Study of Dominant Path Probability

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Abstract **– 3GPP has begun a study item to define the 5G channel models. It has been proposed that the 3GPP 3D channel model will be extended for 5G by defining a number of new features and channel model parameters for higher frequencies. We conduct a simulation study to investigate dominant path probabilities. We consider the Madrid grid of the map based METIS model and propose some modifications for the probability of dominating propagation paths such as line of sight, ground reflection and specular reflection.**

Index Terms **— Propagation, stochastic LOS model, LOS probability.**

1. Introduction

The envisioned fifth generation (5G) systems require new and updated channel models. The current 3GPP 3D channel model [2] does not support all requirements for 5G. Key requirements for 5G channel models are listed in [3], [4]. We focus on line-of-sight (LOS), ground reflection and single specular reflection probabilities. Models for these probabilities will be of particular importance for millimeter wave (mmW) communications where the signal power is typically low. Antenna arrays are considered to steer towards these dominating paths. To do system simulations, design the future 5G mmW interface and decide on cell sizes, we require realistic models for occurrence of these dominant propagation paths. We conduct a Monte Carlo simulation study and compare our results to the 3GPP 3D LOS-probability model [2]. We observe for our considered scenarios that some parameters and the model itself require adjustment.

2. LOS and Specular Reflection Probability

We consider a simulation study to investigate the probability of i) LOS, ii) ground reflection and iii) wall reflection versus the distance between base station (BS) and user equipment (UE). In this study we utilize the METIS Madrid grid [3] shown in Fig. 1(a). We place the BS and UE randomly. We distinguish between urban macro (UMa) and micro (UMi) scenarios based on different BS placements within the Madrid grid. For these scenarios we investigate the distance dependent probability and compare it with the proposed model in 3GPP [2] and its settings.

(1) *Simulations of UMi – Street Level and UMa*

For simplicity we consider two nodes A and B. We sweep in steps of 1m over a distance range between Node A and B from 1m to 300m corresponding to the distance between BS and UE. For each distance, we drop node A uniformly in the x-y plane of the Madrid grid. For the considered distance we randomly select a direction between 0 and 360 degree towards node B. For the given placement of A and B, we consider the following classification into scenarios:

- If none of the nodes are placed within the boundaries of a building, we consider the placement as a valid UMi – street level scenario. A height of 1.5m is considered for both nodes.
- If only one of the nodes is placed within the boundaries of a building, this node is considered as a BS and is elevated to 10m above rooftop. The height of the other node is 1.5m. This is classified as a UMa scenario.
- If both nodes are placed within the boundaries of buildings, the drop is invalid.

We generate for each distance 10000 valid realizations of both scenarios. For each realization we investigate if there are LOS, ground reflection and specular reflection paths and evaluate their probability.

(2) *Simulations of UMi – Square*

In this case we fix the location of node A in the center of the square at coordinate x=207m, y=345m and z=28m of the Madrid grid. Node B is obtained similarly as in Section (1) for each distance and by randomly selecting directions to node B. Again we evaluate the three types of propagation paths and their respective probabilities from 10000 realizations. Note that our investigation differs from [5]. In [5] a grid of fixed locations in the square was considered to obtain an averaged probability from all locations for the square.

(3) *Simulations of UMi – Below Rooftop*

For node A we select randomly one of the fifteen buildings in the Madrid grid and subsequently select randomly one of the four walls. On the selected wall we place node A randomly and fix its height to 28m. For node B we consider the same placement procedure as before. We reject the placement of node B inside a building and draw new random realizations until 10000 allowed placements are obtained.

3. Results and Discussion

For the UMa scenario the results are presented in Fig. 1(b). As the BS is placed randomly on the rooftop, the roof edge blocks some regions. Consequently, a LOS–probability of one predicted by the 3GPP model as the distance between the stations approaches zero cannot be observed.

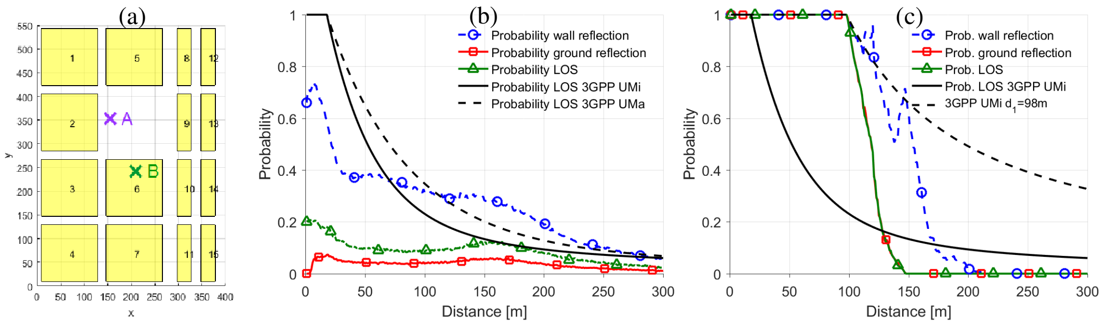

Fig. 1: (a) METIS Madrid grid and placement of nodes A and B. According to our classification, this is a UMa scenario. Node B is the BS at 10m above rooftop. Node A is the UE with 1.5m height. (b) Probabilities versus BS – UE distance in the UMa case. (c) Probabilities versus BS – UE distance in the UMi – open square case.

At very close distances we observe zero probability for ground reflection for the same reason. We observe that the simulated LOS–probability is much lower than predicted by the 3GPP model. For mmW beamforming the system will have to rely mainly on the specular reflection for such a placement. Diffracted propagation paths via the rooftop edges at mmW frequencies are strongly attenuated and thus the system cannot rely on these paths in comparison to <6GHz frequencies.

The results for the UMi street level scenario are not presented as the 3GPP model can represent them well with some minor parameter adjustments. Noticeable is however that for short distances we do not obtain probability one for the specular reflections (only approx. 0.9). This is due to possible placement of both nodes in areas like street crossings where no specular reflections can occur. In this scenario, LOS and ground reflection probability are the same as no rooftop edges block the ground reflection.

We fixed for the open square scenario the BS (node A) at the center of the square. The results for this case are shown in Fig. 1(c). We observe that the break-off distance from probability one is highly related to the size of the square and where the BS is placed. This distance should be much larger than the “standard” value in [2]. Due to the construction of the model in [2] adjusting the break-off distance to such a large value affects the possible decay rate, see Fig. 1(c). In fact we cannot adjust the rate to the observed one.

The results for the UMi – below rooftop case are not shown due to space restrictions. We observe a similar behavior as for the UMi – street level except that the value for the probability of specular reflections is only approx. 0.7.

The LOS probability model, together with a 2 dimensional uniformly distributed random process allows generating spatially consistent maps for LOS, ground reflection and specular reflection [6] with appropriately adjusted parameter settings.

4. Conclusion

This paper discussed the probabilities of dominant paths such as LOS, wall reflection and ground reflection.

In general we observe that the LOS probability model of 3GPP is applicable as well for ground reflections and specular reflections. However, the parameters need adjustment for these paths, in particular the specular reflection path. The parameter values depend on the considered Madrid grid with its specific street widths, sizes of building blocks, and the open square. A more elaborate simulation with various city layouts is required for standardization.

In the UMa case, the random placement on top of the building leads due to blockage by the rooftop edges to lower LOS probability than proposed by the standard settings by 3GPP.

The open square scenario, where we did not consider spatial averages over multiple BS locations, requires a modified model to adjust for the larger break–off distance.

Spatially consistent LOS and reflection probability can be obtained by combing the map based LOS with a random process.

References

[1] 3GPP RP-151606, “New SID Proposal: Study on channel model for frequency spectrum above 6 GHz”, 3GPP TSG RAN Meeting #69, Phoenix, USA, 14 – 16 September 2015.

[2] Study on 3D channel model for LTE, 3GPP TSG RAN, TR 36.873, September 2014.

[3] ICT-317669 METIS project, “METIS Channel Models”, Deliverable D1.4, April 2015, https://www.metis2020.com/documents/deliverables/

[4] NTT DOCOMO, CMCC, Ericsson, Huawei, HiSillicon, Intel, KT Corporation, Nokia, Qualcomm and Samsung, “Channel modeling for higher frequency bands”, RP-151306, 3GPP TSG RAN Meeting #69, Phoenix, USA, 14 – 16 September 2015.

[5] J. Jarvelainen et al., “Evaluation of Millimeter-wave Line-of-Sight Probability With Point Cloud Data,” in *IEEE Wireless Communications Letters* , vol.PP, no.99, pp.1-1

[6] ZTE, “To maintain spatial consistency in LoS/NLoS decision”, R1-161646, 3GPP TSG RAN WG1 #AH Channel Model, Ljubljana, Slovenia, March, 2016.