Coverage Estimation and Performance Analysis of 5G over Millimeter Waves

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Abstract— **The use of millimeter waves (mmWave) provides high data rates in 5G due to the higher bandwidths available. However, signal coverage may be limited by several factors, including atmospheric conditions. This paper evaluates the performance of 5G over mmWave. Simulations are carried out aiming to provide an estimation of signal coverage in two bands, i.e., 28 GHz and 39 GHz, over scenarios of Line-of-side (LOS) and Non line-of-side (NLOS). The results of this study attest to the higher sensitivity of mmWave 5G and show that, to ensure acceptable performance, indoor applications through Picocells, whose coverage radius does not exceed 150m are recommended.**

5G, mmWaves, performance, coverage.

I. INTRODUCTION

Long Term Evolution (LTE) has brought great improvements to mobile networks in terms of data rates, connectivity and user Quality of Experience (QoE). However, LTE does not meet the new requirements, e.g., higher bandwidths, ultra-low latency, massive connectivity, and reliability demands for future generation networks [1]. In turn, 5G provides at least ten times higher data rates and much lower latency than LTE. Thus, more reliable transmissions and higher end-users connection density will be possible with 5G networks. To ensure such technological advances to be implemented, it is required to deploy a wider spectrum in frequency bands above 6 GHz, such as the mmWave, which compose the Frequency Range 2 (FR2).

Millimeter wave spectrum covers bands from 24 GHz up to around 300 GHz and, it's usage has been proposed to improve 5G technology. Several benefits can be provided by mmWave in terms of data transmission, due to available higher bandwidths of up to 400MHz. However, mobile operators have many challenges to deploy 5G in mmWave due to the smaller signal coverage and lower penetration rate. Then, the complexity of deployment and coverage design for 5G using mmWaves may impact the system performance [2]. Several studies on the performance of 5G over mmWave were presented in the literature. In [3], authors propose a cross-layer framework for analyzing performance of mmWave 5G. Blocking probability, mean service time of user requests, and utilization rate of base stations are evaluated based on stochastic geometry, teletraffic models, and the classical Erlang Fixed Point Approximation method. In [4], the performance of TCP protocols is analzyed over mmWave 5G. Three performance parameters are considered, i.e., roundtrip time, congestion and throughput. Also, the uplink of millimeter-wave massive MIMO 5G is invetigated in [5]. System performance according to the separation distances and number of transmit to receive antennas is analyzed.

Different from aforementioned works, this paper provides an analysis of 5G by assessing the performance of throughput (THP) and error vector magnitude (EVM). Different levels of received signal power are considered for emulating different scenarios, e.g., bad, good and excellent signal quality. Also, the 5G coverage estimation is performed for both $n260$ (39 GHz) and $n261$ (28 GHz). The results presented in this work may provide insights to operators for better planning of 5G signal networks.

II. ANALYSIS METHODOLOGY

The analysis presented in this work is performed through simulations developed using Python. First, we estimate the coverage of 5G using a propagation model to calculate the pathloss of the transmission channel in frequency f. The methodology adopted consists of:

- Define vector with typical values of Reference Signal Received Power (RSRP) at the user equipment (UE);
- Use defined RSRP values for calculating the pathloss (PL) as $\mathrm{PL} = \mathrm{P_T} - \mathrm{RSRP}$, where $\mathrm{P_T}$ is the transmission power;
- Use the calculated *PL* values as inputs of the propagation model to estimate the 5G coverage distances (d).

In this case, the Urban Macrocell (UMa) model, given by Equation 2 [6], is adopted.

$$\mathrm{PL}[dB] = \mathrm{FSPL} + 10 \times \mathrm{n}\log_{10}(d/1m) \tag{1}$$

where, $\mathrm{FSPL}[dB] = 20 \times log_{10}(4\pi f/c)$ is the Free Space Propagation Loss and n is the pathloss exponent.

Then, the coverage distance d is given by Equation 2.

$$d[m] = e^{(PL - \mathrm{FSPL})/10n} \tag{2}$$

For the performance analysis of 5G, two metrics are considered, i.e., end-user THP and EVM. In case of THP calculation, Equation (3) is considered, according to [8], in which details on equation's parameters are provided. Note that Q_m is the modulation scheme, which varies according to the Signal to noise ratio (SNR).

$$\mathrm{THP} = 10^{-6} \times \sum_{j=1}^{J} \left\{ v_{layers}^{j} \times Q_m^j \times F^j \times R_{max} \frac{12 \times N_{PRB}^{BW(j),\mu}}{T_s^{\mu}} \times \left[1 - OH^{(j)}\right] \right\} \tag{3}$$

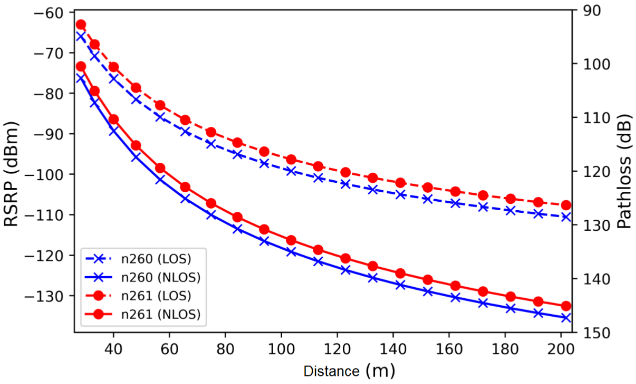

Fig. 1. RSRP/PL versus distance in LOS/NLOS environments.

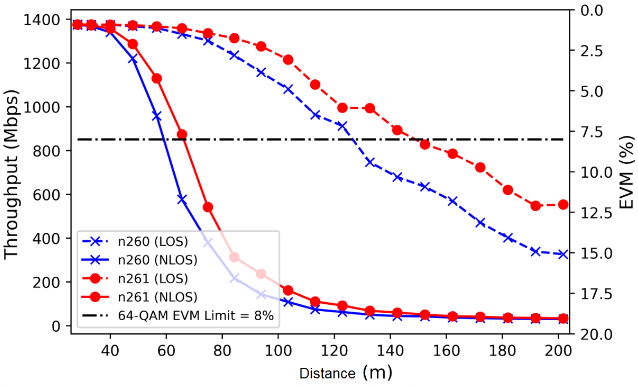

Fig. 2. Throughput/EVM versus distance for 64-QAM modulation.

In turn, EVM is computed by using Equation (4) of the Modulation Error Ration (MER), which is the relation between EVM and SNR [7].

$$\text{SNR} = -[3.7 + 20 \times log_{10}(\text{EVM}/100\%)] \qquad (4)$$

The simulation parameters are presented in Table I.

TABLE I

SIMULATION PARAMETERS.

Parameters	**Values**
Transmission Bands	n260 (39 GHz) and n261 (28 GHz)
Nr of transmitters, nr of users	1
Signal Bandwidth	400 MHz
5G Pathloss Model	UMa LOS/NLOS
Transmit Power (P_T)	25 dBm
Transmission scheme	SISO
RSRP	[-140 dbm up to -60 dBm]
pathloss exponent (n)	2 (LOS) and 3 (NLOS)
T_s^{μ}, R_{max}, OH	$8.928{\times}10^{-6}, 0.925, 0.18$
J, v_{layers}, F	1
Subcarrier Spacing	120 kHz
Modulation	64-QAM

III. RESULTS AND DISCUSSIONS

Figure 1 presents the relation between RSRP and distance between the UE and 5G base station in LOS and NLOS scenarios. As expected, RSRP received by UE varies due to distance, transmission frequency, and presence of obstacles. For greater distances and higher frequency, lower RSRP is achieved due to signal attenuation. For n260 band, RSRP varies around -75dBm and -66dBm, for distances of 30m. However, RSRP tends to decrease exponentially to around -140 dBm and -108 dBm, for NLOS (solid blue) and LOS (dashed blue), considering distance of up to 200 m. On the other hand, for the n261 band, RSRP varies around -135dBm and -64dBm, for distances of around 30m and, as in previous case, RSRP tends to decrease exponentially to around around -135 dBm and -102 dBm for distances up to 200 m. Note that, depending on the separation distance, the RSRP difference between LOS and NLOS may reach around 20dB. Also, the RSRP difference between n260 and n261 can be around 5dB.

Figure 2 shows the variation of THP and EVM due to the separation distance. For distances below 40m, maximum THP of 1400Mbps is achieved regardless of the scenario. In the case of LOS, although THP decreases due to distance increase, 5G operates with EVM below 8% (EVM threshold for 64 QAM modulation) up to 130m and 150m, for n260 and n261, respectively. On the other hand, in the case of NLOS, higher THP decrease is observed due to the rapid increase of EVM, which reaches 8% at distances of only 60m and 70m, for n260 and 261, respectively.

IV. CONCLUSION

This paper analyzed the performance of 5G over mmWaves and estimated the coverage distances. Two frequency bands, i.e., 28 GHz and 39 GHz were considered to assess Throughput and EVM, through simulations. The results of this study attested the sensitivity of 5G in mmWave through the reported smaller coverage distances. Basically, to ensure acceptable performance of 5G in mmWave with quality of service, indoor applications with Picocells whose coverage radius does not exceed between 50 and 150m for NLOS and LOS scenarios, respectively, are recommended. For future works, the presented results will be compared to lab experiments, which are in progress.

ACKNOWLEDGMENTS

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