

Feasibility Study of 5G-based Localization for Assisted Driving

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Abstract—5G assisted driving applications demand the provision of centimetre-accurate positioning. Automated vehicles typically use several positioning systems, such as radars, cameras and sensors, in addition to Global Navigation Satellite Systems (GNSS). This is necessary to ensure integrity and reliability, as well as precise positioning. The deployment of 5G cellular networks along roads are envisaged to complement these existing technologies for assisted driving. Thus, this paper provides a feasibility study of the positioning capabilities for future 5G vehicle-to-infrastructure (V2I) networks, considering 5G-like multicarrier signals. Simulation results indicate achievable localization accuracies below 30 centimetres by using cellular ranging measurements with 50 and 100 MHz of system bandwidth.

I. INTRODUCTION

Road safety and efficient mobility are the main drivers for intelligent transport systems (ITS). In this sense, automated driving is a key technology for the future of transportation. Full automation of vehicles is expected to be introduced towards 2030 [1]. One of the main challenges is the provision of centimetre-level positioning accuracy. Main applications, such as automated overtake, cooperative collision avoidance or vulnerable road user (VRU) discovery, require a vehicle localization accuracy equal or below 30 cm, with additional requirements on security, integrity, authentication and privacy [2]. Thus, multiple technologies, such as Global Navigation Satellite Systems (GNSS), radars, cameras or sensors, are integrated to achieve centimetre-accurate positioning.

The fifth-generation (5G) of mobile networks are expected to support and complement current technologies for assisted or automated driving applications. In addition, positioning methods based on 5G networks are envisaged to benefit from the high density of base stations (BSs), very high signal bandwidths, multi-antenna beamforming, and millimetre wavelength. Recent studies on 5G-based localization show positioning accuracies below one meter by means of network-based time-of-arrival (ToA) and direction-of-arrival (DoA), such as in [3] and [4]. However, no feasibility study is available yet on the specific application of assisted driving, where 5G can certainly play a major role.

The current deployment of vehicular cellular networks for localization purposes is only based on the provision of communications for emergency services, such as eCall [5], where GNSS is the primary positioning technology. Although the role of positioning was already highlighted in 3G networks, the use of dedicated positioning resources has not been established until 4G Long Term Evolution (LTE) [6], by defining the

positioning reference signal (PRS) in specific time periods used only for localization. Thus, 4G and 5G cellular networks are known to provide many advantages for positioning applications. However, these existing wireless standards have not been fully exploited for vehicular positioning, which has extraordinary future applications, such as assisted driving.

Our focus is on 5G, which will inherit many of the physical-layer characteristics of LTE, such as the use of multicarrier signals [7], with a modulation similar to orthogonal frequency-division multiplexing (OFDM). Because of that evolution, we will consider the use of PRS multicarrier signals with the network planning and design considerations of 5G networks, to target the specific characteristics of road assisted driving. In this context, this paper is aimed to study the achievable localization of 5G networks based on time difference of arrival (TDoA) for assisted driving, inherited from LTE. In this sense, a single-antenna approach and a signal bandwidth up to 100 MHz are only considered. The TDoA performance limits in additive white Gaussian noise (AWGN) channel with shadowing are first used to design the 5G network deployment of roadside BSs for highways, by considering a target position accuracy of 30 cm. This is a novel approach on the 5G network design for assisted driving applications. Simulation results using vehicle-to-infrastructure (V2I) channel models are then computed to validate the achievable localization accuracy in the highway assisted driving scenario. Finally, conclusions and future work are drawn.

II. 5G NETWORK DESIGN FOR ASSISTED DRIVING

Assisted driving poses tremendous challenges on positioning in terms of very high accuracy, integrity and security, as well as on communications due to the low latency required. Thus, current GNSS technologies may not be sufficient to fulfil these localization requirements, and they may need to be integrated with additional positioning systems. In order to complement GNSS, the solution envisaged is the dedicated design of 5G vehicular networks for positioning and communications purposes targeting assisted driving applications. This dedicated design implies specific network planning and optimized signal parameters in order to maximize the positioning performance of vehicles. However, the target problem has particular constraints, such as geometrical considerations due to the placement of BSs or the allocation of network resources (e.g. transmit power or bandwidth). Thus, a dedicated infrastructure for vehicular positioning may be based on the introduction of specific deployments, such as roadside BS

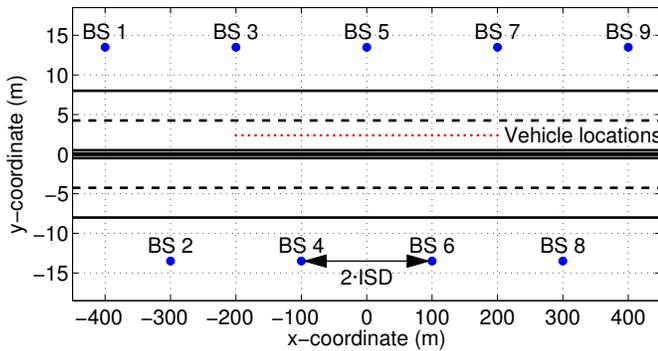


Fig. 1. Example of cellular network dedicated for assisted driving positioning.

along a highway, or the reuse of existing cellular networks, or a hybrid combination of both. This design should also consider the characteristic propagation channel with dominant line-of-sight (LoS), due to the clear view from vehicle to roadside BSs, and with close multipath, due to the presence of nearby vehicles. This section describes the network design necessary to fulfil the positioning requirements for 5G assisted driving.

A. Scenario definition

The current study is aimed to assess the impact of the linear placement of BSs along the road on the positioning performance, which is a completely different approach to the typical hexagonal cellular deployment. In particular, highways are here considered because these are the scenarios being targeted first by car manufacturers and experimental pilots.

The general V2I scenario studied in this paper is based on a straight section of the highway, where BSs are deployed on the roadsides at equi-spaced distances, as it is shown with an example network in Figure 1. In 802.11p networks [8], roadside units (RSUs) or access points (APs) are typically deployed at similar heights to the vehicles, such as at emergency phone booths [9]. In contrast, cellular BSs are expected to be located at elevated points [9], such as at the top of road lamp posts and high-mast lighting of around 10 and 30 meters high, respectively. These roadside BSs are usually considered small cells with a coverage up to hundreds of meters [10]. The inter-site distance (ISD) is defined as the separation between BSs along the road. The reuse of the existing road infrastructure considerably reduces the V2I network deployment cost, such as by installing BSs at light poles. However, the definition of the BS locations is then limited to the location of the existing infrastructure, such as the distance between light poles or the separation between light poles and the road. In addition, the highway has several parameters regulated by governmental bodies, such as the number, width and separation of lanes, which are considered in the scenario definition.

B. Channel models

A key aspect on the simulation of road scenarios is the use of realistic propagation channel models, which represent macroscopic path loss, shadowing and multipath. These channel models are typically provided in the cellular standards for reproducibility of simulations, such as in [11], [12], [13] with the path loss models shown in Figure 2. But, further advances

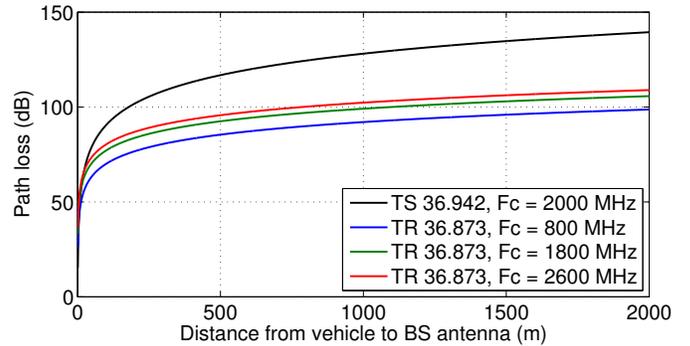


Fig. 2. Distance-dependent path loss using standard 3GPP models [12], [13].

in channel modelling are studied for future 5G systems [14], such as vehicle-to-everything (V2X) applications. Three main classes of models can be found in the literature [9], [15], [16]:

1) *Geometry-based deterministic models (GBDM)*: The physical channel is modelled based on deterministic propagation paths for a specific environment. Typically, these models are obtained with ray tracing methods. They are very accurate and representative, but their simulation implies a high computational complexity.

2) *Geometry-based stochastic models (GBSM)*: Channel realizations are randomly generated according to a stochastic distribution of scatterers. The WINNER channel model is an example widely used for cellular networks [13].

3) *Non-geometrical stochastic models (NGSM)*: Physical channel is stochastically modelled without considering a specific geometry, but with predefined parameters for a specific environment. As an example, the tapped delay line (TDL) models are typically defined in the cellular standards [11].

Vehicular channel models for V2I can be found for 802.11p networks. For instance, the V2I model in [17] is based on empirical measurements for urban, suburban and highway environments, and it has been applied to LTE vehicular networks in [18]. A key feature of these vehicular models is the characterization of LoS conditions, where the distance between mobile and BS, as well as the height between them, plays a significant role on the LoS probability. As an example, a similar height between transmitter and receiver antennas in a V2I network can induce a high non-LoS (NLoS) probability due to the obstruction from surrounding vehicles.

C. Main design parameters

The design of dedicated 5G cellular networks for assisted driving requires the optimization of several network parameters, in order to achieve the stringent positioning requirements. The main design parameters for 5G assisted driving are:

1) *Transmit power*: The coverage of the roadside BS is determined by the transmit power, which limits the achievable ranging accuracy. According to the LTE standard [12], the maximum power P_{\max} of macro cell BSs is set to 43 dBm for 1.4, 3 and 5 MHz of system bandwidth, and to 46 dBm for above 5 MHz. The deployment cost of the BS can be reduced by using low power nodes (LPNs), which have a transmit power between 23 and 33 dBm [19].

2) *Transmit gain*: The transmit gain is mainly defined by the sectorial antenna gain (plus connector loss) G_{TX} , and the antenna pattern [12]:

$$A(\theta) = G_{\text{TX}} - \min \left(12 \left(\frac{\theta - \theta_{\text{dir}}}{\theta_{3\text{dB}}} \right)^2, A_{\text{min}} \right), \quad (1)$$

where $-180 \leq \theta \leq 180$ is the angle between mobile and BS, θ_{dir} is the direction of the antenna sector, $\theta_{3\text{dB}}$ is the 3-dB beamwidth (e.g. 65 degrees), and the A_{min} is the minimum attenuation (e.g. 20 dB). In communications, the directional antenna is configured to avoid overlapping between the coverage of BSs, such as in [10]. In contrast, for positioning purposes, a mobile device needs to receive sufficient signal power from multiple BSs. Thus, the coverage of the BSs can be increased by using multiple sectors and by configuring their antenna direction. The directivity of the antenna can also be improved by doing beamforming with an antenna array.

3) *BS location*: The geographic location of the BS determines the dilution of precision (DOP) and the propagation channel conditions, such as path loss, shadowing, multipath and LoS conditions. The horizontal coordinates of the BS are mainly defined by the ISD, as well as the distance from the cell tower to the road, which has a negligible impact on the positioning assessment. The vertical coordinate is defined by the height of the antenna post. The horizontal DOP (HDOP) is improved by alternating the position of the BSs at each roadside, as in Figure 1, instead of locating the BSs at the center of the road. The vertical DOP (VDOP) is improved by increasing the height of the BS antenna, but it can still be poor. Considering the BS location at light poles, the minimum ISD and the height of the antenna are directly related by the illumination design for the road lighting, e.g. a high density of light poles typically result in a small height of the pole.

4) *Carrier frequency*: The propagation path loss and the Doppler shift decrease with the transmit carrier frequency F_c . Thus, low frequency bands, such as 800 MHz, are desirable. However, this implies a constraint on the signal bandwidth allocation due to spectrum limitations.

5) *Signal bandwidth*: In addition to the received signal power and the integration time, the signal bandwidth B mainly determines the achievable ranging accuracy. In LTE, the allocated bandwidth is defined by N_{RB} resource blocks (RB), which contain 12 subcarriers and 7 OFDM symbols. The LTE signal bandwidth ranges from 6 to 100 RB, by using a system bandwidth from 1.4 to 20 MHz, respectively. LTE-Advanced (LTE-A) uses carrier aggregation (CA) to achieve a system bandwidth up to 100 MHz.

D. Design methodology

The methodology to design a dedicated network for assisted driving applications is shown in Figure 3 with five main steps. First, the range of possible values for the main design parameters is defined. These values are the main inputs for the design algorithm. Second, the road scenario is configured by setting the location of the BSs and vehicles, being the road parameters already predefined. In parallel, a combinatorial sequence with the values of the design parameters is generated.

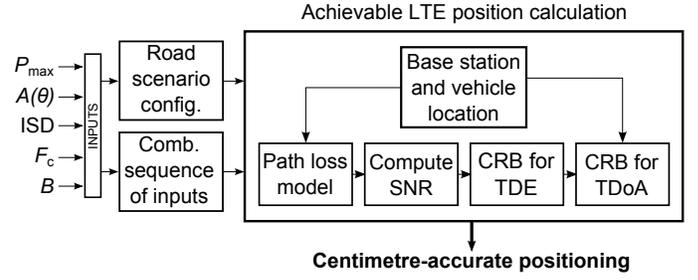


Fig. 3. Conceptual methodology for analytically determining the positioning accuracy of a cellular network.

Then, the SNR is calculated and applied within the Cramér-Rao bound (CRB) for time-delay estimation (TDE). The resulting ranging variance is used as an input for computing the CRB for TDoA, which provides the achievable localization accuracy in LoS and AWGN conditions. Further details of this process are provided in the following section. Finally, a predefined criterion is used to select a network solution from the multiple designs that may fulfil the target positioning accuracy. This criterion may also consider requirements for communication purposes. Since this combinatorial problem rapidly increases with the number of possible values per parameter, the following section describes the performance limits of TDoA localization, considering the minimum and maximum values for the main parameters.

III. IDEAL TDOA PERFORMANCE LIMITS

The achievable TDoA localization accuracy for dedicated 5G multicarrier-based systems is discussed in this section, by considering theoretical bounds for ranging and positioning over AWGN channel and LoS conditions. These ideal conditions determine the performance limits with 5G-like multicarrier signals. Thus, this approach provides an adequate network design for assisted driving.

A. Assumptions

Future 5G networks will be able to provide coordinated transmission of positioning resources, which is already feasible in LTE with non-overlapping PRS subcarriers or PRS muting, as well as tight network synchronization. Our analysis is based on a single-antenna approach, i.e., the sectorial BS antenna has only one antenna element. The 5G mobile device is assumed to receive multiple frequency bands with perfect time, frequency and phase synchronization, resulting in a coherent TDE for a signal bandwidth up to 100 MHz, such as CA in LTE-A. The assessment of the positioning accuracy only considers a two-dimensional (2D) problem, where the horizontal coordinates of the mobile device are estimated. This work could be easily extended to include the estimation of the receiver clock offset and the vertical dimension.

B. SNR computation

Let us consider the distance and angle between the vehicle and the i -th BS as $d_{\text{BS},i}$ and θ_i , respectively, with a maximum distance $d_{\text{BS,max}}$. The macroscopic path losses of this link are defined (in decibels) as

$$L_i = \max(\text{PL}(d_{\text{BS},i}) - A(\theta_i) - G_{\text{rx}}, \text{MCL}), \quad (2)$$

where G_{RX} is the receiver antenna gain, and MCL is the minimum coupling loss (MCL). Then, the received signal power from the i -th BS is

$$C_i = P_{\text{max}} - L_i - \text{SF}, \quad (3)$$

where SF is the shadow fading, which follows a log-normal distribution with standard deviation σ_{SF} . The resulting C/N_0 at the output of the receiver RF front-end is

$$(C/N_0)_i = C_i - N_0 - \text{NF}, \quad (4)$$

where N_0 is the noise spectral density, i.e., approximately -174 dBm/Hz, and NF is the receiver noise figure (NF). The SNR is finally computed as

$$\text{SNR}_i = (C/N_0)_i - 10 \cdot \log_{10}(B), \quad (5)$$

where the multicarrier signal bandwidth is $B = N_a \cdot F_{\text{sc}}$, which is defined in LTE as $N_a = 12 \cdot N_{\text{RB}} - 4$ active subcarriers with a number of scattered PRS pilots equal to $N_{\text{PRS}} = 2 \cdot N_{\text{RB}}$, and subcarrier spacing $F_{\text{sc}} = 15$ kHz.

C. CRB for TDE

The minimum achievable variance on the estimation of time delay τ_i with respect to the i -th BS is found in [20] and [21] with the CRB as

$$\sigma_i^2 \geq \text{CRB}(\tau_i) = \frac{T^2}{8\pi^2 \cdot \text{SNR}_i \cdot \sum_{n \in \mathcal{N}_{\text{PRS}}} p_n^2 \cdot n^2}, \quad (6)$$

where $T = 1/F_{\text{sc}}$ is the OFDM symbol period, \mathcal{N}_{PRS} is the subset of PRS pilot subcarriers, and p_n^2 is the relative power weight of subcarrier n . The CRB for TDE using different LTE and LTE-A signal bandwidths under AWGN channel is shown in Figure 4. The minimum signal level required to achieve the cm-level ranging accuracy can be defined as $(C/N_0)_{\text{thr}}$, whose values are shown in Table II for every signal bandwidth. Thus, the network design has to ensure this C/N_0 threshold at the receiver in order to fulfil the accuracy requirements. As it can be noticed, the transmit power can be relaxed as the signal bandwidth increases. Thus, the maximum power may not be needed with a high signal bandwidth in order to achieve centimetre-accurate positioning.

Let us define the C/N_0 limits for two main network designs with high and low ISD, i.e., d_{BS} equal to 2 km and 400 m, respectively. The highway scenario is defined using the predefined parameters in Table I. Two antenna sectors are considered per BS, using $\theta_{\text{dir}} = \{-60, 60\}$ degrees facing the road. In the first case, the maximum path losses are assumed. As it is shown in Figure 2, the most restrictive path loss model, which is defined in [12], results in a path loss of around 140 dB for $d_{\text{BS}} = 2$ km at $F_c = 2$ GHz. Using $P_{\text{max}} = 43$ dBm and $\text{SF} = 2\sigma_{\text{SF}}$, the C/N_0 limit is at 66.42 dB-Hz, which only allows to achieve a target accuracy of 30 cm with a signal bandwidth higher than 20 MHz. In the second case, minimum path losses are considered, thus a low carrier frequency is chosen, i.e., $F_c = 800$ MHz. Using the 3D-UMa LoS model in [13], the resulting path loss is 83.33 dB, which is higher than MCL = 70 dB. Thus, with $P_{\text{max}} = 43$ dBm and $\text{SF} = 2\sigma_{\text{SF}}$, the C/N_0 limit is equal to 121.98 dB-Hz, and the target accuracy can be achieved with any signal bandwidth. These two C/N_0 limits are shown in Figure 4.

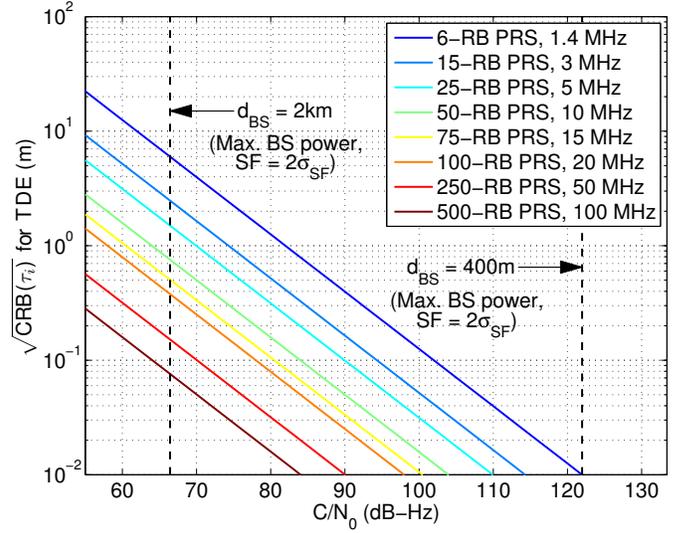


Fig. 4. CRB for TDE using different LTE and LTE-A system bandwidths, and considering the possible range of C/N_0 in the 5G assisted driving scenario.

TABLE I. HIGHWAY SCENARIO DEFINITION.

| Road parameters | | Network parameters [13] | |
|-------------------------|--------|-------------------------|--------|
| BS height | 10 m | # of ant. sectors | 2 |
| BS-to-road separation | 5 m | G_{TX} | 17 dBi |
| # of lanes | 4 | G_{RX} | 0 dBi |
| Central lane separation | 1 m | MCL | 70 dB |
| Lane width | 3.75 m | NF | 9 dB |
| BSs separation | ISD | σ_{SF} | 8 dB |

The minimum ISD to achieve a ranging accuracy equal or above 1 cm, i.e., ISD_{thr} , can be approximated considering the maximum distance between vehicle and BS to ensure $C/N_0 > (C/N_0)_{\text{thr}}$, that is,

$$\text{ISD}_{\text{thr}} \approx \frac{2 \cdot d_{\text{BS,max}}}{M} \leftrightarrow C/N_0 > (C/N_0)_{\text{thr}}, \quad (7)$$

where M is the number of most powerful BSs used for positioning. Considering $M = 4$, Table II shows ISD_{thr} for the different path loss models [12], [13] and carrier frequencies, with the maximum power and shadowing fading. Assuming the most restrictive path loss model [12], minimum ISD above 30 meters should be designed for the lowest system bandwidth of 1.4 MHz, and between 100 and 350 meters for a system bandwidth between 10 and 100 MHz, respectively.

As a final remark, the design assessment has considered an integration time of only one OFDM symbol. Thus, the C/N_0 threshold could be decreased by increasing the integration time with more pilot symbols.

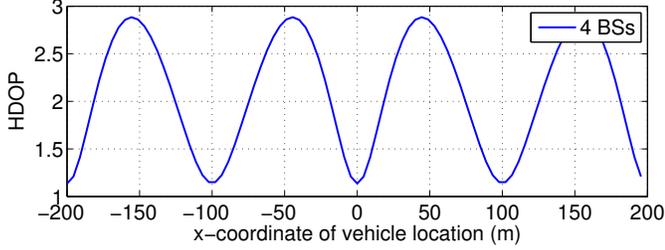
D. CRB for TDoA and HDOP

The achievable localization accuracy is finally computed by using the CRB for TDoA, as in [20] and [22]. Let us define the vehicle location as $\mathbf{x} = (x, y)^T$ and the i -th BS location as $\mathbf{x}_i = (x_i, y_i)^T$. The position accuracy obtained with the CRB for TDoA is [20], [22]

$$\varepsilon_{\mathbf{x}} = \sqrt{\text{tr}(\text{CRB}(\mathbf{x}))} = \sqrt{\text{tr}((\mathbf{D}^T \mathbf{R}^{-1} \mathbf{D})^{-1})}, \quad (8)$$

TABLE II. ISD_{thr} FOR DIFFERENT PATH LOSS MODELS IN THE HIGHWAY SCENARIO, WITH $P_{max} = 43$ DBM AND $SF = 2\sigma_{SF}$.

| System bandwidth [MHz] | 1.4 | 3 | 5 | 10 | 15 | 20 | 50 | 100 |
|---|-------|-------|-------|--------|--------|--------|--------|--------|
| Signal bandwidth B [MHz] | 1.02 | 2.64 | 4.44 | 8.94 | 13.44 | 17.94 | 44.94 | 89.94 |
| $(C/N_0)_{thr}$ [dB-Hz] | 122.1 | 114.5 | 110.0 | 104.0 | 100.5 | 98.1 | 90.1 | 84.2 |
| ISD_{thr} [m] for TR 37.873 PL model [13], $F_c = 800$ MHz | 221.5 | 494.5 | 789.0 | 1000.0 | 1000.0 | 1000.0 | 1000.0 | 1000.0 |
| ISD_{thr} [m] for TR 37.873 PL model [13], $F_c = 1800$ MHz | 106.0 | 236.5 | 377.5 | 705.5 | 1000.0 | 1000.0 | 1000.0 | 1000.0 |
| ISD_{thr} [m] for TR 37.873 PL model [13], $F_c = 2600$ MHz | 75.5 | 169.5 | 270.0 | 505.0 | 729.0 | 937.5 | 1000.0 | 1000.0 |
| ISD_{thr} [m] for TR 36.942 PL model [12], $F_c = 2000$ MHz | 34.0 | 54.5 | 71.5 | 103.5 | 128.0 | 148.5 | 243.5 | 349.5 |


 Fig. 5. HDOP of an assisted driving scenario with $ISD = 100$ m.

where the geometry matrix \mathbf{D} is defined by the Jacobian of \mathbf{x} ,

$$\mathbf{D} = \begin{bmatrix} \frac{x-x_1}{d_1} - \frac{x-x_2}{d_2} & \dots & \frac{x-x_1}{d_1} - \frac{x-x_M}{d_M} \\ \frac{y-y_1}{d_1} - \frac{y-y_2}{d_2} & \dots & \frac{y-y_1}{d_1} - \frac{y-y_M}{d_M} \end{bmatrix}^T, \quad (9)$$

and the covariance matrix \mathbf{R} is computed using the CRB for TDE from (6) as

$$\mathbf{R} = \begin{pmatrix} \sigma_1^2 + \sigma_2^2 & \sigma_1^2 & \dots & \sigma_1^2 \\ \sigma_1^2 & \sigma_1^2 + \sigma_3^2 & \dots & \sigma_1^2 \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_1^2 & \sigma_1^2 & \dots & \sigma_1^2 + \sigma_M^2 \end{pmatrix}. \quad (10)$$

As it can be noticed in (9) and (10), one of the BSs is considered as a reference, which is the serving or most powerful BS. Then, the geometry matrix is used to calculate the HDOP as [23, p.149]

$$HDOP = \sqrt{\text{tr}\{(\mathbf{D}^T\mathbf{D})^{-1}\}}. \quad (11)$$

The HDOP for an assisted driving scenario with $M = 4$ and $ISD = 100$ meters is shown in Figure 5. Very good HDOP can be found with values between 1 and 3 for the vehicles locations defined in Figure 1.

IV. SIMULATION RESULTS OVER VEHICULAR CHANNELS

This section is aimed to complete the feasibility study on 5G-based localization by means of numerical results with multipath channels for vehicular scenarios. For this purpose, 5G-like multicarrier signals, such as LTE PRS, are used to assess the achievable positioning capabilities for assisted driving. Considering the performance limits shown in the previous section, the simulations consider a vehicle moving at a speed of 100 km/h over a highway, following the scenario defined in Figure 1 with the parameters in Table I. The network design chosen is based on a high-density of low power BSs, i.e., $ISD = 100$ meters and $P_{max} = 25$ dBm. This transmit power is much smaller than the maximum power initially considered in Figure 4 and Table II, thus the simulation results are more realistic. The height of the BSs is 10 meters, and the

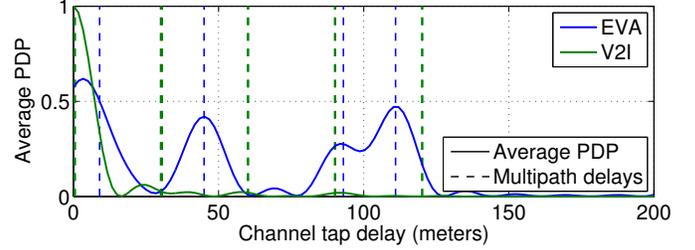


Fig. 6. Average PDP of EVA and V2I channel models for 20-MHz bandwidth.

height of the vehicle antenna is assumed to be negligible. The propagation path loss are based on the 3D-UMa LoS model in [13] for a low carrier frequency, i.e., $F_c = 800$ MHz. Shadow fading is not considered, and multipath channel is introduced using TDL models.

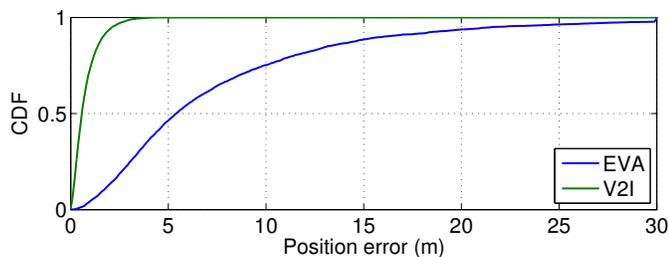
The TDE is implemented with a threshold-based estimator, such as in [21], in order to mitigate the effect of multipath. This estimation is based on finding the first peak of the correlation between the received signal and the PRS. The threshold is set to 13 dB (i.e., minimum SNR margin in LTE for neighbour cell detection) below the maximum peak of the correlation function. The PRS periodicity is set to 160 ms, thus 1800 ToA measurements are obtained for 90 positioning occasions. The dynamic scenario is repeated 50 times. The position is estimated using four BSs, i.e., $M = 4$, with the non-linear least squares (NLS) method, which is implemented with the Gauss-Newton algorithm [24].

A. Assessment of vehicular TDL channel models

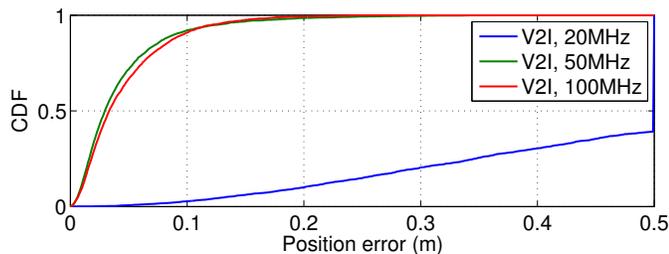
Vehicular TDL channel models are used in this paper to assess the multipath impact on the positioning performance for assisted driving. The standard extended vehicular A (EVA) model defined in [11] and the roadside-to-mobile (RTM) or V2I expressway model defined for 802.11p networks in [17] are considered. The delay spread of the EVA and V2I models is equal to 2510 and 401 ns, respectively. For sake of simplicity, a rounded Doppler spectrum is assigned to every path in the V2I model. Considering a system bandwidth of 20 MHz, the average power delay profile (PDP) is shown for both models in Figure 6. As it can be seen, the V2I model is more suitable for highway scenarios than the EVA model, because of the predominant energy close to the LoS. However, none of these models include distance-dependent LoS conditions.

B. Achievable localization accuracy in V2I multipath channels

The positioning performance is assessed with the cumulative density function (CDF) of the position error obtained with these multipath channels. As it is shown in Figure 7(a), with a system bandwidth of 20 MHz, the position accuracy



(a) EVA and V2I models for 20 MHz



(b) V2I model for 20, 50 and 100 MHz

Fig. 7. Position accuracy for EVA and V2I channel models using high signal bandwidths.

for the EVA model is higher than 20 meters for the 95% of the cases, while the accuracy for the V2I model is below 5 meters. Still, centimetre-accuracy cannot be achieved with 20 MHz of bandwidth. Thus, the bandwidth is increased up to 50 and 100 MHz, by considering coherent TDE with CA. As it is shown in Figure 7(b), the position accuracy achieved with 50 and 100 MHz is below 25 and 20 cm in the 99% of the cases, respectively. Therefore, assisted driving with accuracies below 30 cm are possible with high signal bandwidths, i.e., 50 and 100 MHz. The ultimate position accuracy is limited by NLoS conditions, which induce a multipath bias even if the signal bandwidth is further increased. Future work is aimed to use GBSM to further assess the impact of distance-dependent LoS probability for 5G assisted driving.

V. CONCLUSION

This paper has studied the feasibility to provide 5G-based localization for assisted driving applications. The challenge of providing centimetre-accurate positioning is faced by optimizing the network design in a highway scenario. A methodology to design 5G networks for precise positioning is proposed. Positioning performance limits are then obtained with 5G-like multicarrier signals, in order to assess the achievable localization accuracy in 5G networks. Simulation results with vehicle-to-infrastructure (V2I) multipath channel models show a position accuracy below 25 and 20 cm for 50 and 100 MHz of system bandwidth in the 99% of the occasions. Therefore, centimetre-accurate positioning is possible for assisted driving by using high signal bandwidths, i.e., 50 and 100 MHz. Further assessment of distance-dependent LoS probability with advanced multipath channel models is left for future work.

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