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Comparison of System Capacity between the Millimetre Wavebands and sub-6 GHz Bands in Small Cell 5G Networks

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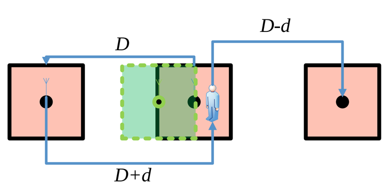
Background and challenges

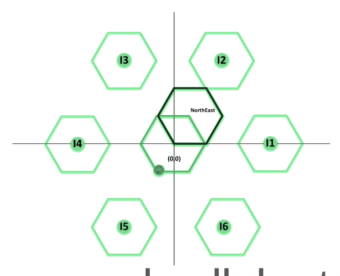
- This work explores essential characteristics of mapping between the average Signal to Interference plus Noise Ratio (SINR) and the supported throughput in a framework of 5G NR Small Cell Networks

Description and main innovation

- Six different frequency bands are considered, ranging from 2.6 GHz in the Ultra High Frequency (UHF) band (FR1) to 73 GHz in the millimetre wave bands (mmWaves) (FR2), using both single-slope and two-slope path-loss models, through an implicit formulation approach that considers the mapping between values for the SINR and Modulation Coding Schemes to acquire values for the PHY throughput. The technical specifications given by Release 15 of the 3rd Generation Partnership Project for 5G NR are followed, while considering a bandwidth of 20 MHz that yields a total of 24 PRBs with 60 kHz SCS for FR1 and for FR2 a bandwidth of 100 MHz that yields a total of 66 PRBs with 60 kHz SCS.



Linear cellular topology



Hexagonal cellular topology

$$P_{LUMiLoS}(d) = 22 \cdot log10(d_{[m]}) + 36.29947, d < 156 \text{ m}$$

$$P_{LUMiLoS}(d) = 40 \cdot log10(d_{[m]}) - 3.12788, d \geqslant 156 \text{ m}$$

$$P_{LUMiNLoS}(d) = 36.7 log10(d_{[m]}) + 33.48$$

UMi LoS outdoor scenario with two-slope model, and UMi NLoS propagation models for UHF/SHF

$$d_{BP} = 4 \cdot h'_{BS} \cdot h'_{UT} \cdot f_c / c$$

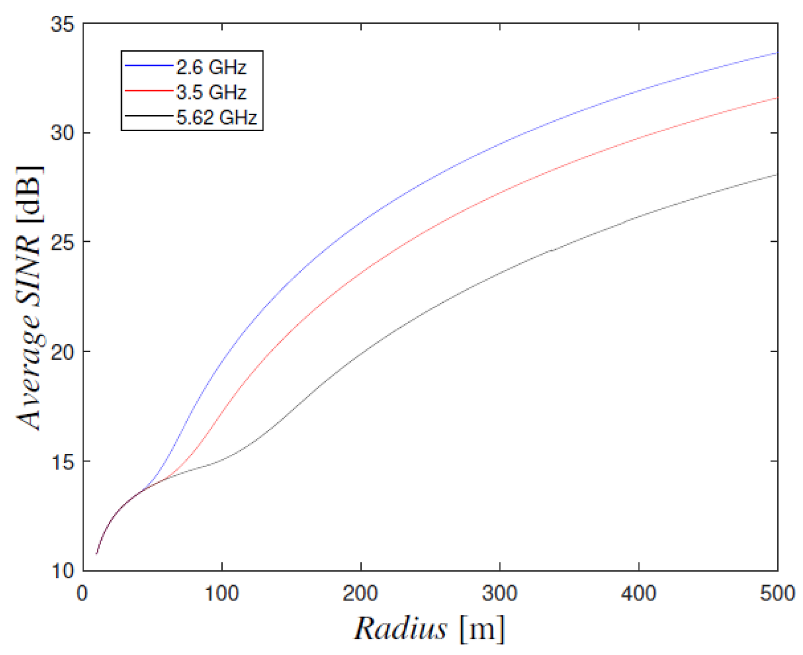
f_c is the centre frequency, in Hertz, c=3.0 x 108 m/s is the propagation velocity in free space. The d_{BP} UMi LoS =156 m

$$PL_{LoS}\ [dB](d) = 20 log_{10}\left(\frac{4\pi}{\lambda}\right) + \bar{n} 10 log_{10}\ (d) + X_\sigma, d \geqslant 1m$$

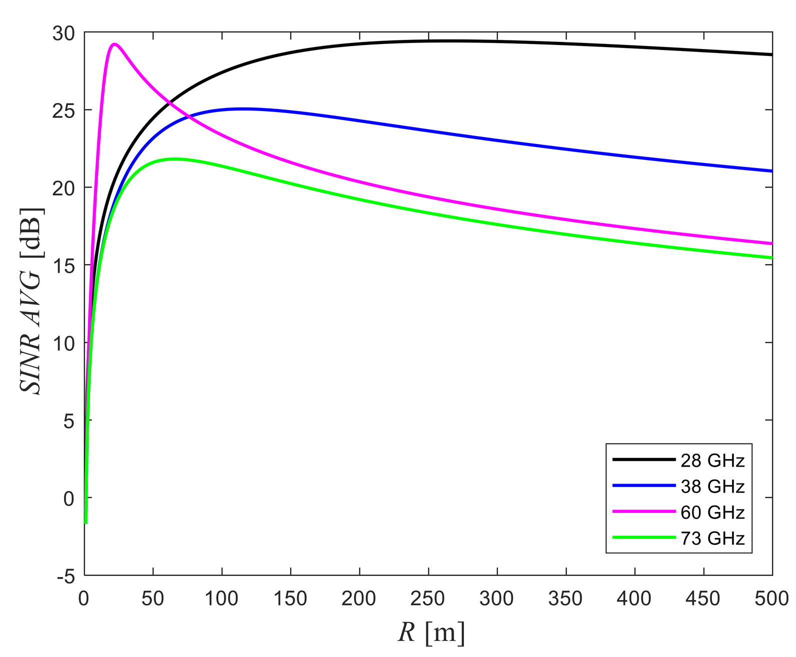
Friis propagation models for Millimetre Wavebands, where Xσ is the typical log-normal random variable with 0 dB mean and standard deviation σ, in decibels, and models shadow fading.

PARAMETERS CONSIDERED IN THE ANALYSIS

Band	mmWaves	2.6 GHz	3.5 GHz	5,.62 GHz
Transmitter Power (DL) dBW	-16.9897	-7	-4.7522	-0.3047
Transmitter gain	5 dBi	5 dBi	5 dbi	5 dBi
Receiver gain	0 dBi	0 dbi	0dbi	0 dBi
Bandwidth	100 MHz			
Noise Figure	7 dB			
Height (BS)	9 m			
Height (User Equipment)	1.5 m			



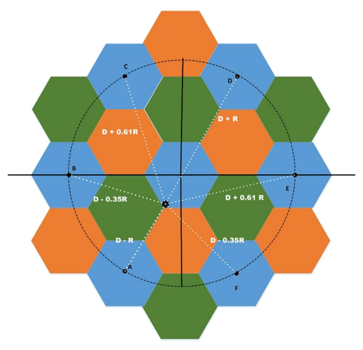
Variation of Average SINR with the distance d for the 2.6, 3.5, 5,62 GHz frequency bands and R = 500 m.

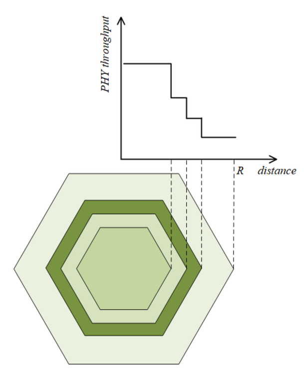


Variation of SINR with the distance d for the 28, 38, 60 and 73 GHz frequency bands and R = 500 m.

$$SINR(P_{tx}, x, y) = \frac{P_{OW}(P_{tx}, x, y)}{(1-\alpha)P_{OW}(P_{tx}, x, y) + P_{nh}(P_{tx}) + P_{Noise}}$$

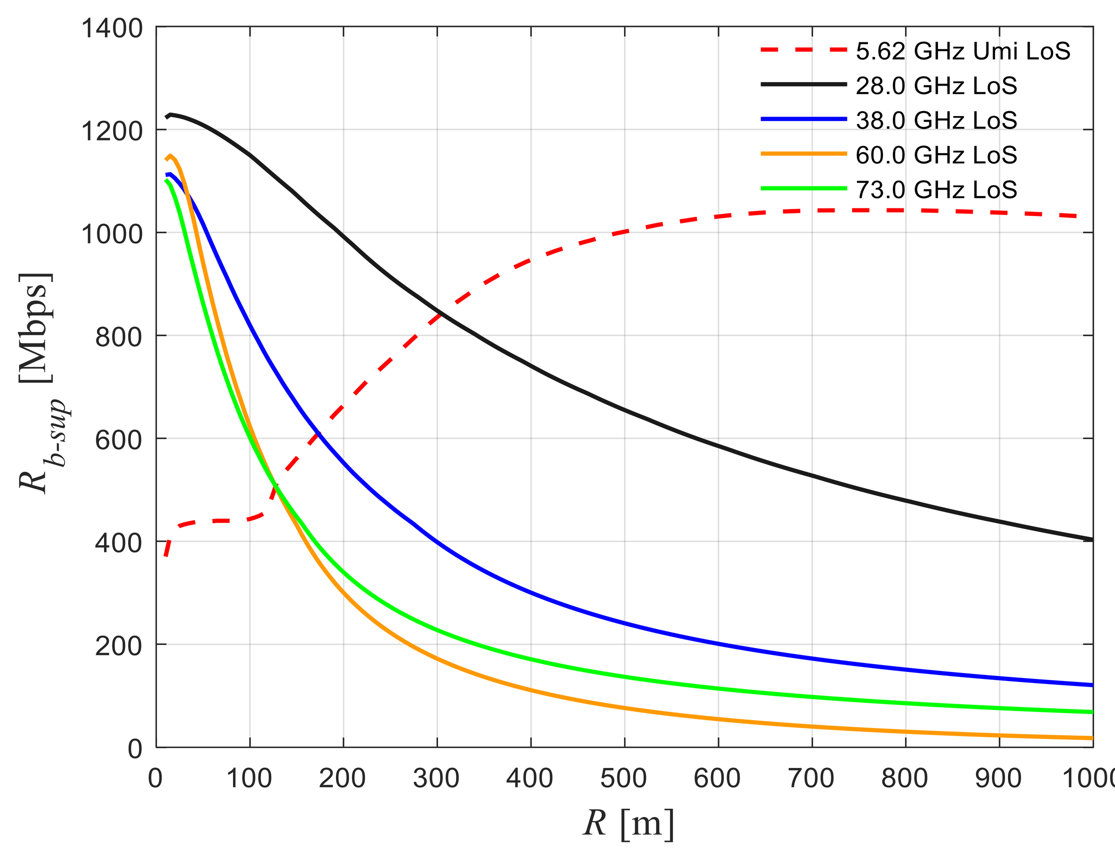
Signal-to-interference-plus-noise ratio





$$R_{b\_sup} = \sum_{i=1}^{n} \frac{R_{b_i}(d_i^2 - d_{i-1}^2)}{R^2}$$

Supported throughput



Variation of the supported throughput for 2.6 GHz, 3.5 GHz, 5.62 GHz, 28 GHz, 38 GHz, 60 GHz, 73 GHz frequency bands and R = 1000 m.

- By analyzing the results, one concludes that there is a one-to-one correspondence between the average SINR and the supported throughput, with an enhanced behaviour for cell radii longer than the ratio between the breakpoint distance and the co-channel reuse factor.
- The signal-to-interference-plus-noise ratio, as estimated with the more realistic two-slope model, is lower for devices that are within the break-point of the transmitter, which is a small distance in the UHF/SHF band. Correspondingly, spectral efficiency is higher with mmWaves than with UHF/SHF spectrum when cell radius is under 40 meters but not when cells are larger. Accordingly, mmWaves spectrum will be more appreciated as cells get small, also the capacity as estimated with the two-slope model is noticeably smaller than one would obtain with the one-slope model once cells are small but there is little variance in the models when cells are larger. Therefore, as cells become smaller, the use of one-slope models may undervalue the number of cells that must be deployed. [1][2][3]

[1] E. Teixeira, S. Sousa, F. J. Velez and J. M. Peha, "Impact of the propagation model on the capacity in small-cell networks: Comparison between the UHF/SHF and the millimeter wavebands," in Radio Science, vol. 56, no. 5, pp. 1-13, May 2021, doi: 10.1029/2020RS007150.

[2] **E. Teixeira, F. J. Velez, Jon Peha "Economic Trade-off of Small Cell Networks: Comparison Between the Millimetre Wavebands and UHF/SHF Bands," accepted in 2019 IEEE 30th Annual International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC)**

[[3] **Emanuel B. Teixeira, Anderson R. Ramos, Marisa S. Lourenco, Fernando J. Velez, Jon M. Peha, "Cost Benefit Analysis: Evaluation Among the Millimetre Wavebands and SHF Bands of Small Cell 5G Networks," ICEEE 2020: International Conference on Electronics and Electrical Engineering, Toronto, Canada, July 2020.**

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