Poster: Revisiting Vehicle Obstacle Shadowing for Long Homogeneous Platoons in VEINS

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***Abstract*—Vehicle-to-Vehicle (V2V) wireless links are susceptible to shadowing & diffraction by vehicular obstacles. We address the scenario of long platoons of similar-shaped vehicles (homogeneous). VEINS, a well-established vehicular networking simulation library, represents vehicular shadowing using Fresnel zones and the knife-edge model. We conduct a literature review of outdoor experimental results that are close (but not equal) to the scenario we are addressing in VEINS.**

***Index Terms*—ITS, vehicular communication, wireless signal propagation, wireless communication obstacles.**

I. Introduction

Intra-platoon vehicle-to-vehicle (V2V) connectivity is key for efficient and safe coordinated operation of all platoon members. Modelling V2V links with vehicles in-between Tx and Rx must include not only long-distance path loss and stochastic fading models, but also account for the impact of obstacles on the received signal arising from shadowing, reflection (on the vehicles top surfaces) and diffraction (by in-between vehicles). In the literature, Fresnel zones and the knife-edge model have been used to model vehicular obstacles [1]. This is the approach used by the vehicular networking simulation library VEINS [2]. We review the models underlying the implementation of vehicle obstacle shadowing in VEINS and discuss their suitability for platoon scenarios. Using VEINS, we produce simulation results for platoon scenarios where all vehicles are either of passenger or truck type, and transmitter (Tx) and receiver (Rx) observe line-of-sight (LOS). Finally, we compare our simulation results against literature experimental data (collected in outdoor measurement campaigns), for similar Tx-Rx distances both in LOS and non-LOS conditions.

II. Vehicle Obstacle Shadowing (VOS)

1) Fresnel Zone & Knife-Edge Model: The impact of obstacles between transmitter and receiver in the propagated signal can be modeled by Fresnel zones (Fig 1). The Fresnel ellipsoids represent signal copies that follow different paths between transmitter and receiver due to obstructions or deflecting objects. The radius of the n^{th} Fresnel ellipsoid is denoted by r_n. For the purpose of quantifying attenuation, the Fresnel radius at the distance of the first obstacle to Tx, d_1, must be determined. The Fresnel radius value can be computed according to Eq.1, where λ is the wavelength and d_2 the distance from Rx to the obstacle ($d_2 = d_{\text{total}} - d_1$).

$$r_n = \sqrt{\frac{n\lambda d_1 d_2}{d_1 + d_2}} \tag{1}$$

Following [3], the guideline for LOS microwave links is that, as long as 55% of the first Fresnel zone is kept clear, then further Fresnel zone clearance does not significantly alter loss. Attenuation caused by obstacles can be modeled by the knife-edge model. Each obstacle is represented as a knife-edge, or a semi-infinite, perfectly-absorbing plane placed perpendicular to the radio link between Tx and Rx. The dimensionless parameter ν provides a measure of how much the knife-edge intrudes the first Fresnel zone. ν is defined by Eq. 2:

$$\nu = \frac{\sqrt{2}H}{r_1} \tag{2}$$

where H the height difference between obstacle and LOS, and r_1 is the radius of the 1st Fresnel zone at the distance of the obstacle to Tx. From [4], additional attenuation (in dB) due to a single knife-edge A_{sk} can be expressed by Eq. 3:

$$\text{A}_{\text{sk}} = \begin{cases} 0, & \text{if } \nu \le -0.7 \\ 6.9 + 20\log_{10}\left(\sqrt{(\nu - 0.1)^2 + 1} + \nu - 0.1\right), & \text{otherwise} \end{cases} \tag{3}$$

The extension of the single knife-edge obstacle case to the multiple knife-edge is not immediate. We select as reference the ITU-R method [4]. It has been used in literature [1] and is implemented by the VEINS library. Vehicle obstacles between Tx and Rx are modeled as multiple knife-edges, and a modified version of the Epstein-Patterson method [4, Sec.4.4]

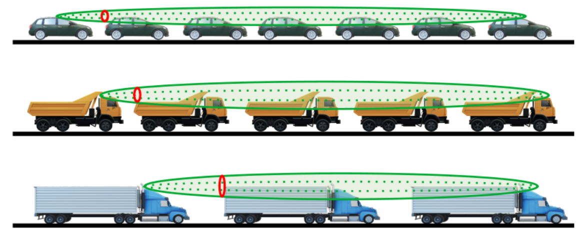

Fig. 1: Long platoons of different vehicle classes. Leftmost vehicle (Tx) unicasts to rightmost one (Rx). Also shown is Fresnel zone and Fresnel area at location of first obstacle.

This work was supported by national funds through FCT/MCTES (Portuguese Foundation for Science and Technology), within the CISTER Research Unit (UIDP/UIDB/04234/2020) and under the project Intelligent Systems Associate Laboratory - LASI (LA/P/0104/2020). The work of Saeid Sabamoniri is supported by a Ph.D. Scholarship from FCT, grant nr. 2023.00896.BD.

is applied. The first step is to identify the tallest (or *major*) obstacles; to this end, a *rope-stretching* algorithm is applied to the height profile between Tx and Rx. Individual contributions of major obstacles to attenuation can be added straightforwardly: $A_{\mathrm{mk}} = \sum_{i=1}^{N} A_{\mathrm{sk}_i}$. In a scenario where all obstacles are taller than LOS, selected contributions from smaller (or *minor*) obstacles in-between major ones, and correcting factors must be added for a better estimate. If all obstacles are below LOS and have the same height (hence, all are *minor* obstacles), only the obstacle nearest to the transmitter needs to be considered.

2) VEINS Implementation: The VEINS module `Vehicle Obstacle Shadowing` (VOS), found under *Analogue Models*[1], represents vehicles as bounding boxes and, at each packet transmission, identifies all obstacle vehicles intersecting the direct line connecting Tx and Rx. The Tx and Rx height considered for the Fresnel radius computation is the sum of the vehicle height plus the antenna height. The implementation applies the *rope-stretching* algorithm mentioned in the previous section to identify major and minor obstacles. We confirmed that the implementation considers solely attenuation caused by the vehicle closest to the transmitter if all the vehicles have the same height and do not block LOS.

III. Literature Review on VOS Impact

1) Our Platooning Scenario: We implemented some vehicle shadowing scenarios in VEINS. We consider three types of vehicle classes – Passenger, Truck and Trailer – addressed in separate scenarios. Each scenario uses a 30 vehicle-platoon, with all vehicles being of the same class and having the same height (including Tx and Rx). The distance between vehicle antennas is 6 m for the Passenger vehicles, 11.6 m for Trucks, and 21 m for Trailers. Antennas are 10 cm high, placed on the front edge of the vehicle. IEEE802.11p-equipped (operating at 5.9 GHz) On-Board Units broadcast 5 beacons per second. Used propagation models are: (Free-Space) `Simple Path Loss`, `Vehicle Obstacle Shadowing`, and `Nakagami Fading`. Attenuation considering contributions from all models are shown in Table I. Fig. 2 illustrates the impact of VOS in a platoon of passenger vehicles (all below LOS), considering V0 as Tx and every other platoon member as Rx. As only the closest obstacle is considered for attenuation, increases of the Fresnel radii are due solely to increasing distances between Tx and Rx.

2) Literature Review: Several works report outdoor experimental campaigns to evaluate vehicular obstructions, but typically they focus on a full LOS-blocking vehicle(s) rather than platoon scenarios. We address a platooning scenario where all vehicles are the same height and, while they do not obstruct LOS between antennas, they affect propagation by intruding into the (1^{st}) Fresnel ellipsoid. Thus, while scenarios may not exactly match, it is informative to compare outdoor LOS/NLOS RSS measurements with the (simulation-based) RSS values for a platoon scenario. Segata et al. [6] took measurements in a highway scenario, aiming at 80 to 120m between Tx and Rx with a single vehicle in-between. Meireles et al. [5] assess the impact of LOS and NLOS conditions on RSSI and PDR. They carried out experiments in a parking lot, with two passenger vehicles in LOS and with a van in between. The links between vehicles V0-V9 (in the Truck scenario) and vehicles V0-V17 (in the Passenger scenario) are the closest to the scenarios of [5] and [6]. Table I presents reported RSS from selected scenarios from each work; notice the differences in Tx power. Simulation results seem in line with [5], and more pessimistic than [6], albeit in that work it is not clear the distance of blocking vehicle to Tx and Rx.

3) Future Work: We will: (i) extend this literature review; (ii) validate VEINS results by replicating literature scenarios in simulation; and (iii) perform our own measurements.

[1] https://github.com/sommer/veins/tree/master/src/veins/modules/analogueModel

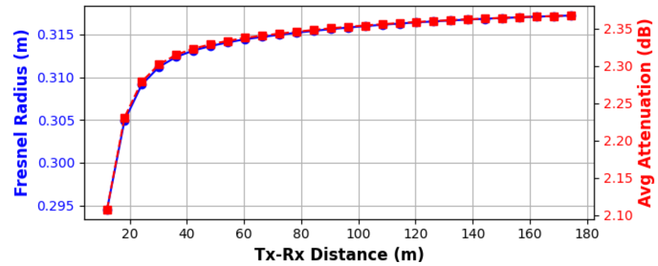

Fig. 2: V0 is Tx. Shown is Fresnel radii at 1^{st} obstacle and signal attenuation w.r.t. Tx-Rx distance (shown as # vehicles).

TABLE I: RSS collected in outdoor measurements and simulation in different LOS conditions; target Tx-Rx dist: 100m.

Parameter	**Ref. [5]**		**Ref. [6]**			**Our work**	
LOS or obstacle	LOS	Van	LOS	Passenger	Truck	V0-V9	V0-V17
Tx-Rx Dist. (m)	100	100	80	80	80	104	102
Tx Power (dBm)	10	10	20	20	20	13.01	13.01
Rx Power (dBm)	-75	-82	-60	-62	-69	-83.14	-82.92
Atten. (dB)	**85**	**92**	**80**	**82**	**89**	**96.15**	**95.93**
Scenario	Static	Static	Dyn.	Dyn.	Dyn.	Static	Static
Tx/Rx Type	Pass.	Pass.	Pass.	Pass.	Pass.	Truck	Pass.
Antenna Spec.							
Height (cm)	26		36			10	
Gain (dBi)	5		9			0.745	
Roof Position	Middle		Rear			Front	
Type	Custom		Monopole			Dipole	

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