs quickly as vehicles turn at the intersection. TBRPF and DSDV then take a long time to re-establish another link and a quite number of packets get dropped during the link rupture. This can be confirmed further by the results of Fig. 5(b). Indeed, packet drops experienced in case of DSDV and TBRPF are significantly higher than the number of packet losses experienced by the proposed scheme. On the other hand, using the velocity vectors of vehicles, the proposed scheme predicts the link breakage event and manages to anticipate the reconstruction of another route during a shorter period of time. This reduces the number of packet drops and eventually increases the overall throughput of the connection.

V. CONCLUSION

In this paper, we proposed a vehicle heading based routing protocol for VANET networks. The basic idea behind the proposed scheme is to group vehicles according to their velocity vectors. The system can predict a possible breakage of a route when the route is set up between two vehicles from two different groups. To avoid link ruptures and thus guarantee stable routes for communication, routes between vehicles from the same group are preferred. For this purpose, penalties are added to routing metrics of links set up between vehicles from different groups.

The performance of the proposed scheme is evaluated through simulation and is compared to two other proactive schemes, namely DSDV and TBRPF. Encouraging results are obtained. Indeed, the proposed scheme reduces the number of packet drops and achieves higher throughput. While the paper considered the case of implementing the proposed scheme over proactive routing protocols, incorporation of the scheme in



(a) End-to-end throughput.

(b) Packet drops.

Fig. 5. Overall performance of VHRP, TBRPF, and DSDV for different vehicle speeds.

reactive protocols forms the focus of our future research work.

REFERENCES

[1] C. Perkins, “Highly Dynamic Destination-Sequenced Distance-Vector Routing (DSDV) for Mobile Computers”, in Proc. of ACM SIGCOMM 1994, London, UK, Aug. 1994, pp. 234-244.

[2] M. Heddebaut, J. Rioult, J.P. Ghys, Ch Gransart, and S. Ambellouis, ”Broadband vehicle-to-vehicle communication using an extended autonomous cruise control sensor”, Measurement Science and Technology, vol. 16, no. 6, pp. 1363-1373, Jun. 2005.

[3] M. Shulman, and R. Deering, ”Third Annual Report of the Crash Avoidance Metrics Partnership April 2003 - March 2004”, DOT HS 809 837, National Highway Traffic Safety Administration (NHTSA), Jan. 2005.

[4] C. Bergese, A. Braun, and E. Porta, ”Inside CHAUFFEUR”, the 6th ITS World Congress, Toronto, Canada, Nov. 1999.

[5] L. Andreone, and C. Ricerche, ”Activities and Applications of the vehicle to vehicle and vehicle to infrastructure communication to enhance road safety”, the 5th European Congress and Exhibition on ITS 2005, Hannover, Germany, Jun. 2005.

[6] R. Kruger, H. Fuler, M. Torrent-Moreno, M. Transier, H. Hartenstein, and W. Effelsberg, “Statistical Analysis of the FleetNet Highway Movement Patterns”, Technical Report TR-2005-004, Jul. 2005.

[7] W.-B. Zhang, H.-S. Tan, A. Steinfeld, B. Bougler, D. Empey, K. Zhou, and M. Tomizuka, “Implementing Advanced Vehicle Control and Safety Systems (AVCSS) for Highway Maintenance Operations”, in Proc. of the 6th Annual World Congr. on ITS, Toronto, Canada, Nov. 1999.

[8] S.Tsugawa, K. Tokuda, S. Kato, T. Matsui, and H. Fujii, “An overview on DEMO 2000 cooperative driving”, in Proc. of the IEEE Intelligent Vehicle Symposium, May 2001, pp. 327-332

[9] S. Sesay, Z. Yang, and J. He, “A Survey on Mobile Ad Hoc Wireless Network”, Information Technology Journal, vol. 3, issue 2, pp. 168-175, 2004.

[10] C. Perkins, E. Belding-Royer, and S. Das, “Ad hoc On-Demand DistanceVector (AODV) Routing”, Network Working Group, RFC 3561, Jul. 2003.

[11] D.B. Johnson, D.A. Maltz, and Y.-C. Hu, “The Dynamic Source RoutingProtocol for Mobile Ad Hoc Networks (DSR)”, IETF MANET Working Group, Internet Draft, Jul. 2004.

[12] A. Schumacher, S. Painilainen, and T. Luh, “Research Study of MANET Routing Protocols”, Research Seminar on Hot Topics in Internet Protocols, Helsinki, Finland, Spring 2004.

[13] Y.B. Ko, and N.H. Vaidya, “Location-Aided Routing (LAR) in Mobile Ad Hoc Networks”, in Proc. of the 4th ACM MobiCom 1998, Dallas, USA, Oct. 1998.

[14] X. Yang, J. Liu, F. Zhao, and N.H. Vaidya, “A Vehicle-to-Vehicle Communication Protocol for Cooperative Collision Warning”, in Proc. of MobiQuitous 2004, Boston, USA, Aug. 2004.

[15] T. Clausen, and P. Jacquet, ”Optimized Link State Routing Protocol (OLSR)”,Network Working Group, RFC 3626, Oct. 2003.

[16] C. Santivanez, R. Ramanathan, and I. Stavrakakis, “Making link-state routing scale for ad hoc networks”, in Proc. of ACM MobiHoc 2001, Long Beach, USA, Oct. 2001.

[17] R. Ogier, F. Templin, and M. Lewis, “Topology Dissemination Based on Reverse-Path Forwarding (TBRPF)”, Network Working Group, RFC 3684, Feb. 2004.

[18] T. Thongpook, and T. Thumthawatworn, “Adaptive Zone Routing Technique for Wireless Ad hoc Network”, in Proc. of ITC-CCSC 2002, Phuket, Thailand, Jul. 2002.

[19] K. Chin, J. Judge, A. Williams, and R. Kermode, “Implementation experience with MANET routing protocols”, ACM Sigcomm Com. Commun. Review, Vol. 32, No. 5, Nov. 2002.

[20] J. Broch, D.A. Maltz, D.B. Johnson, Y.-C. Hu, and J. Jetcheva, “A performance comparison of multi-hop wireless ad hoc network routing protocols”, in Proc. of the 4th ACM on Mobile Computing and Networking, Dallas, USA, Oct. 1998, pp. 85-97.

[21] R. Tatchikou, and S. Biswas, “Vehicle-to-vehicle packet forwarding protocols for cooperative collision avoidance”, in Proc. of Globecom 2005, St. Louis, USA, Nov. 2005.

[22] A.Nandan, S. Das, G. Pau, M.Y. Sanadidi, and M. Gerla, “Cooperative downloading in Vehicular Ad Hoc Networks”, in Proc. of WONS 2005, St. Moritz, Switzerland, Jan. 2005.

[23] L. Wischof, A. Ebner, and H. Rohling, “Information dissemination in self-organizing intervehicle networks”, IEEE Trans. intelligent transportation systems, vol. 6, no. 1, pp. 90-101, Mar. 2005.

[24] R. Morris, J. Jannoti, F. Kaashoek, J. Li, and D. Decouto, “CarNet: A scalable Ad-hoc wireless network system”, in Proc. of the 9th ACM SIGOPS European Workshop, Kolding, Denmark, Sep. 2000.

[25] H. Menouar, M. Lenardi, and F. Filali, “A movement prediction based routing protocol for vehicle-to-vehicle communications”, in Proc. of V2VCOM 2005, San Diego, USA, Jul. 2005.

[26] The Network Simulator - NS2 [online] Available: http://www.isi.edu/nsnam/ns/