V2VUNet - A Filtering Out Concept For Packet Forwarding Decision in Three-Dimensional Inter-vehicular Communication Scenarios

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

Abstract—Reliability and stability for connectivity are the important factors to enhance inter-vehicular communication. In order to achieve such factors, challenges especially in a large city environment due to signal attenuation and a typically poor transmission coverage issues are investigated. Both issues are caused by the existence of obstacles (i.e., overpass constructions and buildings) and road level topology (i.e., a three-dimensional case). Thus, this paper investigates explicitly the horizontal and vertical transmission distances that apply in a three-dimensional case. These distances are covered by existing propagation models of a large city by modeling them as a log-distance path loss with obstacle fading. The scenario of the dedicated three-dimensional case is simulated through the introduction of Vertical Relative Angles (VRA) and Horizontal Relative Angles (HRA) as supporting factors for the forwarding decision. The evaluation shows that applying HRA and VRA reach higher delivery ratio and reduces relatively lower delay in a large city scenario.

Index Terms—Vertical relative angle (VRA), Horizontal relative angle (HRA), Forwarding scheme, Inter-vehicular communication

I. INTRODUCTION

Inter-vehicular communications can support both safety and non-safety applications. Safety applications, i.e. car crash prevention [2], typically take into account a short range wireless transmission technology like Dedicated Short Range Communication (DSRC) [29]. For non-safety applications, i.e., Web surfing and social networking [3], other aspects are relevant, since these applications typically benefit from the use of alternative communication options of the unlicensed spectrum, such as for Wi-Fi and WiMAX [1]. One challenge of providing non-safety application is the high mobility of vehicles, which leads to frequent topology changes of the communication network based on nodes (i.e., vehicle) and respective disconnections. In case of frequent topology changes, vehicles will have to search for a new communication path in order to substitute the “broken” path. This will introduce higher transmission delay. Several studies show that DSRC can run non-safety applications [26]. However, as of today, not that many vehicles are fully equipped with IEEE 802.11p [1], [30], thus the basic study of the dedicated three-dimensional case of Inter-vehicular communications here introduces Vertical Relative Angles (VRA) and Horizontal Relative Angles (HRA) compared to IEEE 802.11a [31].

Another challenge related to inter-vehicular communication is the real environment of a large city itself, such as traffic conditions and road level topology. The traffic conditions can create high load and poor connection situations. Road topologies include massive obstacles, such as overpass constructions and buildings, and other static and dynamic objects, such as trees and tall vehicles [15].

Due to these challenges, inter-vehicle communications offer several alternative forwarding schemes as an approach to increase the network performance to good throughput and low delay. Forwarding schemes determine the core of the routing mechanism and they use several metrics as weight values to forward the packet [10]. These weighted parameters, such as distance, direction, and angle, are used to determine neighboring vehicles to be used as the next relay hop, i.e., intermediate node. Thus, the optimized decision on determining the next intermediate node does support efficient forwarding schemes [19]. As up to now these weight values almost only are exploited in a two-dimensional case. Thus, the distance from the source node to the next intermediate node in a three-dimensional case is very different compared to the distance in a two-dimensional case. While a few approaches investigate routing methods in three-dimensional environments [13], [14], these three-dimensional approaches do not...
consider the different road level, where vehicles are located. Since the location coordinate of vehicles on different road levels within a given and dynamically changing topology do affect the decision of any forwarding scheme, the forwarding scheme in this paper here takes explicitly into account the distance between two communicating vehicles [11]. As the distance as a weight value in a three-dimensional case is less sufficient to be used to determine the intermediate node, this paper applies the real transmission coverage distance among vehicles in a scenario where the disconnection occurs under the overpass. Moreover, due to the high mobility and the existence of obstacles, the added angle weight value improves the forwarding scheme. Finally, this improved forwarding scheme is proposed to be part of a Vehicular-to-vehicular Urban Network (V2VUNet), which is designed especially to suit large city environments [5].

The remainder of this paper is organized as follow, Section II describes related work. Section III introduces the key idea of the angle forwarding scheme being part of a V2VUNet. The simulation and preliminary results are discussed in Section IV, followed by the summary and future work in Section V.

II. RELATED WORK

A reliable and stable inter-vehicular communication covers the need for a successful delivery of messages and an immediate finding of a new path due to the frequently changing topology [8]. Participating vehicles operate as a sender S, a receiver R, or a relay I. The degree of a successful delivery is defined by the Packet Delivery Ratio (PDR) given in percentage.

Unlike in several three-dimensional environments such as in an Under Water Acoustic (UWA) [32] or Unmanned Aerial Vehicle (UAV) [33] Network, the inter-vehicular network coverage and connectivity are more complex due to a Non-Line-Of-Sight (NLOS) propagation [27]. The NLOS propagation in inter-vehicular network is a result of the vehicle’s road path. Therefore, this paper here focuses on suitable propagation and forwarding schemes in a large city environment only and is described as follows:

A. Propagation in Large City Environment

In a large city environment, roads have many different contours and different amount of traffic depending of time of a day. Thus, static and dynamic objects may influence the signal transmission and reception. Objects with different heights do also influence an inter-vehicle communication. The transmission and reception of signals are diffracted (i.e., by buildings and overpass) and scattered (i.e., by trees and any small objects) as illustrated by the dashed arrows in Fig. 2 [34].

A number of various propagation models have been developed to obtain a realistic large city environment [7], [8]. The signals are effected by large- and short-scale fading during transmission. In case of an ideal condition [13], in a three-dimensional area, the signal attenuation is not considered [14]. The prominent propagation models for a large city environment are the log-distance path loss and the shadowing model. The latter considers various building sizes and various obstructions [15], [16]. Therefore, it is necessary to consider propagation models that take into account the existence of obstacles to be used as an approach to determine an optimum transmission. The obstacle fading model is a type propagation model, where the existence of a concrete block, for example, being under the overpass, will attenuate or even restrict the signal transmission and reception. Fig. 3 shows a test measurement done in last August when a mobile phone is used inside a bus in Indonesia. The mobile phone is used to track the vehicle’s mobility and the arrows in the Fig. 3 indicate the two occurring signal loss periods while driving beneath two overpasses.

B. Angle-based Forwarding Scheme

The angle-based forwarding scheme (AFS) takes into account angle measurements between source S and receiver R [18]. The distance between S and R in a planar area is determined based on the imaginary line as illustrated in Fig. 4. This imaginary line is used as the reference for the angle calculation. An angle $\theta$ is a shape formed by two straight lines, S to R and S to C, that has a vertex as illustrated in Fig. 4. The AFS selects the candidate having the smallest angle $\theta$ measurement [19]. The advantage of an angle-based forwarding scheme is to limit the forwarding area, thus, the efficient routing can be obtained [22].
III. PROPOSED V2VUNET APPROACH

The concept of selecting the proper intermediate node is a first part of the proposed V2VUNET approach here. V2VUNET indicates the transmission range depending on measuring factors:

1) Distance: As shown in Fig. 5, there is a difference between the distance in two-dimensional and in three-dimensional case. In two-dimensional case, the distance is shown by the solid line indicated by $d_x$, which actually shorter compared to the distance in three-dimensional case, which is shown by the dashed line $d_z$.

Fig. 5. Horizontal and Vertical Distances

2) Angle: A current node and intermediate node on a different road hierarchical topology (i.e., vehicles on upper road layer and lower road layer) contribute to angular difference between them as shown in Fig. 5. The angle measurement in two-dimensional area aims to calculate the actual distance between $S$ to $R$. In case of three-dimensional area, the distance between $S$ to $R$ is relatively different with the planar area.

The proposed V2VUNET approach forwards packets using the filtering out concept. The forwarding decision based on the distance and angle of the potential intermediate nodes. Therefore, two assumption must be made:

First, the angle is measured from origin node to destination node. The origin node is assumed to be located on upper layer. The $x$-axis represents the width of road, $y$-axis represents the length of road, and $z$-axis represents the height of road. In order to simplify the angle calculation between two nodes (i.e., source and intermediate nodes), the $z$-axis is pre-defined.

Second, the angle is measured when a source node detects an intermediate node located on the lower layer and in line with the current source node on the upper layer. Thus, the measured angle forms perpendicular intersection of two straight lines.

A. Horizontal and Vertical Relative Angle

HRA forwarding scheme, which is basically a distance scheme in two-dimensional environment, is compared to VRA [9]. The difference between HRA and VRA is shown in Fig. 6. HRA works actually by considering the distance in two-dimensional case, while VRA works to discover the real distance in three-dimensional case. When the angle measurement is calculated within the same road level topology, it is called HRA. In contrast, VRA is a term that refers to angle

Fig. 6. HRA and VRA Schemes

As illustrated in Fig. 6, the sender is on the overpass i.e. located on $h$ and the receiver is under overpass. The imaginary line (cf. Fig. 4) is also defined as $k$ (cf. Fig. 6) can be obtained by the Equation 1.

$$
\Delta k = \sqrt{(x_R-x_S)^2 + (y_R-y_S)^2 + (z_R-z_S)^2} 
$$
(Eqn. 1)

B. Packet Forwarding Scheme Using Filtering Out Concept

The concept of V2VUNET shows the angle forwarding scheme with a real location coordinate (e.g., provided by GPS) of mobile node. This angle forwarding scheme is applicable for mobile node’s location coordinates on top of other mobile node’s location coordinates. This condition has been neglected at most simulations although it is significant in the real experiments. The reason is that mobile nodes (i.e., usually vehicles) are moving on the ground level. Using distance between mobile nodes in planar position will influence the signal power (transmission power information), speed and direction (mobility information), and angle (non-planar position information) as parameters of forwarding decision. It is obvious that the higher the overpass, the larger the distance between two communicating vehicles becomes. Therefore, the height of overpass leads to another impact factor with respect to transmission coverage.

Fig. 7. Filtering out Concept

Both HRA and VRA are implemented in forwarding decision. This forwarding decision works by applying a filtering out concept. The principal of filtering out concept is to select the relay node (I) which fulfills HRA and VRA requirements. There are two steps of filtering out concept by implementing HRA and VRA as follow:
1) HRA and VRA Decision:

This filtering out concept selects neighboring nodes within the transmission range of source node $S$ restricting the searching area for intermediate node candidates. HRA and VRA implementations as illustrated in Fig. 7 define the $\theta_1$ as the maximum angle of transmission area. The value of $\theta_1$ decreases to $\theta_3$ in order to restrict candidates and select the node located closest to planned receiver $R$. Dashed lines indicate the search radius of source $S$ for the intermediate candidate in direction of receiver $R$. A node satisfying both HRA and VRA decision will be determined as an intermediate node candidate $I$.

2) HRA and VRA Execution:

Once the HRA and VRA decision has been made, the next step is to execute the packet forwarding. This execution involves two cases. The first case is when vehicles are located on the same road level. Here, the log-distance path loss model is applied. The second case is when vehicles are located on the different road level and experiencing a connection loss as described in Section II.B.

IV. SIMULATION

The evaluation of the two applied metrics VRA and HRA in the proposed filtering out concept is conducted in simulations to determine the performance of a V2VUNet approach in a large city environment including the three-dimensional case. In order to obtain a realistic city environment, typical parameters for the influencing factors are chosen as shown in Table I. The Network Simulator-3 (NS-3) [23] is used to simulate wireless technologies (i.e., IEEE 802.11p and IEEE 802.11a), the routing protocol (i.e., Greedy Perimeter Source Routing (GPSR) [17]), the mobility, the road topology, and the network density. The IEEE 802.11a is considerable to be used because it is a well-deployed wireless technology in Indonesia, however IEEE 802.11p is used to support the frequent topology changing in VANET. In order to reach a realistic mobility, the speed of vehicles on average is between 40 and 70 km/h, low and high network density with various number of nodes (i.e., 10 to 40 vehicles) are simulated to determine peak time and a non-peak time road traffic in 0.25 km² area. Pairs of connections (i.e., $S$ to $R$) are generated randomly, which means that any participant nodes can be $S$ or $R$, and/or $I$. In addition, $S$, $R$, and $I$ are placed randomly both on two different road level. However, the direction of vehicles is set as non-random, because vehicles have to follow the predefined driving lane.

<table>
<thead>
<tr>
<th>TABLE I: PARAMETER SETTINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>Transmission Range IEEE 802.11a/p</td>
</tr>
<tr>
<td>Routing Protocols</td>
</tr>
<tr>
<td>Number of Nodes</td>
</tr>
<tr>
<td>Simulation Area</td>
</tr>
<tr>
<td>Upper Road Height</td>
</tr>
<tr>
<td>Average Vehicle Velocity</td>
</tr>
<tr>
<td>Packet Size</td>
</tr>
<tr>
<td>Simulation Time</td>
</tr>
<tr>
<td>Number of Driving Lanes</td>
</tr>
</tbody>
</table>

Moreover, the number of $S$ and $R$ are generated linearly, which means a 10 nodes network contains of 5 senders and 5 receivers. The simulation area covers an environment, which involves a road with an overpass for the three-dimensional case. This overpass represents the filtering out concept scenario since vehicles that move under the overpass will be excluded from the potential relay nodes list. The simulation...
time is set to 200 s in order to reach the required transmission time of 1024 Bytes packet size. In addition, during 200 s of simulation time, each vehicle is expected to run a distance with the experience of moving under and on the overpass on two driving lanes.

First results are shown in Fig. 8 and 9 as an initial part of the V2VUNet approach. Fig. 8 shows the PDR using both IEEE 802.11a and IEEE 802.11p, indicates that HRA and VRA weight values have significant impacts on the connection. This means when candidates do not fulfill HRA and VRA measurements, the sender will not forward the packet. The filtering out scheme shows better PDR results compared to an unfiltering out scheme. This indicates that the proposed V2VUNet with filtering concept including the relative angle as an additional metric to the forwarding decision is necessary to determine the proper intermediate node out of the neighboring candidates. However, the highest obtained PDR for IEEE 802.11a and for IEEE 802.11p are 20% and 30%, respectively. These considerably low percentages are caused by the overpass and the specific feature of the selected routing protocol. Since the scenario under investigation focuses on the road topology with overpasses, obstacles (i.e., overpass constructions) are added between two different levels of roads and those obstacles block the signal reception. Additionally, the routing protocol chosen, GPSR, and its search location mechanism considers vehicles, which are located under the overpass as “undetected” vehicles’ location coordinates, if vehicles are at the exact same position, but on a different level, since the GPSR algorithm relies on two-dimensional location coordinates only. Overall, the PDR is decreasing due to the higher speed of vehicles and due to frequent disconnections.

However, handling the End-to-End (E2E) delay is considered as a trade-off. Fig. 9 shows the E2E delay of IEEE 802.11a and IEEE 802.11p. The filtering out concept reduces the E2E delay, even though fluctuating results shown on higher number of participant nodes. The delay observed is the result of the routing protocol mechanism applied, which searches for a new connection or path once the current path is disconnected.

V. SUMMARY AND FUTURE WORK

This work proposed a V2VUNet approach with filtering out concept to establish a better inter-vehicle communication in three-dimensional large city environments. This solution includes additional weight values to known HRA and VRA algorithms to determine the next intermediate node candidate in the communication way between two vehicles. Furthermore, it is shown that HRA and VRA metrics avoid unnecessary candidates with a high chance of disconnection in crossing overpass scenario and out of transmission range in parallel overpass scenario. Additionally, the E2E delay becomes significant better by the proposed approach.

In future work, the V2VUNet is expected to address the movement challenge by adding a direction weight value to improve the filtering out concept, thus a more realistic mobility model will be used. The direction of vehicles will be applied in order to predict vehicles’ movements. Furthermore, the movement prediction will be combined with filtering concept as a complete part of V2VUNet approach.

ACKNOWLEDGMENT

This work was supported in parts by the Ministry of Research, Technology and Higher Education of the Republic of Indonesia and the University of Zürich, CSG@IHI, Switzerland.

REFERENCES
