A Filtering Concept for Improving the Angle-based Forwarding Scheme in Vehicular Ad-hoc Network Communications

Lisa Kristiana, Corinna Schmitt, Burkhard Stiller
Communication Systems Group CSG, Department of Informatics IFI, University of Zurich UZH
Binzmühlestrasse 14, CH—8050 Zurich, Switzerland
[kristiana|schmitt|stiller]@ifi.uzh.ch

***Abstract*—Vehicular Ad-hoc Network (VANET) communications are mobile communication alternatives allowing vehicles to exchange information among them with a suitable forwarding scheme. The forwarding scheme is a mechanism to select proper candidate nodes as the intermediate node. Current angle-based forwarding schemes take into account a Horizontal Relative Angle (HRA) and propose Vertical Relative Angle (VRA) as an alternative. The introduction of a filtering concept, implementing both HRA and VRA, restricts the number of insignificant candidates. Under various VANET communication factors (*e.g.*, network density, mobility, and road level topology) the work presented here investigates the VRA scheme to improve the forwarding decision especially in the three-dimensional case within a large city environment.**

***Index Terms*—Vehicular-to-Vehicular (V2V) networks, Vertical Relative Angle (VRA), Horizontal Relative Angle (HRA), Vehicular Ad-hoc Network (VANET), Forwarding scheme**

I. Introduction

The population in cities rises in close relation to the development of public transport and mobility demands of the population. However, many people prefer to use their own car for comfort reasons, when commuting. In order to convince them to use public transportation, incentives beyond financial issues must be provided. One such incentive can be personal network connectivity (*e.g.,* Internet access for social media access, messaging services, or news updates) because most people own Smartphones [2] and it was proven that this has an effect on people's behavior [1]. Thus, the support of Internet connectivity is the key incentive assumed here to convince people to use public transport. When applying those ideas to countries like Indonesia, people can be convinced additionally when this service is free of charge, furthermore resulting in less traffic on the roads.

The solution of providing Internet connectivity is inspired by the principle of Vehicular Ad-hoc networks (VANETs). VANETs can form either Vehicular-to-Vehicular (V2V) or Vehicular-to-Infrastructure (V2I) approaches both offering several applications to support the driver, passenger, and vehicles [4]. The safety application *i.e.* car crash prevention, takes into account of short range wireless transmission technology *i.e.*, Dedicated Short Range Communication (DSRC) [6]. Non-safety applications, *i.e.,* Web surfing and social networking, are the other interesting aspect to explore, and they can use other options of unlicensed spectrum such as Wi-Fi or WiMAX [30]. The integration of non-safety application using Wi-Fi is even possible to be implemented in V2V [3], [6], also known as inter-vehicular networks [5].

Fig. 1. Scenario in a large city environment

The successful transmission of data is the main goal of the routing mechanism, which additionally can be complemented with Quality-of-Service (QoS) parameters, including throughput and stable data rates [7]. However, maintaining QoS brings trade-offs (*e.g.*, communication delay and number of hops) [8] that need to be investigated. Existing research has implemented and simulated a realistic city environment [9], [10]. To the best of the author's knowledge, the two-dimensional case is used in the majority of scenarios, since vehicles move on the road, *i.e.*, not considering ramps or overpasses. Thus, this work here focuses on the three-dimensional case within a city environment [12], [14], which considers the altitude position coordinate as a new key element in terms of location information as illustrated in Fig. 1 [26]. In order to improve a reliable and stable transmission of data, three research questions are to be investigated:

(i) How stable and reliable is the connectivity in a three dimensional environment? The three-dimensional environment is shown in Fig. 1 including key parameters in V2V communications, such as the impact of obstacles (*e.g.,* buildings, trees, overpass, and other vehicles [16]) in this environment. The modelling of the scenario of a large city environment covers here the complexity of propagation and considering the details of overpasses [11], [13].

(ii) How feasible is Wi-Fi in a V2V communication? Thus, the performance of IEEE 802.11b/g [17] for different road-level topologies [13] and non-safety application integration issues is investigated. In addition, the duration of connection is also investigated.

(iii) How to improve the forwarding strategy with respect to such a three-dimensional environment? Thus, selecting the proper intermediate node based on distance and angle measurement among cars are considered [9].

The reminder of this paper in Section 2 discusses the related work. Section 3 proposes the filtering concept by applying the Vertical Relative Angle (VRA) scheme and its initial modeling. The evaluation in Section 4 is followed by the summary and a future work perspective in Section 5.

II. Related Work

A reliable and stable V2V communication refers to a successful delivery of messages [8] and immediately finding the new path due to frequent changing topology. In V2V, any participant vehicles can behave as source node *S*, receiver node *R*, or relay *I*. The degree of successful delivery is defined by the high percentage of packet delivery ratio (PDR). The routing process requires proper calculation of weights (*e.g.,* hop counts, link quality, delay constraint, geographical distances, or signal strength) for each path foreseen to decide upon the "best" path to transmit relevant information from *S* to *R*. The decision of this process is handed over to the forwarding scheme, which utilizes local port information of a relay to forward packets [19].

In order to design the appropriate forwarding scheme, it is necessary to consider various factors of VANETs communications [27]. Those factors include the environment, network type, and mobility as shown in Fig. 2. The environment factor describes characteristics of road topologies, which are classified as a two-dimensional case *i.e.,* the highway or city roads with intersections [9], [10] or as a three-dimensional case *i.e.,* overpass or underpass [11], [13]. The second factor is the network type, which is based on the number of participating nodes and divided into a dense network, which involves many vehicles as participating nodes and a sparse network, which lacks of active participating nodes [18]. The third factor is the mobility, which can be classified by participant nodes with a high or low speed and with random or non-random directions [18]. However, in case of VANET, vehicles have non-random directions since vehicles move on predefined road path. In order to address those VANET communication factors, several related works in establishing communication among vehicles are discussed in following:

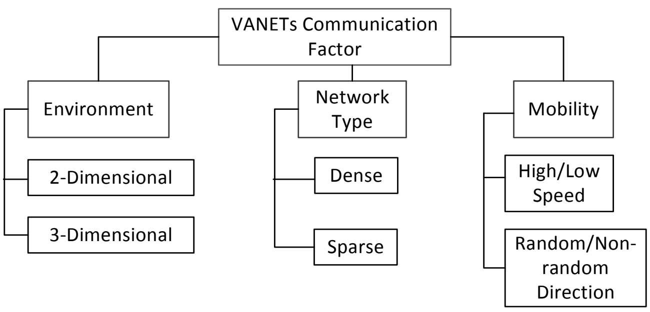

Fig. 2. VANETs Communication Factor

A. Transmission Range

The transmission range in the three-dimensional case is different compared to two-dimensional case because the height of the road topology does impact the transmission range [13]. Fig. 3 illustrates the maximum transmission range in a three-dimensional perspective. The transmission range of S, can cover both on different road level topologies with several requirements are discussed in the two section below.

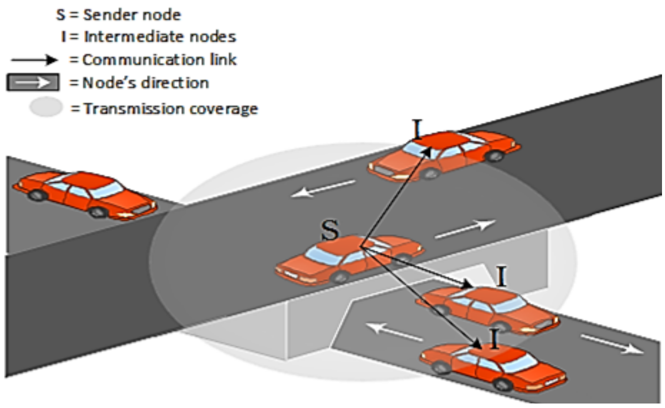

Fig. 3. Transmission Range in Three-dimensional Perspective

B. Wireless Communication Technology

In V2V, the term mobile node represents a vehicle and it is assumed to be equipped with a navigation system as Global Positioning System (GPS) and wireless communication (Wi-Fi/IEEE 802.11b/g), therefore, the term mobile node and vehicle can be used alternately.

In V2V network, Wi-Fi/IEEE 802.11 as a short-to-medium range radio technology is possible to be used to establish a communication among vehicles [17]. A Wi-Fi ad-hoc mode can support inter-vehicular networking through the ad-hoc broadcast [29]. This communication technology has been enhanced for non-safety applications with required modification since it has to support communication among vehicles moving at high speeds [30].

C. Propagation Model

The characteristic of a propagation channel may vary depending on the environment and influences both signal transmission and reception. A consideration of a propagation model that is influenced by the existence of obstacles is proposed as an approach to obtain an optimum transmission [31]. In case of buildings, composed out of a concrete block, signal transmission will be attenuated or even restricted [21]. In case of overpasses, it is assumed that the overpass is not made from material with good conductivity, thus, signals attenuate or are restricted along the overpass [20].

By definition, signal transmissions that enter the overpass are assumed as a signal loss since they do fade and distract, depending on the overpass' length *e.g.*, GPS signal for navigation systems and Wi-Fi signals degradation [21]. The longer the overpass, the signal loss probability rises and the signal reception is decreased. There is a trade-off whether to disconnect the transmission and search for a new connection or to maintain the current and distracted connection *i.e.,* when a vehicle moves below an overpass with high speed, but suddenly decreases the speed due to traffic conditions, the distracted connection expands or the vehicle becomes temporary unreachable [19].

It is important to define the particular environment as a preliminary set up. In a free space environment (*i.e.* the environment where the electromagnetic wave transmits without any obstructions), the propagation channel is considered as the line-of-sight (LOS) propagation model. This model determines a theoretical case and is used as a reference for other propagation models. In case of the urban environment topology, the propagation channel is modeled as a path loss propagation model [20]. This model takes into account buildings and assumes electromagnetic waves are diffracted [21]. In case of other objects, e.g., an overpass, the propagation model is assumed as the obstacle propagation model. This model assumes that electromagnetic waves are blocked by the overpass [13]. This work combines the non-line-of-sight (NLOS) propagation and obstacle propagation model in order to obtain a realistic propagation of a large city environment.

D. Angle Forwarding Scheme

A forwarding scheme has various methods that rely on positions [22]. The initial assumption holds that all nodes are equipped with GPS, therefore, all nodes know their current position and the position of their neighbors within their communication range (*i.e.*, transmission range, where the communication process is assumed to be successful).

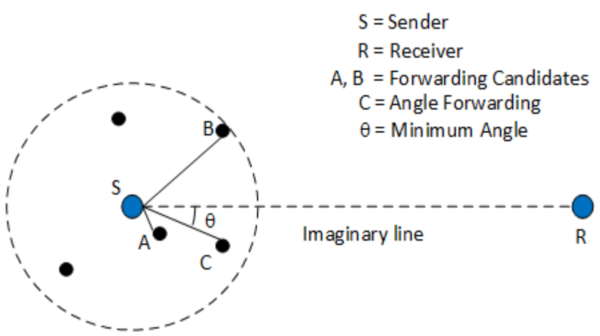

Fig. 4. Forwarding Scheme

As there exists 3 types of forwarding schemes based on such a position information, each of them is presented below.

Most Forwarding Scheme (MFS), calculates the path from a source S to its neighbors in order to obtain the best path to the receiver R. The way this forwarding scheme calculates the distance from S to R by forming the imaginary line between S and R, as illustrated in Fig. 4. The MFS selects the intermediate node (I), which has the closest distance to the receiver amongst the forwarding nodes within the transmission range of a source node. Therefore, A is selected by S and A becomes the intermediate node because A fulfills aforementioned requirement [22].

Near Forwarding Scheme (NFS), Basically, this scheme is the opposite to MFS since NFS selects the intermediate node that has the closest distance to S (c.f. Fig. 4). Therefore, the intermediate node is indicated as node B [22].

The Angle Forwarding Scheme (AFS) relies on an angle calculation. An angle θ is a shape formed by two straight lines, S to R and S to C, that have a vertex as illustrated in Fig. 4. [22]. Based on the imaginary line, AFS provides an additional measurement metric, which is known as the relative angle [23], [24], [25].

III. Filtering concept

The three-dimensional case determines the additional location coordinate *i.e.,* altitude, to the existing location in the two-dimensional case *i.e.,* latitude and longitude. The altitude is the important parameter to signal reception calculation since it indicates the distance parameter in three-dimensional case. Due to the fact of location coordinates in three-dimensional case, the filtering concept applies both HRA and VRA introduced as follows:

A. Vertical Relative Angle

Relative angles in degrees are measured in two ways: First, the angle θ_x is measured between the positive x-axis and positive y-axis. Second, the angle θ_z is measured between the positive z-axis and the imaginary line. Here the angle θ_x is defined as HRA and the angle θ_z is defined as VRA.

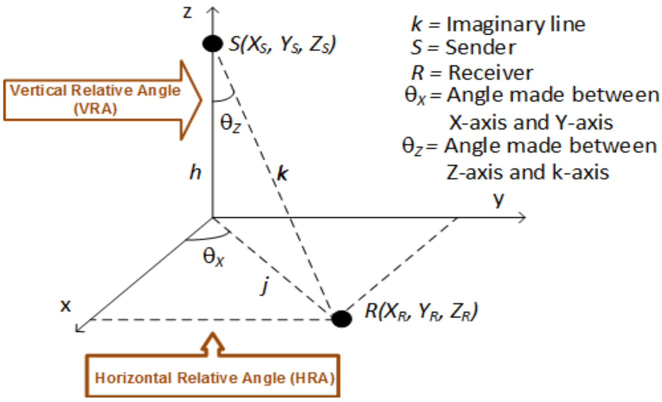

Fig. 5. Vertical Relative Angle and Horizontal Relative Angle

The ***imaginary line*** for two- and three-dimensional areas, which is formed by line S and R, represents the dashed line k as shown in Fig. 5. The j line is also an imaginary line formed between S (*i.e.,* in case of S has zero value in both x and y-axis) and R based on the x and y-axis, while k line is formed between S and R based on the z, y and x-axis. Therefore, the location coordinate of S and R are $S(x_S, y_S)$ and $R(x_R, y_R)$ in the two-dimensional area, while $S(x_S, y_S, z_S)$ and $R(x_R, y_R, z_R)$ determine those in the three-dimensional area. Based on these location coordinates, the imaginary line can be defined generally as Equation 1 and 2.

$$\Delta j = \sqrt{(x_R - x_S)^2 + (y_R - y_S)^2} \tag{1}$$

$$\Delta k = \sqrt{(x_R - x_S)^2 + (y_R - y_S)^2 + (z_R - z_S)^2} \tag{2}$$

$$\theta = acos\left(\frac{SR \cdot SR}{|SR| \times |SR|}\right) \tag{3}$$

Given h, j, and k (cf. Fig. 5), angles θ_x and θ_z are calculated by Eqn. 3. Thus, the relative angle is defined as the angle measured between the imaginary line and the current node. Thus, relative angle various angle-based forwarding schemes can be designed addressing key network characteristics [27].

B. Filtering Scheme

The concept of filtering scheme is introduced in two steps. The first step is to select the proper candidates as the intermediate node in two-dimensional case, by implementing HRA. This filtering concept selects the candidates within the *S* transmission range, by restricting the searching area. The HRA implementation as illustrated in Fig. 6 defines the θ_1 as the maximum angle of transmission area. The value of θ_1 decreases to θ_3 in order to restrict candidates and select the node which is located closest to R.

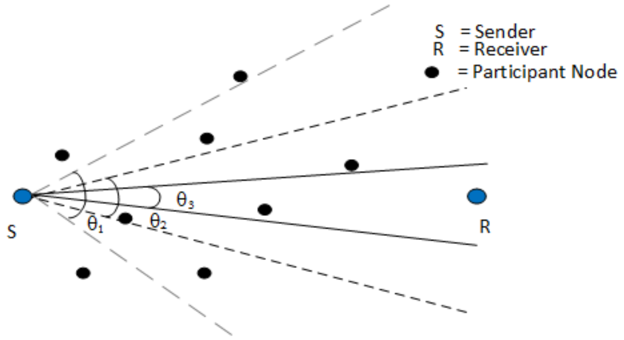

Fig. 6. Filtering Concept using HRA

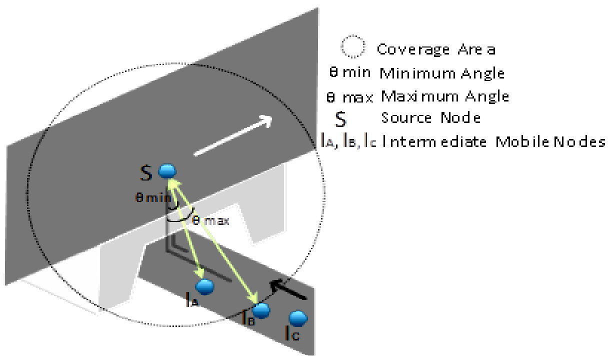

Fig. 7. Filtering Concept using VRA

The second step is the VRA implementation in the three-dimensional case. The minimum and maximum anglesare denoted as θ_{min} and θ_{max}. Under the assumption that intermediate nodes (*I* nodes) are within the transmission range of *S*, these θ_{min} and θ_{max} angles determine which intermediate node becomes the next forwarding node. The selection of candidates located withinthe θ_{min} area is avoided, since nodes within this area will experience the disconnection status soon. The preference area of the VRA forwarding scheme is between θ_{min} and θ_{max}. Thus, the VRA scheme will only transmit packets, if intermediate nodes are within this area. The HRA and VRA (*i.e.,* relative angles) schemes are combined in order to cope with both two-dimensional and three-dimensional cases. The detailed algorithm of the filtering scheme is shown in Fig. 8.

IV. Evaluation

The evaluation of filtering concept implementing HRA and VRA in V2V scenario started with the parameter settings listed in Table I. The Network Simulator-3 (NS-3) [28] is used to generate specific condition and environment, such as wireless technology (*i.e*., IEEE 802.11b/g), routing protocol (*i.e.*, Greedy Perimeter Source Routing (GPSR) [22]), mobili-

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S ← sender node
R ← receiver node
I all neighboring nodes of S
θ_h,max ← maximum boundary of the
          horizontal angle
θ_v,min ← minimum boundary of the
          vertical angle
θ_v,max ← maximum boundary of the
          vertical angle
for all I
θ_h ← horizontal angle made by n to S
θ_v ← vertical angle made by n to S
I_filtered ← only I that is
             within [-θ_h,max, θ_h,max]
             and [θ_v,min, θ_v,max]
end for
d ← distance from I_filtered to R
next_hop ← arg_min(d)
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Fig. 8. Algorithm 1 Filtering Scheme

To obtain a realistic speed of vehicles in a large city environment, the average speed of vehicles is set between 40 and 70 km/h, high and sparse density, various type of obstacles (*i.e.,* building and overpass construction), and the direction of vehicles is usually a non-random way due to the natural vehicle movement on predefined lanes. Various numbers of nodes are simulated to investigate the effect of network's density. Pairs of connections (*i.e*., *S* to *R*) are generated randomly, which means that any participant nodes can be *S* or *R*, and/or *I*. The number of *S* and *R* are generated linearly, which means a 40 nodes network contains of 20 senders and 20 receivers. In addition, *S*, *R*, and *I* are placed randomly both on two different road level. The simulation area covers an environment that involves a road with an overpass crossing in the middle and buildings which are located on the road side. While the evaluations' impacts onto the Packet Delivery Ratio (PDR) are addressed, the simulation time is set to 200 s in order to obtain the required transmission time for realistic packet sizes and the expected round trip distance of vehicles within two driving lanes. Finally, the particular use case is defined for Jakarta, Indonesia due to a specific mobility model, traffic behaviour and velocity, road level topology, and the author's fellowship granted by the Indonesian Government.

TABLE I: Parameter Settings

Parameter	**Units**
Transmission Range IEEE 802.11	140 m
Number of Nodes	10 - 40
Simulation Area	500 m x 500 m
Upper Road Height	10 - 20 m
Average Vehicle Velocity	40-70 km/h
Packet Size	2048 Byte
Simulation Time	200 s
Number of Driving Lanes	2

The first result in Fig. 9 shows the impact of overpass construction in three-dimensional case and the impact of buildings in two-dimensional case to network performance. The

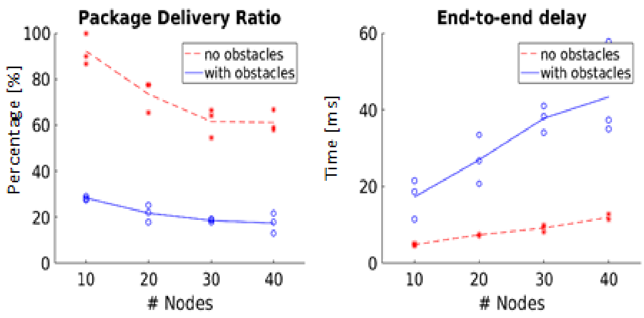

Fig. 9. Impact of Obstacle

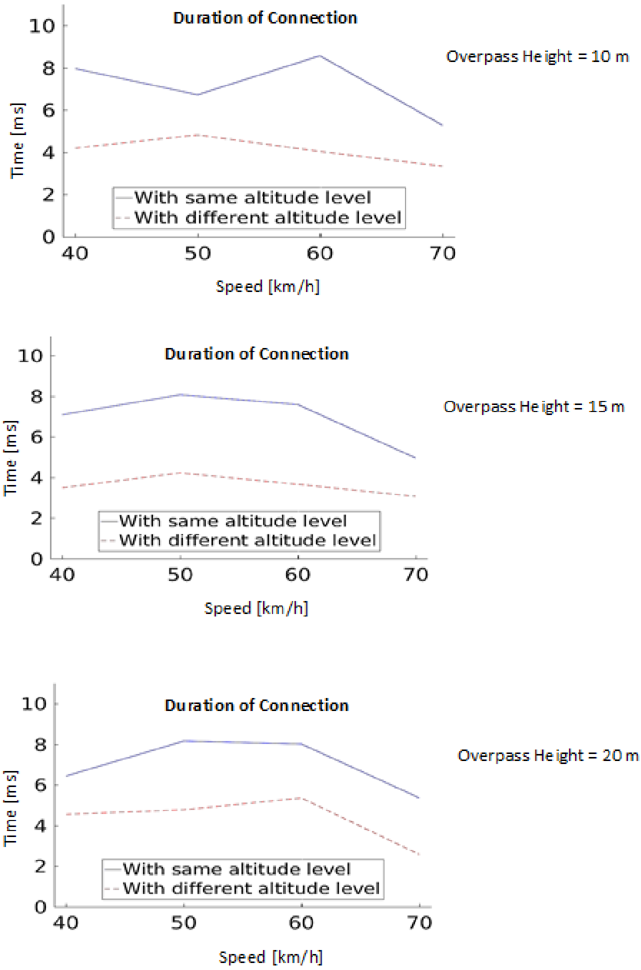

Fig. 10. Duration of connection

solid line describes the lower PDR that includes the existence of an obstacle and compares to the dashed line, which describes the PDR without an obstacle. The highest obtained PDR with obstacles is 30 percents, which is considerably low. The low PDR is caused by the overpass construction. Since the scenario which is under investigation focuses on the road topology with obstacles (*i.e.,* overpass constructions) are added between two different levels of roads, thus, those obstacles block the signal reception. Additionally, the chosen routing protocol, GPSR, and its search location mechanism considers vehicles, which are located under the overpass as "undetected" vehicles' location coordinate. The end-to-end (E2E) delay indicates that the obstacle decreases the connectivity. Due to those findings, the following evaluations address all the network performance and takes into account the obstacle propagation model.

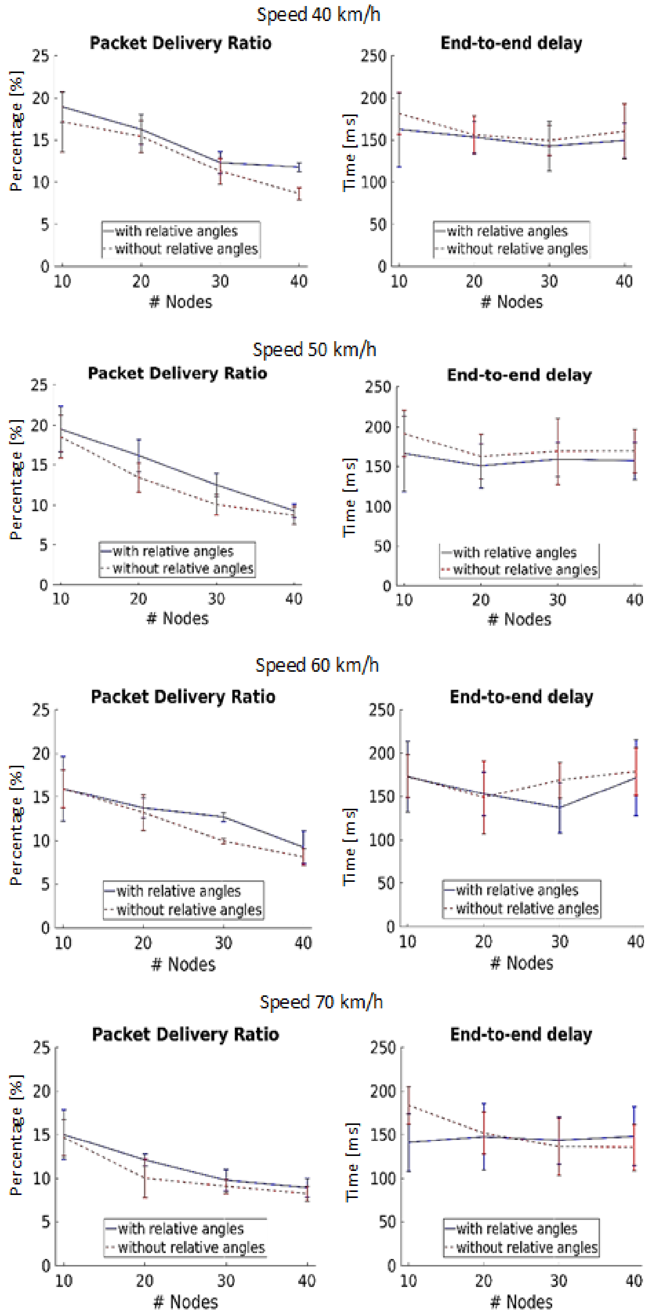

Fig. 11. HRA and VRA Implementation in Filtering Concept

The second result related to a different road level topology *i.e.,* vehicles located both on overpass and under overpass is shown in Fig. 10. The connectivity, indicated as millisecond (ms), among vehicles on the same altitude (*i.e.*

road level) has the longer duration than on the different altitude. This indicates that the altitude factor cannot be neglected, since vehicles obviously select the intermediate node within the suggested transmission range *i.e.,* the transmission range as defined in Section III.

By indicating the obstacle and the altitude, the filtering concept results are shown in Fig. 11. The solid blue lines indicate the implementation of filtering concept using the relative angle *i.e.,* VRA and HRA. The PDR of each speed shows that filtering reveals the better result compared to an unfiltering scheme. This indicates that involving the relative angle as the additional metric to the forwarding decision is necessary to determine a proper intermediate node out of available neighboring candidates. The highest obtained PDR is 20 percent and it is also considerably low due to the specific feature of the selected routing protocol which rely on the location coordinate of vehicle. Overall, the PDR is decreasing due to the higher speed of vehicles and due to frequent disconnections. However, the end-to-end delay considered has to be handled as a trade-off. The end-to-end delay shows fluctuating results (cf. Fig. 11) and has larger delays on average. The speed of vehicles has an insignificant impact to the end-to-end delay. Thus, the delay reached determines the result of the routing protocol mechanism searching for the new connection or path once the current path is disconnected or broken.

V. Summary and Future work

This paper evaluated a V2V communication by improving the angle-based forwarding scheme. This V2V communication has potentials to provide non-safety applications in addition to safety applications. Obstacles decrease the network performance both in two-dimensional case and three-dimensional case. The proposed VRA combined with HRA shows a better packet reception by filtering candidates in a dense network. The filtering concept increases the effectiveness of locating the intermediate node, which subsequently minimizes the number of hops and reduces message overhead. While the transmission coverage is assumed to be evenly distributed, the situation is improved by applying VRA since it addresses the propagation loss and antenna type for evaluations.

In next steps, multiple lanes scenarios will be evaluated in depth to increase the understanding of VRA scenarios and derive applicable observations for the real Jakarta traffic and map. Moreover, besides IEEE 802.11a/n/g the IEEE 802.11p technology will be used additionally in simulations since it is designed to cope the frequent topology changes in a VANET characteristics. The interesting comparison will be investigated with respect to those different non-safety- vs. safety-critical applications.

Acknowledgments

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References

[1] K. Barry, *How Smartphones Can Improve Public Transit*, Magazine WIRED, http://www.wired.com/2011/04/how-smartphones-can-improve-public-transit/, August 4, 2011, Last visit: October 15, 2014

[2] eMarketer, *Smartphone Penetration Doubles in Indonesia*, eMarketer, August 2, 2013, http://tinyurl.com/indosmart, Last visit: October 15, 2014

[3] T. H. Luan, R. Lu, X. Shen, F. Bai, *Social on the Road: Enabling Secure and Efficient Social Networking on Highways*, IEEE Wireless Communications, Vol. 22, No. 1, New York, NY, U.S.A., February 2015, pp 44-51.

[4] M. Mauve, B. Scheuermann, V*ANET Convenience and Efficiency Applications*, VANET Vehicular Applications and Inter-Networking Technology, John Wiley & Sons Ltd., Chichester, UK., pp 81-105.

[5] M. Aoki, H. Fujii, *Inter-vehicle Communication: Technical Issues on Vehicle Control Application*, IEEE Communications Magazine, Vol. 34, No. 10, New York, NY, U.S.A., August 2002, pp 90-93.

[6] P. Papadimitratos, A. D. La Fortelle, M. Paristech, K. Evenssen, Q. Asa, *Vehicular Communication Systems: Enabling Technologies, Applications, and Future Outlook on Intelligent Transportation*, IEEE Communication Magazine, Vol. 47, No. 11, New York, NY, U.S.A., November 2009, pp 84–95.

[7] M. Torrent-Moreno, F. Schmidt-Eisenlohr, H. Füssler, H. Hatenstein, *Packet Forwarding in VANETs, The Complete Set of Results,* Technical Report Universität Karlsruhe, Karlsruhe, Germany, 2006, http://www.fmi.uni-mannheim.de/fileadmin/lehrstuehle/pi4/content/publications/Torrent2006a.pdf.

[8] M. Boban, G. Misek, O. K. Tonguz, *What is the Best Achievable QoS for Unicast Routing in VANETs?* IEEE GLOBECOM Workshops, New York, NY, U.S.A., December 2008, pp 1-10.

[9] M. Jerbi, S. M. Senouci, R. Meraihi, Y. Ghamri-Doudane, *An Improved Vehicular Ad-hoc Routing Protocol for City Environments*. IEEE International Conference on Communications, ICC, New York, NY, U.S.A., June 2007, pp. 3972-3979.

[10] R. Tavakoli, M. Nabi, *TIGeR: A Traffic-Aware Intersection-based Geographical Routing Protocol for Urban VANETs*, IEEE Vehicular Technology Conference (VTC), New York, N.Y., U.S.A., June 2013, pp 1-5.

[11] L. Kristiana, C. Schmitt, B. Stiller, *Investigating a Reliable Inter-vehicle Network in a Three Dimensional Environment*, 3rd GI/ITG KuVS Fachgespräch Inter-Vehicle Communication, Ulm, Germany, March 2015, pp 16-19.

[12] Y. He, C. Li, X. Han, Q. Lin, *A Link State Aware Hierarchical Road Routing Protocol for 3D Scenario in VANETs*, Lecture Notes in Computer Science (LNCS), Springer, Heidelberg, Germany, September 2014, pp 11-20.

[13] L. Kristiana, C. Schmitt, B. Stiller, *Impact of a Three Dimensional Environment to Inter-vehicle Connectivity*, 4th GI/ITG KuVS Fachgespräch Inter-Vehicle Communication, Berlin, Germany, March 2016, pp 28-31.

[14] Q. Lin, C. Li, X. Wang, L. Zu, *A Three-Dimensional Scenario Oriented Routing Protocol in Vehicular Ad-hoc Networks,* IEEE Vehicular Technology Conference (VTC), New York, N.Y., U.S.A., June 2013, pp 1-5.

[15] H. Wang, G. Z. Tan, J. X. Yang, *An Improved VANET Intelligent Forward Decision-making Routing Algorithm,* Journal of Network, Vol. 7, No. 10, October 2012.

[16] M. Boban, T. T. V. Vinhoza, M. Ferreira, J. Barros, O. K. Tonguz, *Impact of Vehicles as Obstacles in Vehicular Ad-hoc Networks*, IEEE Journal on Selected Areas in Communications, Vol. 29, No. 1, New York, N.Y., U.S.A., January 2011, pp 15-28.

[17] X. Chen, L. Rao, Y. Yao, X. Liu, F. Bai, *The answer is Rolling on Wheels: Modeling and Performance Evaluation of In-cabin Wi-Fi Communications*, Vehicular Communication, Vol. 2, No. 1, 2015, pp 13–26.

[18] G. H. Mohimani, F. Ashtiani, A. Javanmard, M. Hamdi, *Mobility Modeling, Spatial Traffic Distribution, and Probability of Connectivity for Sparse and Dense Vehicular Ad-hoc Networks*, IEEE Transactions on Vehicular Technology, Vol. 58, No. 4, New York, N.Y., U.S.A., May 2009, pp 1998-2007.

[19] H. Labiod, ed., *Wireless Ad hoc and Sensor Networks*. Vol. 6. John Wiley & Sons, 2010, pp 315-339.

[20] J. Walfisch, H. Bertoni, *Theoretical Model of UHF Propagation in Urban Environments,* IEEE Transactions on Antennas and Propagation, Vol. 36, No. 12, New York, N.Y., U.S.A., December 1988, pp 1788-1796.

[21] T. Abbas, F. Tufvesson, K. Sjoberg, J. Karedal, *Shadow Fading Model for Vehicle-to-Vehicle Network Simulation*, 5th Management Committee and Scientific Meeting, COST IC1004, Bristol, UK, September 2012, pp 1-11.

[22] B. Karp, H.T. Kung, *GPSR: Greedy Perimeter Stateless Routing for Wireless Network*, International Conference on Mobile Computing and Networking (MobiCom), ACM, New York, N.Y., U.S.A., August 2000, pp 243-254.

[23] P. Spachos, D. Toumpakaris, D. Hatzinakos, *Angle-based Dynamic Routing Scheme for Source Location Privacy in Wireless Sensor Network,* IEEE Vehicular Technology Conference (VTC), New York, N.Y., U.S.A., May 2014, pp 1-5.

[24] R. K. Banka, G. Xue, *Angle Routing Protocol: Location Aided Routing for Mobile Ad-Hoc Networks Using Dynamic Angle Selection,* IEEE Premier International Conference for Military Communications (MILCOM), New York, N.Y., U.S.A., Vol. 1, October 2001, pp 501-506.

[25] P. Latha, R. Ramachandran, *HDA: Heading Direction Angle Based Multicast Routing for Mobile Ad-hoc Networks*, IEEE International Advance Computing Conference (IACC), New York, N.Y., U.S.A., March 2009, pp 1067-1072.

[26] http://news.okezone.com/read/2015/09/09/338/1210867/pembangunan-fly-over-kawasan-gatsu-menuju-kuningan-macet, Last visit: April 20th, 2016.

[27] L. Kristiana, C. Schmitt, B. Stiller, *Survey of Angle-based Forwarding Methods in VANET Communications*, IFIP Wireless Days Conference, Toulouse, France, March 2016, pp 1-3.

[28] Network Simulator 3, NS3, https://www.nsnam.org/, Last visit April 2015.

[29] V. Gonzales, A. L. Santos, C. Pinart, F. Milagro, *Experimental Demonstration of the Viability of IEEE 802.11b Based Inter-vehicle Communication*, International Conference on Testbeds and Research Infrastructures for the Development of Networks and Communities (TridentCom), ACM, New York, N.Y., U.S.A, March 2008, pp 1-7.

[30] L. S. Mojela, M. J. Booysen, *On the Use of WiMAX and Wi-Fi to Provide In-vehicle Connectivity and Media Distribution*, IEEE International Conference on Industrial Technology (ICIT), New York, N.Y., U.S.A., February 2013, pp 1353-1358.

[31] A. F. Molisch, F.Tufvesson, J. Karedal, C. F. Mecklenbräuker, *A Survey on Vehicle-to-Vehicle Propagation Channels*, IEEE Wireless Communication, Vol. 16, No. 6, New York, N.Y., U.S.A., December 2009, pp 12-22.