

## Time to Trigger in NetSim 5G

Software: NetSim Pro v13.2, Visual Studio 2022

Project Download Link:

<https://github.com/NetSim-TETCOS/Time-to-Trigger-v13.2.35/archive/refs/heads/main.zip>

Follow the instructions specified in the following link to download and setup the Project in NetSim:

<https://support.tetcos.com/en/support/solutions/articles/14000128666-downloading-and-setting-up-netsim-file-exchange-projects>

### Background

1. Cellular networks can suffer from *Ping-pong* (or rapid) handovers. In such handovers one successful handover is followed by a handover back to the original cell within short rapid handover time,  $T_{RH}$ , e.g., within 3 seconds. Both handovers could potentially have been saved. Equivalently, if a successful handover is followed by another successful handover to a third cell within  $T_{RH}$ , one could a single handover directly to this third cell would have served the purpose.
2. In the current version of NetSim, A3 based handover event is triggered the *instant* received SNR (on the downlink in the SSB) from target gNB,  $SNR_{UE(SSB)}^{t-gNB}$  is offset,  $\Delta$ , higher than received signal strength (on the downlink in the SSB) from serving gNB  $SNR_{UE(SSB)}^{s-gNB}$ . This offset,  $\Delta$ , is also known as the Hand Over Margin (HOM). Thus, A3 event is triggered when, in dB scale,

$$SNR_{UE(SSB)}^{t-gNB}(t) - SNR_{UE(SSB)}^{s-gNB}(t) \geq \Delta \quad (1)$$

where  $t$  is a discrete time instant.

3. Given the way NetSim measures power,  $SNR$  is used to account for differences in the bandwidth between serving and target gNBs. If their bandwidths are equal, then, in dB scale
$$SNR_{UE(SSB)}^{t-gNB}(t) - SNR_{UE(SSB)}^{s-gNB}(t) = RSRP_{UE(SSB)}^{t-gNB}(t) - RSRP_{UE(SSB)}^{s-gNB}(t)$$
4. In NetSim, SSB power between all UE-gNB pairs are computed
  - a. when a measurement report is sent, which is every measurement interval  $T_{MI}$  (default 120 ms), and
  - b. at every mobility event i.e., whenever a UE moves. Recall here that in NetSim mobility is discretized over instants of time and movement is not continuous over time i.e., a UE moves to  $(x_1, y_1)$  at time  $t_1$ , remains at  $(x_1, y_1)$  till just before time  $t_2$ , and then instantly moves to  $(x_2, y_2)$  at  $t_2$ .
5. Hence, the A3 trigger occurs at the instant power levels at t-gNB and s-gNB satisfy (1). This could occur at a measurement report event or at a mobility event.
6. By definition of time to trigger,  $T_{TTT}$ , a handover event should only be triggered if (1) holds true for a duration equal to  $T_{TTT}$ .
7. Since NetSim is a discrete event simulator its internal virtual clock progresses (virtual) time at events. Therefore, NetSim cannot check for (1) continuously over time. The test of whether (1) would continue to hold true can only be carried out at subsequent measurement report events and mobility events.
8. TTT condition will be successfully met only if powers from t-gNB and s-gNB meet condition (1) at all mobility and measurements events within the TTT period. If condition (1) fails to hold at any event during TTT, then TTT condition will have failed. The A3 trigger will be removed.
9. NetSim does not (recursively) average, or filter,  $SNR_{UE(SSB)}^{t-gNB}$ , or  $SNR_{UE(SSB)}^{s-gNB}$  within the  $T_{TTT}$  window and (1) is evaluated on instantaneous powers at all events.

10. NetSim Time-to-trigger variable
  - a. will be global scope; it remains the constant across the network, and
  - b. can be set by the user in the range [0 ms, 5120 ms] as defined in the standards
11. Let us say condition (1) is met and TTT is initiated. During this TTT period what say power from a new target cell  $t_2$  exceeds the power from serving cell by  $\Delta$ . The algorithm handles this case as well.

### Algorithm

1. When A3 condition is met *AddTrigger* event is added
2. Check (1) at all measurement report events and mobility events
3. If at any event (1) doesn't hold remove the *AddTrigger* event
4. Else, if (1) holds at all events within the TTT, initiate H/O trigger upon expiry of TTT interval.

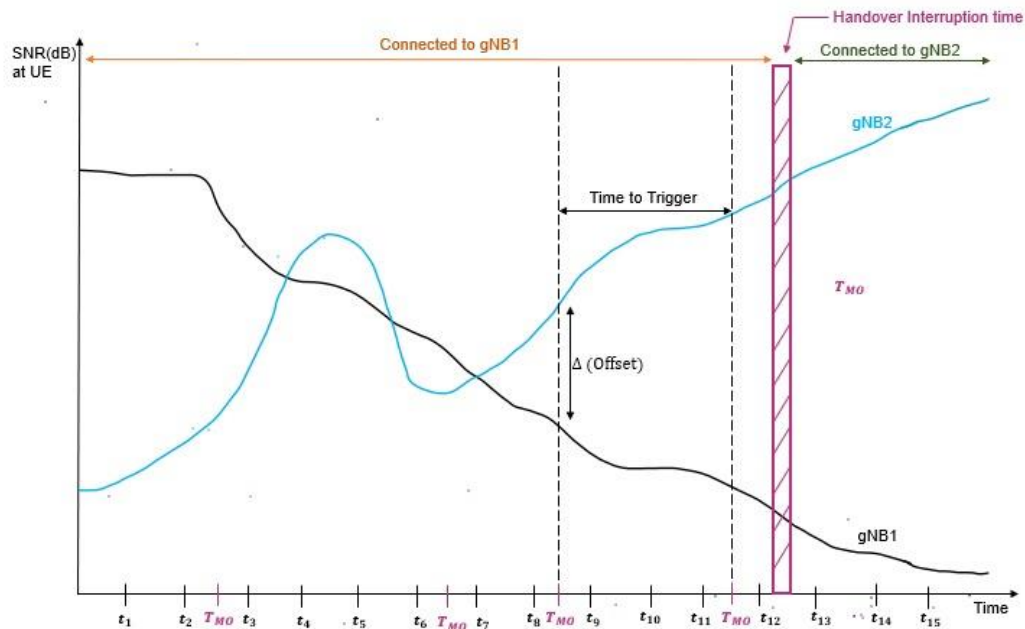


Fig 1: We see the SNR variation with time measured by UE from gNB1 (black) and gNB2 (blue). Time to trigger starts the instant  $SNR_{UE}^{gNB2} - SNR_{UE}^{gNB1} > \Delta$ . Once this condition holds for a duration equal to time-to-trigger, handover is initiated. Users can also configure a handover interruption time during which the UE is not connected to either gNB. Post this the UE gets associated with gNB2

### Assumptions and limitations

1. Time to trigger ( $T_{TTT}$ ) will be implemented for 5G Standalone (SA) mode. Non-stand alone (NSA) mode will not support  $T_{TTT}$
2. NetSim assumes non failure of:
  - a. Measurement reports
  - b. Handover messages
3. Handovers are always successful. There are no handover failures on account of admission control at t-gNB.
4. In NetSim, UEs can be handed over to gNBs of different frequencies as long as (1) is met. There is no difference in handover functionality when the t-gNB and s-gNB operate in (i) the

same frequency (say s-gNb and t-gNB in C-band) and (ii) different frequencies (say s-gNB in C-band and t-gNB in mmWave).

5. Time-to-trigger implementation is based on Rel 15. Enhancements added in Rel 16 namely (i) Dual active protocol stack (DAPS) and (ii) Conditional handovers, are not yet supported in NetSim.

#### Algorithm for implementation in NetSim:

- Each gNB maintains a matrix named as the Conditional HO TTT Matrix
- The rows are the associated UEs, and the columns are all other gNBs in the scenario
- Whenever a  $UE_i$  associates with a gNB
  - Initialize all the matrix entries for all  $j$  (i.e., for all gNBs) for the given row  $i$  as follows
    - $T_{trigger}^j$  to -1 for all  $j$  // #define TTT\_not\_set = -1
- Whenever a measurement report from an associated  $UE_i$  is received
  - If the condition  $(SNR_{UE(SSB)}^{gNB} - SNR_{UE(SSB)}^{s-gNB}) > \Delta$  is met
    - If matrix entry  $T_{trigger}^j$  is currently -1, then //  $i$  is fixed
      - Update the matrix entry,  $T_{trigger}^j = T_{current}$ , where  $T_{current}$  is current simulation time
    - Else (matrix entry is not -1)
      - If  $T_{current} - T_{trigger}^j \geq TTT$ 
        - Initiate handover procedure
  - Else
    - If the matrix entry,  $T_{trigger}^j$  is not -1
      - Set it equal to -1
- Whenever a  $UE_i$  disassociates with a gNB, delete the row  $i$

#### Configuring Time-to-Trigger (Units: Milliseconds)

The LTENR\_GNBRRC.h file contains a TTT macro which can be set to the desired TTT value in milliseconds. This value is common for all gNBs in a network i.e., TTT parameters is global in scope.

```

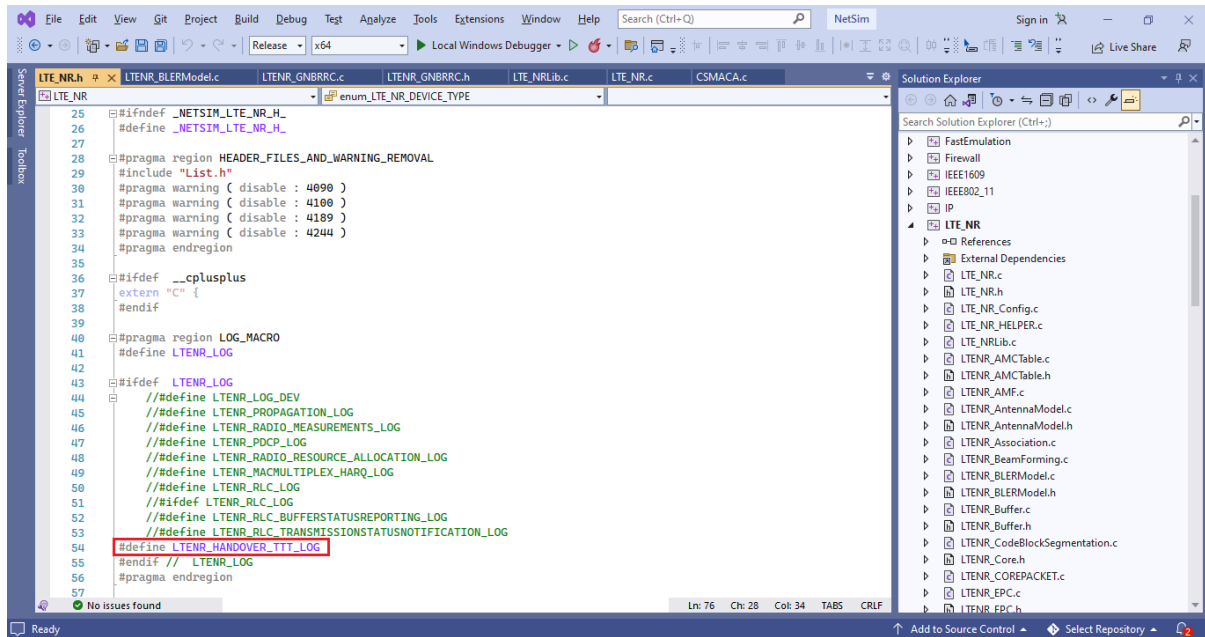
25 #ifndef _NETSIM_LTENR_GNBRRC_H_
26 #define _NETSIM_LTENR_GNBRRC_H_
27
28 #pragma region HEADER_FILES
29 #include "LTENR_Msg.h"
30 #include "LTENR_PDCP.h"
31 #include "LTENR_RLC.h"
32 #include "LTENR_NSA.h"
33 #pragma endregion
34
35 #ifdef __cplusplus
36 extern "C" {
37 #endif
38
39 #pragma region MACROS
40 //Default Timer
41 #define LTENR_MSG_MIB_REGENERATION_TIME 80*MILLISECOND
42 #define LTENR_MSG_SIB1_REGENERATION_TIME 160*MILLISECOND
43 #define LTENR_MSG_UE_MEASUREMENT_REPORT_PERIOD_TIME 120*MILLISECOND
44 #define HANDOVER_DIFF 3//db
45 #define TTT 2560//3GPP defines 16 valid values for time-to-trigger (all in milliseconds):
46 //0, 40, 64, 80, 100, 120, 160, 256, 320, 480, 512, 640, 1024, 1280, 2560, and 5120.
47 #define TTT_NOT_SET -1
48 //Default packet size
49 #define LTENR_MSG_MIB_SIZE 3 // Bytes
50 #pragma endregion
51
52 #pragma region RRC_STATE
53 typedef enum enum_LTENR_UE_RRCSTATE
54 {
55 UERRC_IDLE,
56 UERRC_INACTIVE,
57 UERRC_CONNECTED,

```

Setting TTT to 0 is equivalent to disabling Time-to-Trigger.

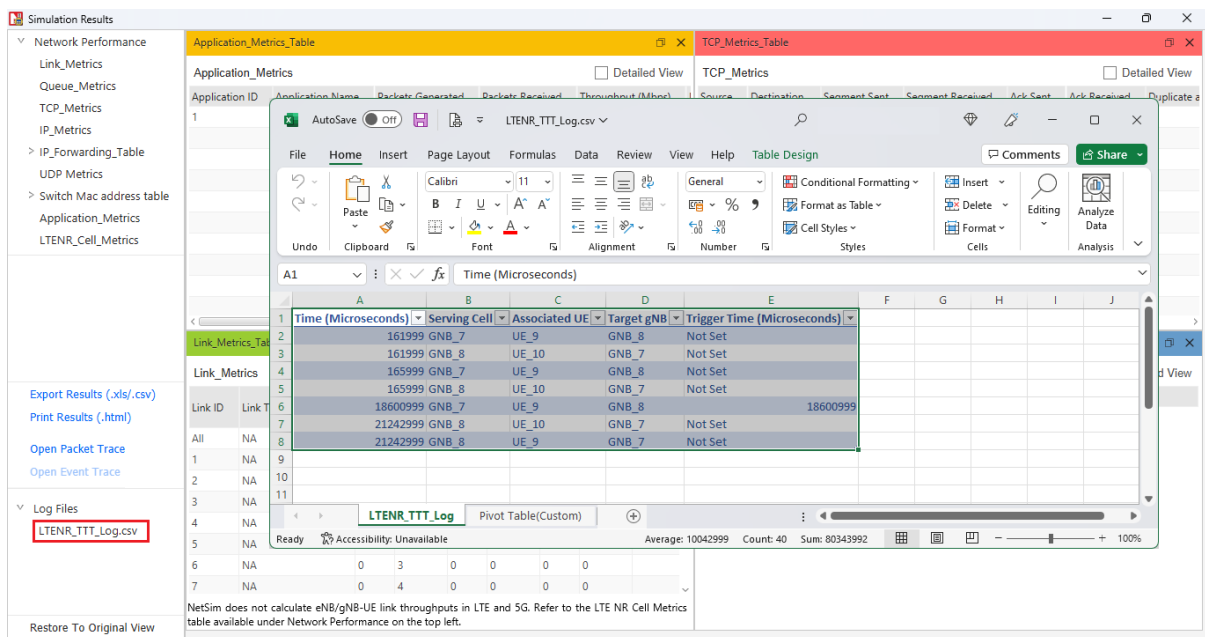
## Enabling the TTT Log

We have added a *rudimentary* Time-to-Trigger log file can be enabled by uncommenting the macro `LTE_NR_HANDOVER_TTT_LOG` defined in the `LTE_NR.h` file as shown below:



```
25 #ifndef _NETSIM_LTE_NR_H_
26 #define _NETSIM_LTE_NR_H_
27
28 #pragma region HEADER_FILES_AND_WARNING_REMOVAL
29 #include "List.h"
30 #pragma warning ( disable : 4090 )
31 #pragma warning ( disable : 4100 )
32 #pragma warning ( disable : 4189 )
33 #pragma warning ( disable : 4244 )
34 #pragma endregion
35
36 #ifdef __cplusplus
37 extern "C" {
38 #endif
39
40 #pragma region LOG_MACRO
41 #define LTE_NR_LOG
42
43 #ifdef LTE_NR_LOG
44 // #define LTE_NR_LOG_DEV
45 // #define LTE_NR_PROPAGATION_LOG
46 // #define LTE_NR_RADIO_MEASUREMENTS_LOG
47 // #define LTE_NR_PDCP_LOG
48 // #define LTE_NR_RADIO_RESOURCE_ALLOCATION_LOG
49 // #define LTE_NR_MACMULTIPLEX_HARQ_LOG
50 // #define LTE_NR_RLC_LOG
51 // #ifdef LTE_NR_RLC_LOG
52 // #define LTE_NR_RLC_BUFFERSTATUSREPORTING_LOG
53 // #define LTE_NR_RLC_TRANSMISSIONSTATUSNOTIFICATION_LOG
54 #define LTE_NR_HANDOVER_TTT_LOG
55 #endif // LTE_NR_LOG
56 #pragma endregion
57
```

Upon running simulations with this log enabled, a `LTE_NR_TTT_Log.csv` file is written and can be accessed from the results dashboard as shown below:



Time (Microseconds)	Serving Cell	Associated UE	Target gNB	Trigger Time (Microseconds)
161999	GNB_7	UE_9	GNB_8	Not Set
161999	GNB_8	UE_10	GNB_7	Not Set
165999	GNB_7	UE_9	GNB_8	Not Set
165999	GNB_8	UE_10	GNB_7	Not Set
18600999	GNB_7	UE_9	GNB_8	18600999
21242999	GNB_8	UE_10	GNB_7	Not Set
21242999	GNB_8	UE_9	GNB_7	Not Set

The log file consists of time stamps in Microseconds, the serving cell name, associated UE name, target cell name, and the trigger time in Microseconds.

Entries to the file are written (i) for initial UE association (will have two entries) (ii) when handover condition is hit (iii) when UE is handed over (iv) when TTT is reset

For example, upon running the inbuilt 5G-Handover example with TTT set to 2560 milliseconds (or 2.56 s), we get the following entries in the log file.

Time (Microseconds) ▾	Serving Cell ▾	Associated UE ▾	Target gNB ▾	Trigger Time (Microseconds) ▾
161999	GNB_7	UE_9	GNB_8	Not Set
161999	GNB_8	UE_10	GNB_7	Not Set
165999	GNB_7	UE_9	GNB_8	Not Set
165999	GNB_8	UE_10	GNB_7	Not Set
18600999	GNB_7	UE_9	GNB_8	18600999
21242999	GNB_8	UE_10	GNB_7	Not Set
21242999	GNB_8	UE_9	GNB_7	Not Set

- From the log file we can see that, around 162 milliseconds, UE 9 gets associated with gNB 7 and UE10 gets associated with gNB 8.
- UE 9 is configured with mobility such that it moves away from gNB 7 and towards gNB 8.
- At 18.6 seconds, the handover condition is met for UE 9 with the SNR from gNB 8 greater than the SNR from gNB 7 by the default margin of 3 dB.
- Trigger Time for UE 9 gNB 8 pair is set to the time at which the condition is met.
- The condition  $(SNR_{UE(SSB)}^{gNB} - SNR_{UE(SSB)}^{s-gNB} > \Delta)$  continues to hold
- At time 21.24 seconds, UE 9 gets handed over to gNB 8 after a duration greater than or equal to the TTT (2560000  $\mu s$ ) successfully.