1 Impact of Handover margin and Time-To-Trigger on the performance of a 5G heterogeneous network

1.1 Objective

In a 5G heterogeneous network we analyse how the handover margin and time-to-trigger parameters influence two performance metrics: the number of handovers and the sum throughput (aggregate throughput of all UEs).

1.2 System model

The study is based on a 3-tier 5G HetNet simulation. The network comprises gNB tiers at 1.5 GHz, 2.1 GHz, and 3.5 GHz. Each tier has a specific pathloss exponent influencing signal attenuation. The transmit power, antenna types (sector and omni-directional), and antenna heights vary across tiers. The simulation area is 10 km², with 60 User Equipment (UEs) distributed randomly and 18 tier-I gNBs, 18 tier-II gNBs, and 12 tier-III gNBs distributed randomly. The gNBs across tiers will not interference since they operate at different frequencies.

Simulation parameters include gNB and UE antenna configurations, pathloss models, interference models, and mobility settings. Shadowing effects are modelled using a lognormal distribution with a standard deviation of 5 dB.

gNB tiers	Frequency (GHz)	Pathloss Exponent (η)	Transmit Power(dBm)	Antenna Type	Antenna Height (m)	Channel Bandwidth (MHz)
Tier 1 gNBs	1.5	2.9	37	Sector (3 Nos)	30	10
Tier 2 gNBs	2.1	2.9	37	Sector (3 Nos)	30	15
Tier 3 gNBs	3.5	3.9	30	Omni-Directional	20	50

Table 1: System parameters for the gNBs in the three different tiers

The Time to Trigger (TTT) and Handover Margin (HO Margin) are variables in the study. An A3 event-based handover model is used. An Event A3-based HO is triggered when

C1.The SINR of a user from target gNB becomes higher than the SINR of the user from the serving gNB by an offset. This offset is termed as handover margin.

C2.And this condition (C1) is maintained for a duration known as the time to trigger.

The model focuses on the interaction of these parameters and their effect on network performance, measured in terms of handover count and sum throughput.

Simulation Area for the RAN	10 km × 10 km
Number of UEs	60 (distributed randomly)
Number of Tier 1 gNBs	18 (distributed randomly)
Number of Tier 2 gNBs	18 (distributed randomly)
Number of Tier 3 gNBs	12 (distributed randomly)
gNB Tx*Rx Antenna Count	1*1
UE Tx*Rx Antenna Count	1*1
gNB Pathloss Model	Log Distance
Downlink Interference Model	Exact Geometric Model
Mobility Model	Random Walk
Velocity	33 m/s
Calculation (update) interval for mobility	0.12 s (120 ms)
Shadowing	Lognormal. Std. dev. = 5 dB
Time to trigger (ms)	Varies; 128, 256, 512, 1024
Handover Margin (dB)	Varies; 0, 1, 2, 3, 4, 5, 6

Table 2: System parameters for the scenario being simulated

The scenario in NetSim looks as shown below.

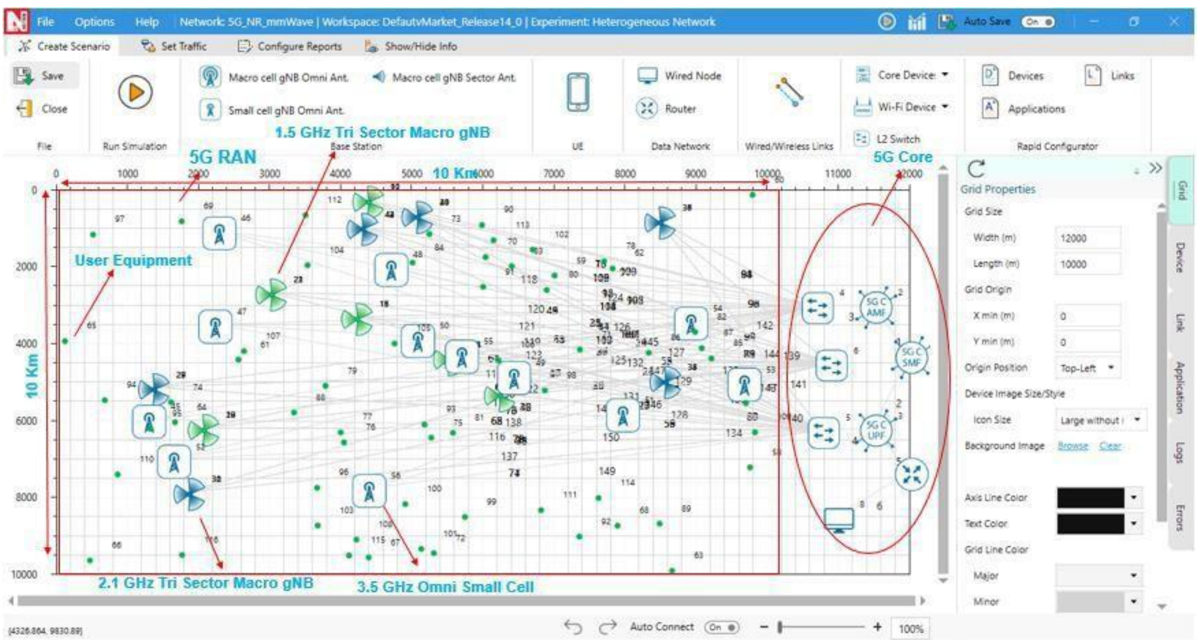


Figure 1: Network set up for Heterogeneous Network

Traffic Model: Saturated (full buffer) downlink traffic from remote server to all UEs.

Procedure to obtain handover count

- Create the simulation with the given properties.
- Open the configuration file in visual studio and replace all the instances of Handover Margin and Time to trigger to Handover Margin = “{1}” and TIME_TO_TRIGGER =”{0}”.

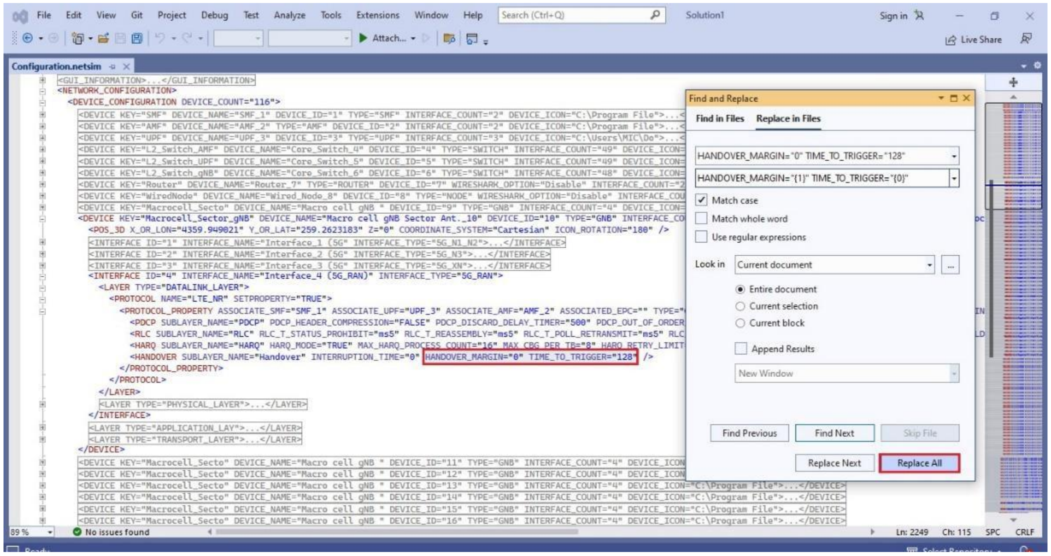


Figure 2: Configuration file changes for Multi-Parameter Sweeper

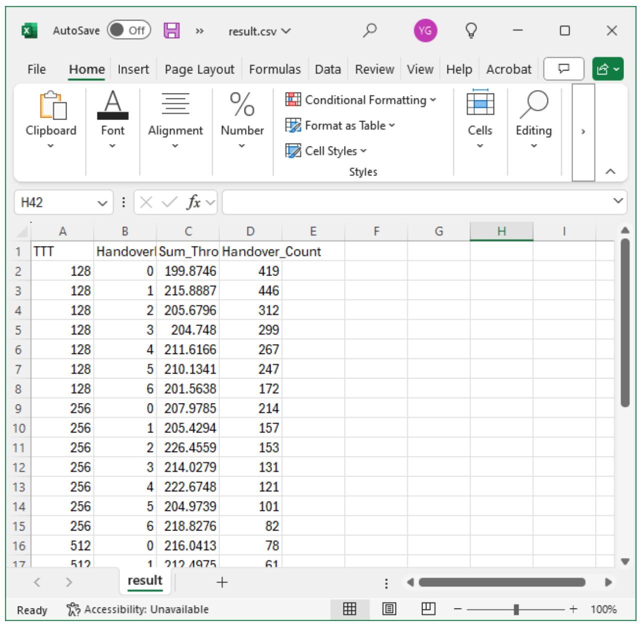
- Rename the file as input.xml, paste the file in 5g-Heterogeneous-Networkv14.3 folder downloaded from the link https://github.com/NetSim-TETCOS/5g-Heterogeneous-Networkv14.3-main/archive/refs/heads/main.zip
- Open MultiParameterSweeper.py file present in 5g-Heterogeneous-Networkv14.3 folder and change NETSIM_PATH variable to current workspace path.
- Open command prompt in 5g-Heterogeneous-Networkv14.3 folder and give command python multi-parameter-sweper.py.

Figure 3: Command Prompt window

- The simulations will be executed across Handover Margin 0, 1, 2, 3, 4, 5, 6 and Time
- to Trigger 128, 256, 512, 1024 values.
- In our setup, running on an i7-6th gen CPU with 16GB RAM, each simulation takes approximately one hour to complete. Given the matrix of parameters, which includes 4

Time-to-Trigger values and 7 Handover-Margin values, we have a total of 28 unique simulation scenarios. Consequently, the complete set of simulations would require around 5 hours, equating to slightly more than a full day of continuous operation.

- After the simulation is completed open the result.csv file in the 5g-Heterogeneous-Networkv14.3 folder. The corresponding Sum Throughput and Handover Count values are obtained for respective Handover Margin and Time to trigger configurations. Individual throughputs have been documented in a distinct CSV file, denoted as individual_throughput.csv.



TTT	Handover	Sum_Thro	Handover_Count
128	0	199.8746	419
128	1	215.8887	446
128	2	205.6796	312
128	3	204.748	299
128	4	211.6166	267
128	5	210.1341	247
128	6	201.5638	172
256	0	207.9785	214
256	1	205.4294	157
256	2	226.4559	153
256	3	214.0279	131
256	4	222.6748	121
256	5	204.9739	101
256	6	218.8276	82
512	0	216.0413	78
512	1	212.4975	61

Figure 4: Results file

1.3 Results and discussion

We tabulate below the handover count and sum throughput for various values of Time to trigger (ms) and Handover margin (dB).

Time-to-trigger (ms)	Handover margin (dB)	Sum throughput (Mbps)	Handover count
128	0	199.87	419
128	1	215.89	446
128	2	205.68	312
128	3	204.75	299
128	4	211.62	267
128	5	210.13	247
128	6	201.56	172

256	0	207.98	214
256	1	205.43	157
256	2	226.46	153
256	3	214.33	131
256	4	222.67	121
256	5	204.97	101
256	6	218.83	82
512	0	216.04	78
512	1	212.5	61
512	2	220.95	49
512	3	219.75	44
512	4	208.35	31
512	5	213.79	25
512	6	204.29	25
1024	0	221.86	25
1024	1	225.63	23
1024	2	214.16	17
1024	3	211.75	14
1024	4	213.87	14
1024	5	218.31	10
1024	6	216.36	8

Table 3: Sum Throughput and Handover Count Value for various Time-to-Trigger and Handover Margin

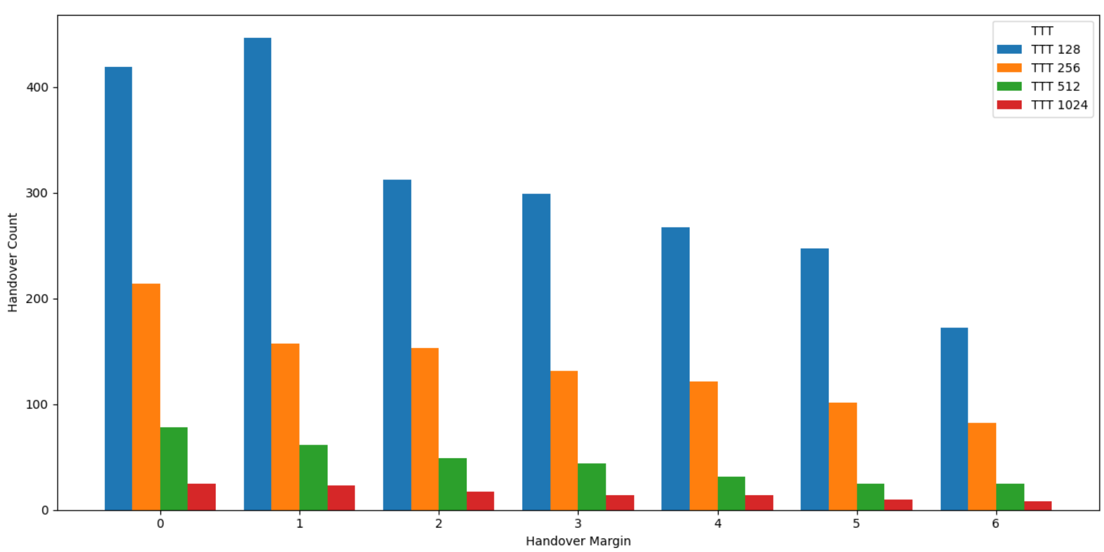


Figure 5: Handover Count vs Handover Margin for Different TTTs

It is evident from the plot that the handover count tends to decrease as the handover margin increases. This trend is consistent across different TTT values, suggesting that a higher handover margin generally results in fewer handovers. The rationale behind this trend it that increased handover margin leads to more stringent conditions for handover and thereby reduces the frequency of handover occurrences. Shorter TTT values lead to quicker responses to signal changes, resulting in more frequent handovers, while longer TTT values delay the handover process, thereby reducing the handover count. The plot highlights the effects of both the handover margin and the TTT on handover count.

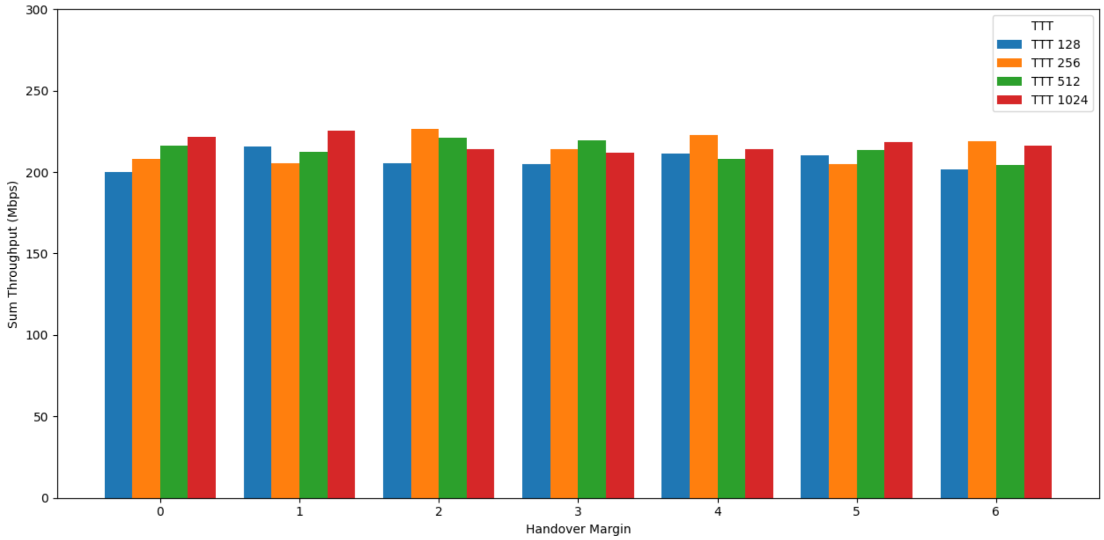


Figure 6: Sum Throughput vs Handover Margin for Different TTTs

In the second chart we see that sum throughput generally rises and then falls with an increasing handover margin. For each handover margin we see the throughput again roughly increases and then drops as TTT increases. Initially, with a higher handover margin and/or higher TTT unnecessary and frequent handovers between cells are avoided. This leads to better throughput, but only to a certain extent. Beyond a point, a high handover margin and/or high TTT cause delayed handovers. Users stay connected to a weaker cell longer, despite being closer to a stronger cell, leading to poorer signal quality and thus lowering throughput.

It is important to note that the presented results are obtained from a simulation run with a single seed. To achieve statistically valid conclusions, it is essential to conduct simulations with multiple seeds