# Predicting Interference in 5G Networks using NetSim

# Objective

In this experiment, we will simulate and study the impact of downlink interference on the signal-to-interference ratio (SINR). We explore a simple case. A UE starts from and moves in a straight line to . While the UE is attached to it experiences interference from . Once it gets handed over to the UE experiences interference from . There is always thus only one interferer, and we analyze the SINR as the UE moves a straight line from to .

Diagram

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Fig 1: UE1 is initially attached to BS1. The signal from BS1 is the desired signal while the signal from BS2 is the interfering signal. Post-handover desired signal is transmitted from BS2 while signal from BS1 is the interfering signal. We assume omni-directional antennas at both BSs and consider cases when the UE is in line-of-sight (LOS) and in non-line-of-sight (NLOS)

# Introduction[[1]](#footnote-1)

Due to the scarcity of the wireless spectrum, it is not possible in 5G networks to separate concurrent transmissions completely in frequency. Some transmissions will necessarily occur at the same time in the same frequency band, separated only in space, and the signals from many undesired or interfering transmitters are added to the desired transmitter’s signal at a receiver.

The main determinants of the interference are

* The network geometry i.e., the location of the receivers and the locations of the transmitters
* Base stations’ (or gNBs’) transmit power, and
* The path loss model (signal attenuation with distance).

The performance and coverage of a 5G network is critically depends on the signal-to-interference-and-noise ratios (SINRs) level at the receivers. This is defined as

Where is the received power of the desired signal, is the bandwidth, is the thermal noise and is the received power of interfering signals.

In 5G, the modulation and coding scheme (MCS) is computed from the SINR. Higher the SINR higher the MCS, and hence higher the date rate. Interference is therefore an important performance-limiting factor in wireless networks and hence it is crucial to exactly characterize interference.

# Network setup: ISD = 500m, C Band, 100 MHz, Urban Macro.

In our network scenario, the inter-site distance (ISD) between and is 500m. Both base stations operate in the 3.5 GHz band, commonly called the C band, with a bandwidth of 100 MHz. The environment is assumed to be urban with signal attenuation per the 3G PP Urban Macro pathloss model. Shadow-fading and fast fading are turned off to avoid sources of randomness.

# Case #1: No interference in both base stations with LOS

## Procedure:

In this section we explain how users can run the simulation and obtain results that match those provided in the document [GitHub link](https://github.com/NetSim-TETCOS/5G_Experiments_v13_2_20/archive/refs/heads/main.zip%20)

1. Use the following download Link to download the workspace
2. Go to NetSim Home window, go to Your Work and click on Import.

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Fig 2: NetSim Home Window

1. In the Import Workspace Window, browse and select the 5G\_Advanced\_IISC\_experiment\_v13.2.20.netsimexp file from the downloads. Click on create a new workspace option and browse to select a path in your system where you want to set up the workspace folder.
2. Choose a suitable name for the workspace of your choice. Click Import.

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Fig 3: Import the downloaded workspace

1. The Imported Project workspace will automatically be set as the current workspace.
2. The list of experiments is now loaded onto the selected workspace.
3. The Experiments/ configuration files associated with the case mentioned above are available in the folder “ISD\_500m\_C-Band” inside the workspace.

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Fig 4: NetSim your work window with list of cases for ISD 500m C-band.

## Network Scenario

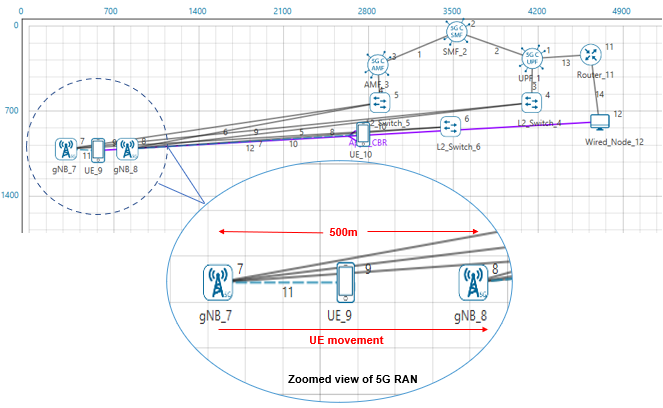


Fig 5: NetSim Scenario.

## Simulation parameters:

Consider the grid environment as 7000m. Place the two gNBs on the grid environment. Distance between two gNBs is 500m.

|  |  |  |
| --- | --- | --- |
| **Devices** | **X** | **Y** |
| gNB\_8 | 800 | 1000 |
| gNB\_7 | 300 | 1000 |
| UE\_9 | 300 | 1000 |
| UE\_10 | 300 | 1500 |

Table 1:Device Co-ordinates

Go to gNB properties. In the RAN interface set physical layer properties as shown in the below table. Similarly set the same properties in another gNB.

|  |  |
| --- | --- |
| gnb> Interface 5G RAN | |
| gNB Height (m) | 10 |
| Tx Power (dBm) | 40dBm |
| Tx Antenna Count | 1 |
| Rx Antenna Count | 1 |
| CA Type | Single Band |
| CA Configuration | n78 (C Band) |
| F\_Low (MHz) | 3300 |
| F\_High (MHz) | 3800 |
| DL: UL Ratio | 4:1 |
| Numerology | 2 |
| Channel Bandwidth (MHz) | 100MHZ |
| MCS Table | QAM64 |
| CQI Table | TABLE1 |
| Outdoor Scenario | Urban Macro |
| Indoor Office Type | Mixed Office |
| Path loss Model | 3GPPTR38.901-7.4.1 |
| LOS Mode | User Defined |
| LOS probability | 1 |
| Shadow Fading Model | None |
| Fading and Beamforming | No Fading |
| O2I Building Penetration Model | None |
| Downlink interference model | No interference |

Table 2: Values set for different parameters in simulation

Go to UE properties. In the RAN Interface set physical layer properties in both UE’s as shown below.

|  |  |
| --- | --- |
| UE > Interface 5G RAN | |
| UE Height | 1.50 |
| Tx Power | 23 dBm |
| Tx Antenna Count | 1 |
| Rx Antenna Count | 1 |

Table 3: Properties set for UE

In the General layer, set UE X and Y coordinates of gNB X and Y coordinates. The initial position of UE must be the position of gNB1.

Set the mobility model as file-based mobility and configure the mobility that UE needs to be travel straight towards to the gNB2. So, configure the mobility file according to the distance that UE needs to travel

For example, in the above scenario 500m case, UE needs to travel 500m from gNB1 to gNB2 So, it is travelling straight towards to another gNB since it’s Y coordinates is fixed.

Run the Simulation 12s. Upon running the simulation, a text file will open for the user to input the parameters and devices (tx-rx pair) for which parameters need to be logged and plotted. Give input as shown in Fig 6

|  |  |
| --- | --- |
| **A picture containing background pattern  Description automatically generated**  Fig 6: UE mobility file for 500m | Fig 7: Input file for logging and plotting |

After simulation, open 5G\_Prameter\_Log present under the Log files section in Result Dashboard.

Table

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Fig 8: ISD 500m simulation result Dashboard

|  |  |
| --- | --- |
| Table  Description automatically generated  Fig 9: 5G LTE Parameter log file | Table  Description automatically generated  Fig 10: Inserting pivot table |
| Fig 11: Creating pivot table | |

In the log file create one more column after UE\_y column and enter the formula in first row of that log file as shown in Fig 8 and create a pivot table for this log file by clicking the pivot option present at the top of the ribbon under insert section as shown in Fig 9

In the pivot table drop gNB/eNB Name, UE Name, Channel and IsAssociated field under filters area, drop column1 in Row area and drop SINR in Value area. set SINR values to max by clicking arrow icon present end of the field ->value filed setting->max as shown below as shown in Fig 10

Now filter gNB as gNB7, UE name as UE\_9, Channel as PDSCH and IsAssociated as TRUE as shown in Fig 11.

Copy the values from 0 to 280 along with Row Labels and Max\_SINR\_dB header and paste it into another sheet. Similarly filter gNB/eNB name to GNB\_8 and copy the row label value along with SINR and paste it into next to 280 in previously created new sheet as shown in Fig 12.

|  |  |
| --- | --- |
| Fig 12: SINR values for 500m | Fig 13: Downlink SINR results for ISD-500m |

# Case #2: No interference in both base stations with NLOS

|  |  |
| --- | --- |
| gNB7 > Interface 5G RAN | |
| LOS Mode | User Defined |
| LOS probability | 0 |
| Downlink Interference | No Interference |
| gNB 8 > Interface 5G RAN | |
| LOS Mode | User Defined |
| LOS probability | 0 |
| Downlink interference | No Interference |

Table 4: Properties set for Case02

Set the above property changes and simulate the scenario for 15 sec. Tabulate the results obtained from 5G\_Prameter\_Log in simulation metrics window.

# Case #3: UE to Both Base stations is in LOS

|  |  |
| --- | --- |
| gNB7 > Interface 5G RAN | |
| LOS Mode | User Defined |
| LOS probability | 1 |
| Downlink Interference | Exact geometric model |
| gNB 8 > Interface 5G RAN | |
| LOS Mode | User Defined |
| LOS probability | 1 |
| Downlink interference | Exact geometric model |

Table 5: Properties set for Case03

Set the above property changes and simulate the scenario for 12 sec. Tabulate the results obtained from 5G\_Prameter\_Log in simulation metrics window.

# Case #4: UE to Both Base stations is in NLOS

|  |  |
| --- | --- |
| gNB7 > Interface 5G RAN | |
| LOS Mode | User Defined |
| LOS probability | 0 |
| Downlink Interference | Exact geometric model |
| gNB 8 > Interface 5G RAN | |
| LOS Mode | User Defined |
| LOS probability | 0 |
| Downlink interference | Exact geometric model |

Table 6:Properties set for Case04

Set the above property changes and simulate the scenario for 12 sec. Tabulate the results obtained from 5G\_Prameter\_Log in simulation metrics window

# Results. UE in LOS and NLOS

|  |  |  |  |
| --- | --- | --- | --- |
| Distance | Case #2 DL SINR (dB) | Case #3 DL SINR (dB) | Case #4  DL SINR (dB) |
| 0 | 65.59 | 41.44 | 60.27 |
| 10 | 65.59 | 41.09 | 60.03 |
| 20 | 57.03 | 35.91 | 51.21 |
| 30 | 50.90 | 32.10 | 44.82 |
| 50 | 42.65 | 26.7 | 35.99 |
| 60 | 39.62 | 24.61 | 32.67 |
| 70 | 37.05 | 22.76 | 29.79 |
| 80 | 34.82 | 21.09 | 27.22 |
| 90 | 32.84 | 19.56 | 24.90 |
| 100 | 31.06 | 18.13 | 22.77 |
| 110 | 29.46 | 16.79 | 20.80 |
| 120 | 27.99 | 15.51 | 18.95 |
| 130 | 26.63 | 14.29 | 17.20 |
| 140 | 25.38 | 13.11 | 15.53 |
| 150 | 24.21 | 11.96 | 13.93 |
| 160 | 23.12 | 10.84 | 12.39 |
| 170 | 22.10 | 9.75 | 10.90 |
| 180 | 21.13 | 8.67 | 9.45 |
| 190 | 20.21 | 7.6 | 8.03 |
| 200 | 19.34 | 6.54 | 6.63 |
| 210 | 18.52 | 5.49 | 5.26 |
| 220 | 17.73 | 4.18 | 3.90 |
| 230 | 16.98 | 2.78 | 2.56 |
| 240 | 16.25 | 1.39 | 1.22 |
| 250 | 15.56 | 0 | -0.12 |
| 260 | 14.90 | -1.39 | -1.46 |
| 270 | 14.26 | -2.78 | -2.80 |
| 280 | 13.64 | -4.18 | -4.16 |
| 280 | 17.73 | 4.18 | 3.90 |
| 290 | 18.52 | 5.49 | 5.26 |
| 300 | 19.34 | 6.54 | 6.63 |
| 310 | 20.21 | 7.6 | 8.03 |
| 320 | 21.13 | 8.67 | 9.45 |
| 330 | 22.10 | 9.75 | 10.90 |
| 340 | 23.12 | 10.84 | 12.39 |
| 350 | 24.21 | 11.96 | 13.93 |
| 360 | 25.38 | 13.11 | 15.53 |
| 370 | 26.63 | 14.29 | 17.20 |
| 380 | 27.99 | 15.51 | 18.95 |
| 390 | 29.46 | 16.79 | 20.80 |
| 400 | 31.06 | 18.13 | 22.77 |
| 410 | 32.84 | 19.56 | 24.90 |
| 420 | 34.82 | 21.09 | 27.22 |
| 430 | 37.05 | 22.76 | 29.79 |
| 440 | 39.62 | 24.61 | 32.67 |
| 450 | 42.65 | 26.7 | 35.99 |
| 460 | 46.30 | 29.14 | 39.94 |
| 470 | 50.90 | 32.10 | 44.82 |
| 480 | 57.03 | 35.91 | 51.21 |
| 490 | 65.59 | 41.09 | 60.03 |
| 500 | 65.59 | 41.44 | 60.27 |

Table 7: Results for SINR vs. distance for ISD-500m downlink.

Fig 14: Downlink SINR vs. distance plot for C-band for different network configurations.

# Discussion

Initially, the UE is attached to . In the scenario, the UE moves in a straight line towards and at 280m it is handed over to Till 280m the “desired” signal is from while the “interfering” signal is from . Post-handover there is a reversal; the desired signal is from while the interfering signal is from

Signals from and from to the UE undergoes pathloss. If the transmit powers at both s are then the comes out to be

Where is the pathloss loss (per the 3GPP pathloss models) at a distance of . Since the distance between the two s is equal to , the inter site distance, the UE is at a distance of ) from the interfering , and hence the term in the denominator.

With this background, let us look at Fig 1.

* In all cases, we see a constant SINR till 10m because the pathloss equations defined in the standard take effect only from 10m.
* SINR. vs distance is plotted for four cases
  + Case #1: UE is LOS with both BSs and Interference is turned off
  + Case #2: UE is in NLOS with both BSs with interference is turned off
  + Case #3: UE is in LOS with both BSs with interference turned on
  + Case #4: UE is in NLOS with both BSs with interference turned on
* In case#1 and case #2, the term in is zero. Therefore .We see the SNR dropping as the UE moves away from . Then at 280m it gets handed over to , and we see the SNR increasing as the UE moves closer to . Why is there a “jump” at the handover point? This is because the standards specify that handover should occur only when target-gNB’s SINR is offset (3dB) higher than serving-gNB’s SINR. This condition is satisfied at 280m.
* Next, we observe that the NLOS curve (blue) is lower than the LOS curve (grey). This is because NLOS pathloss is higher than the LOS pathloss
* Case #3 and Case #4 (i.e., when interference is turned on) show counter intuitive behaviour. The SINR in LOS is lower than the SINR of the NLOS. This is the opposite of Case #1 and case #2. What could cause this behaviour? From the Table 8 below we observe that at 10m
  + The received signal strength is higher for LOS than for NLOS
  + The interference power in LOS is higher than for NLOS. This happens because LOS pathloss is lower (than NLOS pathloss) from interfering BS to UE
  + Interference power difference between LOS and NLOS cases is much higher than pathloss difference.
  + Therefore, NLOS SINR is higher than LOS SINR (thermal noise = -94 dBm)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Case** | **Pathloss from attached to BS (dB)** | **Received signal strength (dBm)** | **Interference signal strength from interfering BS (dBm)** | **SINR (dB)** |
| **UE in LOS (10m)** | 63.60 | -23.60 | -64.69 | 41.09 |
| **UE in LOS (270m)** | 94.35 | -53.69 | -51.56 | -2.78 |
| **UE in NLOS (10m)** | 68.23 | -28.23 | -89.67 | 60.02 |
| **UE in NLOS (270m)** | 119.57 | -79.57 | -76.85 | -2.80 |

Table 8: Radio measurements for the different cases

# Advanced: Understanding the points of handoff

We investigate the point of hand-off for case #1 and case #2 where the interferences are assumed to be absent from the base-stations. This therefore represents a noise limited regime. In such a scenario, as the UE moves from BS 1 towards BS 1, the SNR seen by the car from BS 1 recedes, while the SNR seen from BS 2 grows gradually. Fig 15 shows a zoom of Fig 13 for case #1 and case #2 between distances of 260m to 280m. We clearly see that (unlike Fig 13) the point of handover is different for the NLOS and LOS cases. LOS handover is 272m while NLOS handover is at 280m. This is as expected because LOS and NLOS use different pathloss models (with different the pathloss exponent). Why then does Fig 13 show the handover points to be the same i.e., at 280m?

The answer lies in the fact that in NetSim, the pathloss calculations are not carried out on distance but at *discrete* distances. The calculations are done every time a UE moves with the UE movement (in our example) dictated by a mobility file. The UE is assumed to instantaneously move to a point at time , and stay there till just before time . At the moment, , the UE instantaneously moves to point . Pathloss is computed at and at . In the Fig 13 measurements were every 20m while in Fig 15 measurements are taken every 1m.

Fig 15: Handover point for case #1 (LOS, no interference) is 272m while for case #2 (NLOS, no interference) it is 280m

We leave it to the reader to carry out a similar exercise for cases #3 and #4.

# Exercises

1. Perform a similar experiment using a different band (for example n5 or low band, 850 MHz)
2. Perform a similar experiment with 3 gNBs and the UE moving to a cell corner rather than the cell edge
3. (Advanced) Add on shadowing and observe possible ping-pong handovers
4. (Advanced) Change the handover “Offset” in NetSim code (from default 3 dB) and observe change in ping-pong handovers

# References

|  |  |
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| [1] | M. Haenggi and R. K. Ganti, “Interference in Large Wireless Networks,” 2009. |

1. Some of the content in this section is from [1] [↑](#footnote-ref-1)