LTE X2 Handover

Software Recommended: NetSim Standard v11.1 (32bit/64bit), Microsoft Visual Studio 2015/2017

Follow the instructions specified in the following link to clone/download the project folder from GitHub using Visual Studio:
https://tetcos.freshdesk.com/support/solutions/articles/14000099351-how-to-clone-netsim-file-exchange-project-repositories-from-github-

Other tools such as GitHub Desktop, SVN Client, Sourcetree, Git from the command line, or any client you like to clone the Git repository.

Note: It is recommended not to download the project as an archive (compressed zip) to avoid incompatibility while importing workspaces into NetSim.

Secure URL for the GitHub repository:

https://github.com/NetSim-TETCOS/LTE_X2_Handover_v11.1.git

Handover

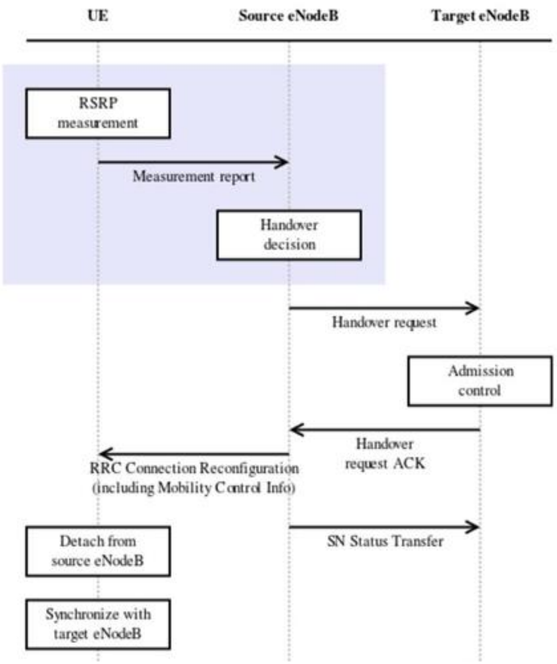
Handover is an important function that maintains seamless connectivity when transitioning from one base station to another.

- Due to mobility UEs can move from one place to another.
- Then UE sends the MEASUREMENT REPORT to the S-eNB.
- The S-eNB issues a HANDOVER REQUEST message to the T-eNB.
- The T-eNB checks for resource availability and, if available, reserves the resources and sends back the HANDOVER REQUEST ACKNOWLEDGE message.

LTE X2 Handover

In event-triggered handover procedures, each UE evaluates the Event condition every time a new averaged measurement sample is available .The evaluated condition is the entering condition of Event whether the RSRP/SNR measured from a neighbouring cell becomes an offset better than the RSRP/SNR measured from the serving cell . The offset is represented as hysteresis.

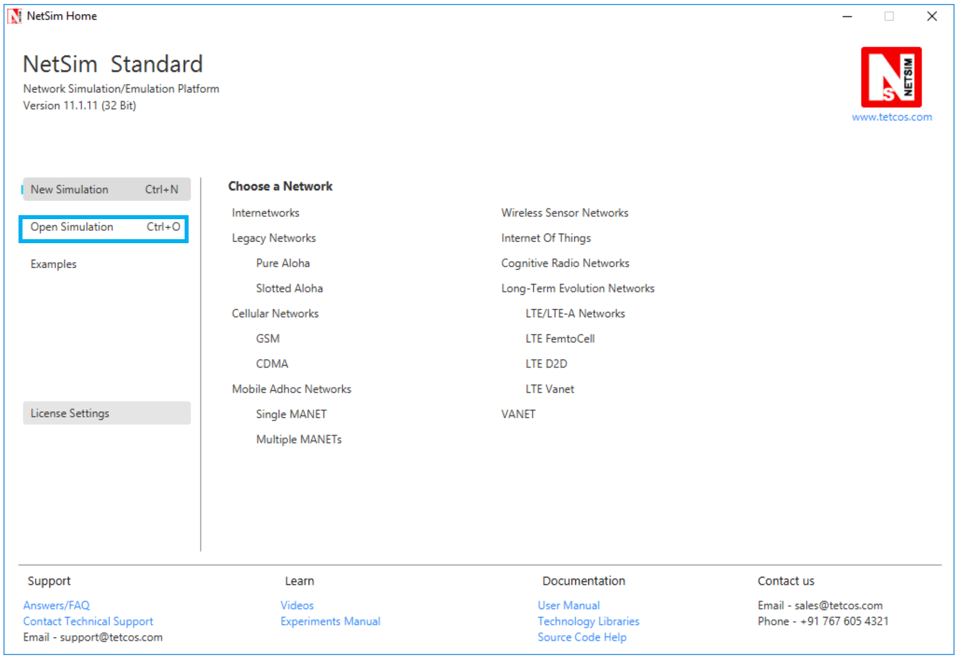
The UE generates a measurement report and transmit it as an RRC message to the serving cell. This report typically contains measurement results of at least the serving cell, but is extendable with measurement results of neighboring cells. Series of steps occurs to carry out handover process which can be seen in the diagram below and also in our table in Result Section.



Code Changes done to obtain SNR logs in NetSim:

1. In the LTE Project of NetSim source codes modifications are done to perform LTE X2 Handover.

2. After downloading the project folder using the GitHub URL, Open NetSim Home Page click on **Open Simulation** option,


NetSim Home

NetSim Standard
Network Simulation/Emulation Platform
Version 11.1.11 (32 Bit)

www.tetcos.com

New Simulation Ctrl+N
Open Simulation Ctrl+O
Examples
License Settings

Choose a Network
Internetworks
Legacy Networks
Pure Aloha
Slotted Aloha
Cellular Networks
GSM
CDMA
Mobile Adhoc Networks
Single MANET
Multiple MANETs
Wireless Sensor Networks
Internet Of Things
Cognitive Radio Networks
Long-Term Evolution Networks
LTE/LTE-A Networks
LTE FemtoCell
LTE D2D
LTE Vanet
VANET

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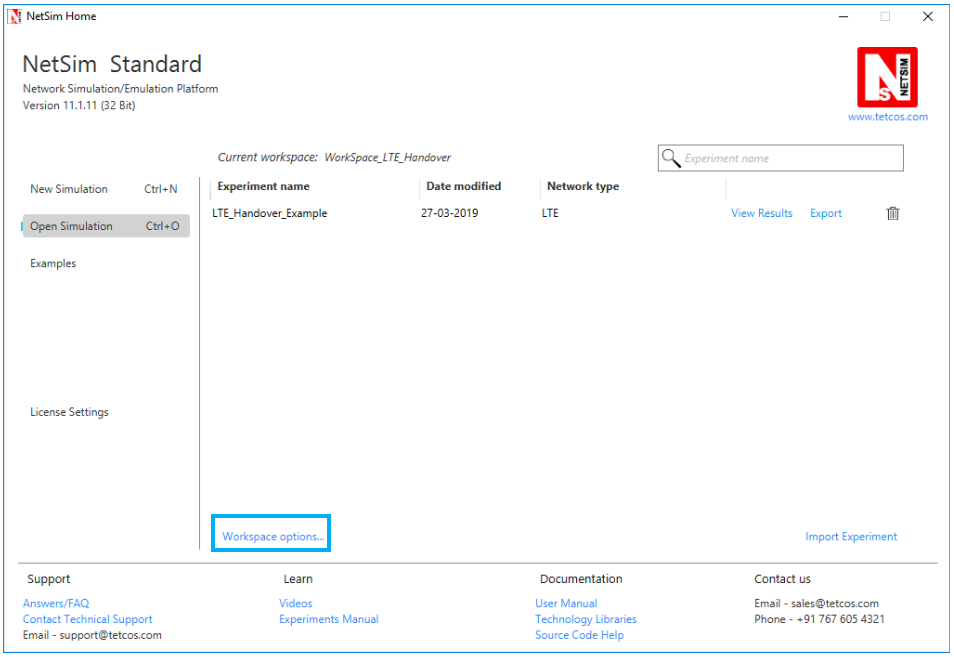
3. Click on **Workspace options**



NetSim Home

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Current workspace: WorkSpace_LTE_Handover

Experiment name	Date modified	Network type			
LTE_Handover_Example	27-03-2019	LTE	View Results	Export	🗑

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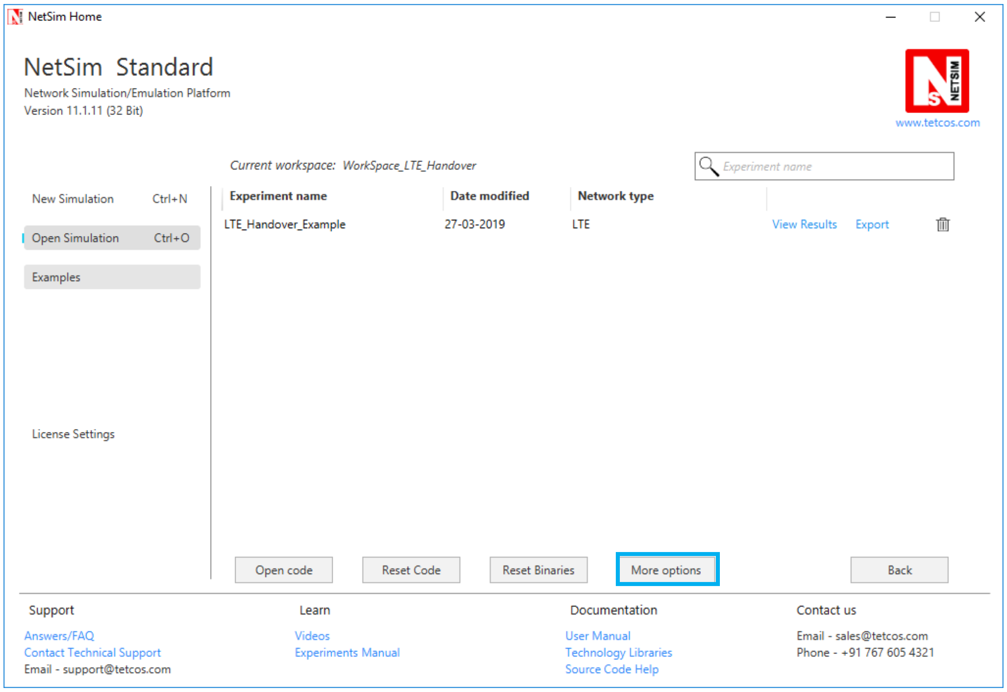
4. Click on **More Options,**



NetSim Home

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Current workspace: WorkSpace_LTE_Handover

Experiment name	Date modified	Network type			
LTE_Handover_Example	27-03-2019	LTE	View Results	Export	🗑

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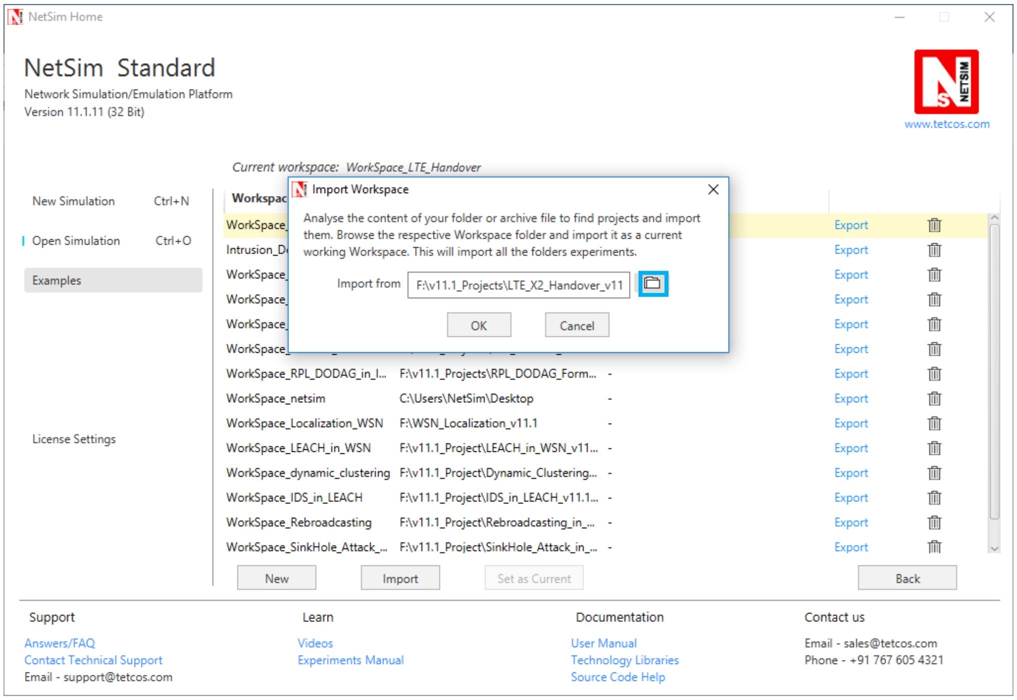
5. Click on **Import**, browse the extracted folder path and go into WorkSpace_LTE_Handover folder. Click on Select Folder and then on **OK.**



NetSim Home

NetSim Standard

Network Simulation/Emulation Platform

Version 11.1.11 (32 Bit)

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Current workspace: *WorkSpace_LTE_Handover*

New Simulation Ctrl+N

Open Simulation Ctrl+O

Examples

License Settings

Import Workspace

Analyse the content of your folder or archive file to find projects and import them. Browse the respective Workspace folder and import it as a current working Workspace. This will import all the folders experiments.

Import from: F:\v11.1_Projects\LTE_X2_Handover_v11

OK Cancel

Workspac				
WorkSpace_			Export	🗑
Intrusion_D			Export	🗑
WorkSpace_			Export	🗑
WorkSpace_			Export	🗑
WorkSpace_			Export	🗑
WorkSpace_			Export	🗑
WorkSpace_RPL_DODAG_in_I...	F:\v11.1_Projects\RPL_DODAG_Form...	-	Export	🗑
WorkSpace_netsim	C:\Users\NetSim\Desktop	-	Export	🗑
WorkSpace_Localization_WSN	F:\WSN_Localization_v11.1	-	Export	🗑
WorkSpace_LEACH_in_WSN	F:\v11.1_Project\LEACH_in_WSN_v11...	-	Export	🗑
WorkSpace_dynamic_clustering	F:\v11.1_Project\Dynamic_Clustering...	-	Export	🗑
WorkSpace_IDS_in_LEACH	F:\v11.1_Project\IDS_in_LEACH_v11.1...	-	Export	🗑
WorkSpace_Rebroadcasting	F:\v11.1_Project\Rebroadcasting_in_...	-	Export	🗑
WorkSpace_SinkHole_Attack_...	F:\v11.1_Project\SinkHole_Attack_in_...	-	Export	🗑

New Import Set as Current Back

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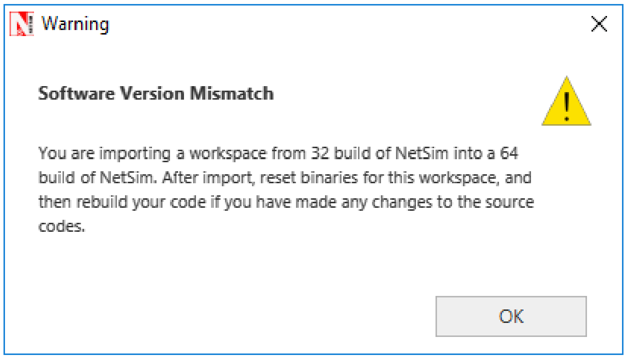
6. While importing the workspace, if the following warning message indicating Software Version Mismatch is displayed, you can ignore it and proceed.



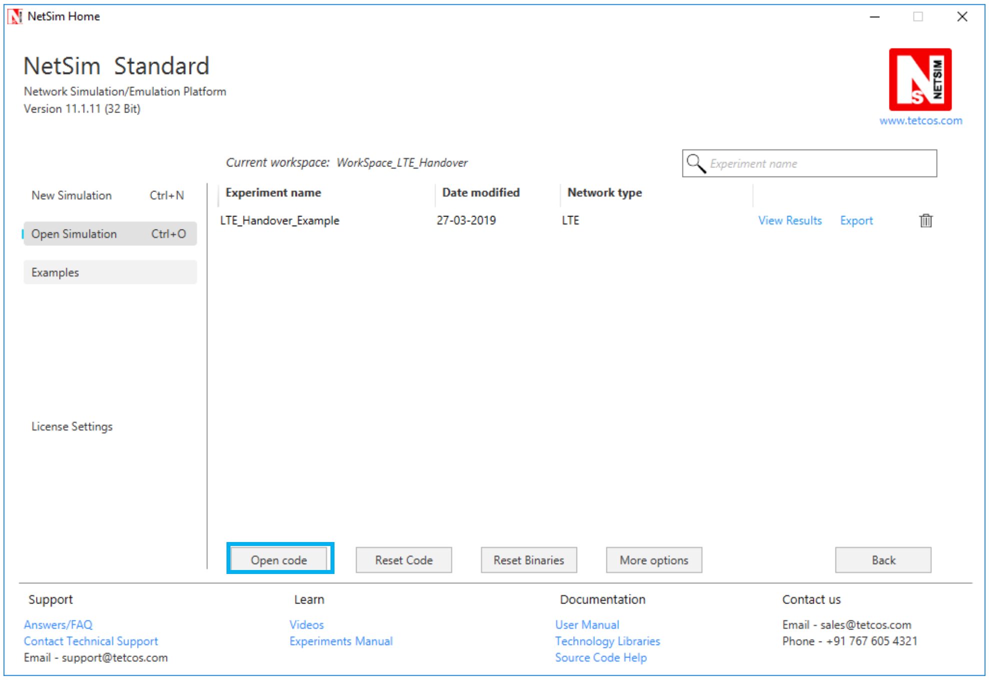
Warning

Software Version Mismatch

You are importing a workspace from 32 build of NetSim into a 64 build of NetSim. After import, reset binaries for this workspace, and then rebuild your code if you have made any changes to the source codes.

OK

7. Go to home page, Click on **Open Simulation → Workspace options → Open code**



Experiment name	Date modified	Network type
LTE_Handover_Example	27-03-2019	LTE

8. In file LTE Phy.c the following changes(highlighted in red) were made:

```
#include "main.h"
#include "LTE.h"
#define devid(id) fn_NetSim_GetDeviceIdByConfigId(id)
NETSIM_ID fn_NetSim_LTE_FindNearesteNB(NETSIM_ID nDeviceId);
FILE* fp;
char snrlog[100];
int fn_NetSim_LTE_CalculateReceivedPower()
{
NETSIM_ID i;
//fp = fopen("LTE_UE_SNR.txt", "w+");
for(i=0;i<NETWORK->nDeviceCount;i++)
{
……………………………………………………………


if(ber<TARGET_BER)
break;
else
{
info->DLInfo[j].nCQIIndex--;
info->ULInfo[j].nCQIIndex--;
}
}
sprintf(snrlog, "LTE_UE_SNR_%d.csv", devid(info->nUEId));
fp = fopen(snrlog, "w+");
int arr[512],k=0,c;
if (fp)
{
for (c = 0; c < NETWORK->nDeviceCount; c++)
{
if (NETWORK->ppstruDeviceList[c]->nDeviceType == eNB)
{
arr[k] = NETWORK->ppstruDeviceList[c]->nDeviceId;
k++;
}
}
fprintf(fp, "UE_ID,Time");
for (c = 0; c < k; c++)
{
fprintf(fp, ",SNR_ENB_ID_%d",arr[c]);
}

fclose(fp);
}
}
info=(LTE_ASSOCIATEUE_INFO*)LIST_NEXT(info);
}
}
}
return 1;
}
```

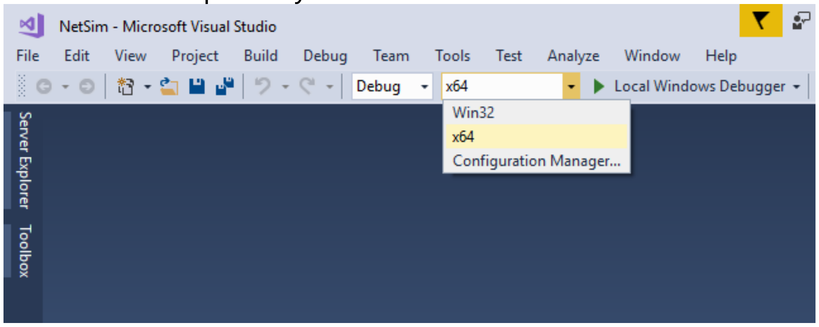
9. Now in NAS.c change the initial function as following

```
#define MEASUREMENT_REPORT_SIZE 184/8.0
#define HO_REQUEST_SIZE 288/8.0
#define HO_CONFIRM_SIZE 112/8.0
#define HANDOVER_DIFF      3 //db
#define devid(id) fn_NetSim_GetDeviceIdByConfigId(id)
int fn_NetSim_LTE_InitHandover(NETSIM_ID ueId,NETSIM_ID nENBId)
{
//Prepare the measurement report
NetSim_PACKET* packet;
LTE_MAC_PACKET* macPacket;
LTE_PHY_PACKET* phyPacket;
LTE_MEASUREMENT_REPORT* report=NULL;
NETSIM_ID i;
FILE* fp = NULL;
char snrlog[100];

sprintf(snrlog, "LTE_UE_SNR_%d.csv", fn_NetSim_GetDeviceIdByConfigId(ueId));
fp = fopen(snrlog, "a+");
fprintf(fp, "\n%d,%lf", fn_NetSim_GetDeviceIdByConfigId(ueId), pstruEventDetails-
>dEventTime);

for(i=0;i<NETWORK->nDeviceCount;i++)
{
//fprintf(fp, "\n%d,%lf", devid(info->nUEId), pstruEventDetails->dEventTime);
if(DEVICE_TYPE(i+1) == eNB)
{
```

```
unsigned int j;
LTE_MEASUREMENT_REPORT* temp=MEASUREMENT_REPORT_ALLOC();
LTE_ASSOCIATEUE_INFO* info = UEINFO_ALLOC();
LTE_ENB_PHY* enbPhy=(LTE_ENB_PHY*)DEVICE_PHYVAR(i+1,1);
info->nUEId=ueId;
info->nUEInterface=1;
temp->nENBId=i+1;
temp->nUEId=ueId;
temp->carrier_count = enbPhy->ca_count;

for(j=0;j<enbPhy->ca_count;j++)
{

fn_NetSim_LTE_CalculateRxPower(i+1,1,info,j);
fn_NetSim_LTE_CalculateSNR(i+1,1,info,j);
fn_NetSim_LTE_GetCQIIndex(i+1,1,info,j);
fn_NetSim_LTE_GetMCS_TBS_Index(info,j);
while(info->DLInfo[j].nCQIIndex>1 && info->ULInfo[j].nCQIIndex>1)
{
double ber;
fn_NetSim_LTE_GetMCS_TBS_Index(info,j);
ber = fn_NetSim_LTE_CalculateBER(0,info->DLInfo[j].MCSIndex,info->DLInfo[j].dSNR);
if(ber<TARGET_BER)
break;
else
{
info->DLInfo[j].nCQIIndex--;
info->ULInfo[j].nCQIIndex--;
}
}

temp->nCQIIndex_DL[j]=info->DLInfo[j].nCQIIndex;
temp->dSNR_DL[j]=info->DLInfo[j].dSNR;


//dETime = pstruEventDetails->dEventTime;

if (fp)
{
if (j == 0)
{

fprintf(fp, ",%lf", info->DLInfo[j].dSNR);
}

}


}
LIST_FREE((void**)&info,info);
LIST_ADD_LAST((void**)&report,temp);
}

}
fclose(fp);
if(report)
```

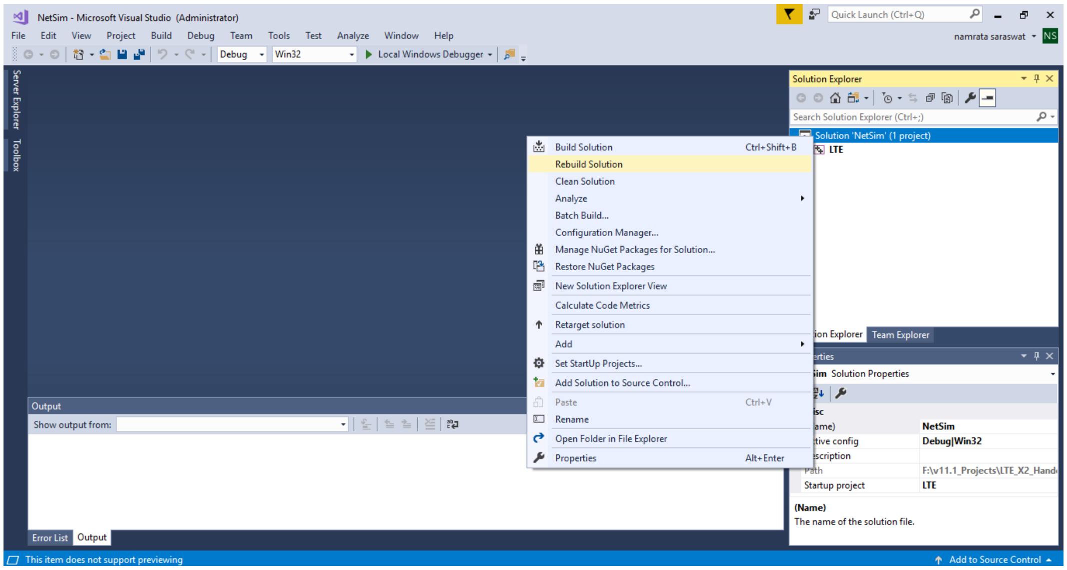
```
{
packet=fn_NetSim_LTE_CreateCtrlPacket(pstruEventDetails->dEventTime,
LTEPacket_MeasurementReport,
nENBId,
ueId,
nENBId,
MEASUREMENT_REPORT_SIZE);
macPacket=calloc(1,sizeof* macPacket);
macPacket->logicalChannel=LogicalChannel_CCCH;
macPacket->MessageType=LTEPacket_MeasurementReport;
macPacket->MessageVar=report;
macPacket->transportChannel=TransportChannel_RACH;
phyPacket=PACKET_PHYPROTOCOLDATA(packet);
phyPacket->physicalChannel=PhysicalChannel_PRACH;

packet->pstruMacData->Packet_MACProtocol=macPacket;
packet->pstruPhyData->Packet_PhyData=phyPacket;

//Add physical out event
pstruEventDetails->nDeviceId=ueId;
pstruEventDetails->nDeviceType=UE;
pstruEventDetails->nInterfaceId=1;
pstruEventDetails->nProtocolId=MAC_PROTOCOL_LTE;
pstruEventDetails->dPacketSize=MEASUREMENT_REPORT_SIZE;
pstruEventDetails->nApplicationId=0;
pstruEventDetails->nEventType=PHYSICAL_OUT_EVENT;
pstruEventDetails->nPacketId=0;
pstruEventDetails->nSegmentId=0;
pstruEventDetails->nSubEventType=0;
pstruEventDetails->pPacket=packet;
pstruEventDetails->szOtherDetails=NULL;
fnpAddEvent(pstruEventDetails);
}
return 0;
}
```

10. Based on whether you are using NetSim 32 bit or 64 bit setup you can configure Visual studio to build 32 bit or 64 bit Dll files respectively as shown below:



NetSim - Microsoft Visual Studio

11. Right click on the LTE project in the solution explorer and select rebuild. Upon rebuilding, **libIEEE802_11.dll** and **libDSR.dll** will automatically get updated in the respective bin folders of the current workspace.


NetSim - Microsoft Visual Studio (Administrator)
File Edit View Project Build Debug Team Tools Test Analyze Window Help
Debug
Win32
Local Windows Debugger
Solution Explorer
Search Solution Explorer (Ctrl+;)
Solution 'NetSim' (1 project)
LTE
Build Solution Ctrl+Shift+B
Rebuild Solution
Clean Solution
Analyze
Batch Build...
Configuration Manager...
Manage NuGet Packages for Solution...
Restore NuGet Packages
New Solution Explorer View
Calculate Code Metrics
Retarget solution
Add
Set StartUp Projects...
Add Solution to Source Control...
Paste Ctrl+V
Rename
Open Folder in File Explorer
Properties Alt+Enter
Output
Show output from:
Error List
Output
Team Explorer
Solution Properties
This item does not support previewing
Add to Source Control

(Name) NetSim
Active config Debug|Win32
Path F:\v11.1_Projects\LTE_X2_Hand
Startup project LTE

(Name)
The name of the solution file.

Steps to be done in NetSim scenario to Create LTE X2 Handover

Configuration

Grid Length: 5000m

Distance between ENB: 5Km

Distance between UE: 5Km

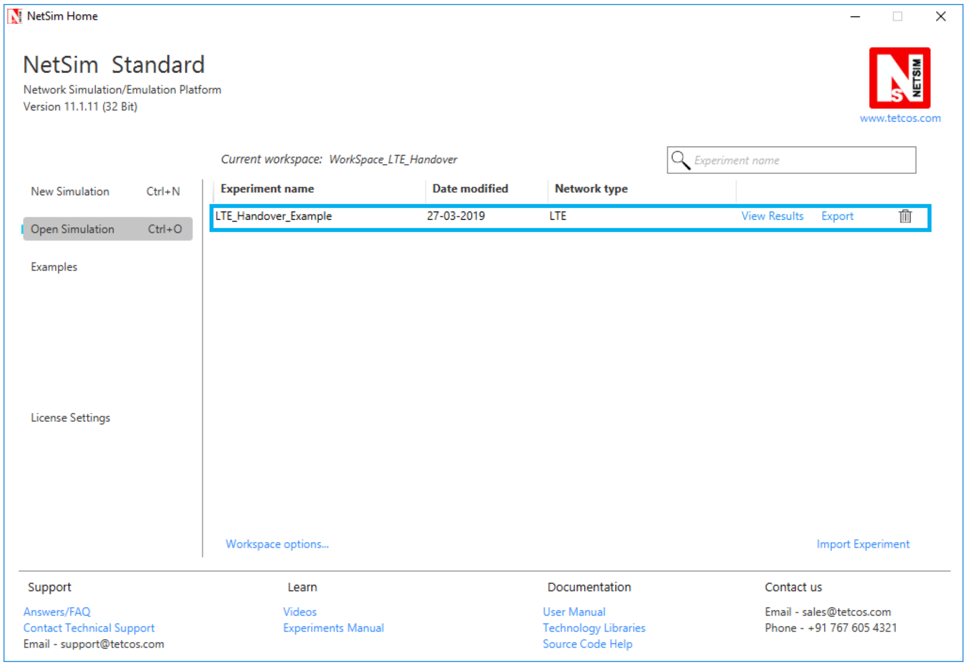
Properties UE-ENB Link: Default

Simulation Time = 300 Sec

Mobility model = File based mobility for UE6, No Mobility for UE 7

A sample **Configuration.netsim** file is provided, with all the above settings which can be directly loaded in NetSim

12. Go to NetSim home page, click on **Open Simulation**, Click on **LTE_Handover_Example.**



NetSim Home

NetSim Standard

Network Simulation/Emulation Platform

Version 11.1.11 (32 Bit)

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Current workspace: WorkSpace_LTE_Handover

Experiment name	Date modified	Network type			
LTE_Handover_Example	27-03-2019	LTE	View Results	Export	🗑

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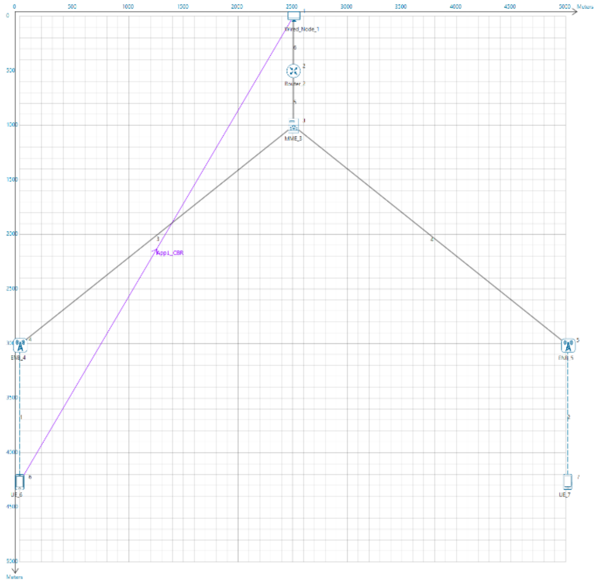
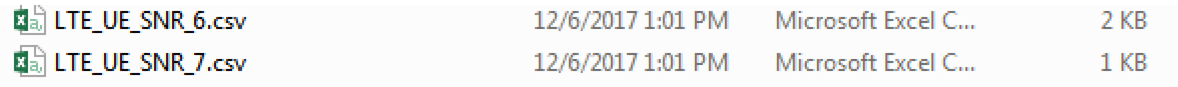
Place the **mobility.txt** file present in the code folder in <NetSim_Install_Directory>/bin Directory.

Network Scenario:

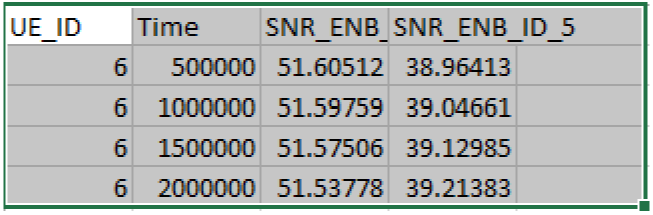


1. Simulate the scenario in Netsim and you will get two .csv files in bin folder of Netsim corresponding to each UE's involved in the simulaiton. Open any .csv file of the UE for which File Based Mobility was configured. You will observe the columns containing SNR measured by each ENB with respect to that particular UE.



LTE_UE_SNR_6.csv	12/6/2017 1:01 PM	Microsoft Excel C...	2 KB
LTE_UE_SNR_7.csv	12/6/2017 1:01 PM	Microsoft Excel C...	1 KB

2. With the help of Excel tools create a graph between SNR measured by each ENB with respect to time period. Properly set the gaps on x-axis and y-axis so you will get a clear graph.

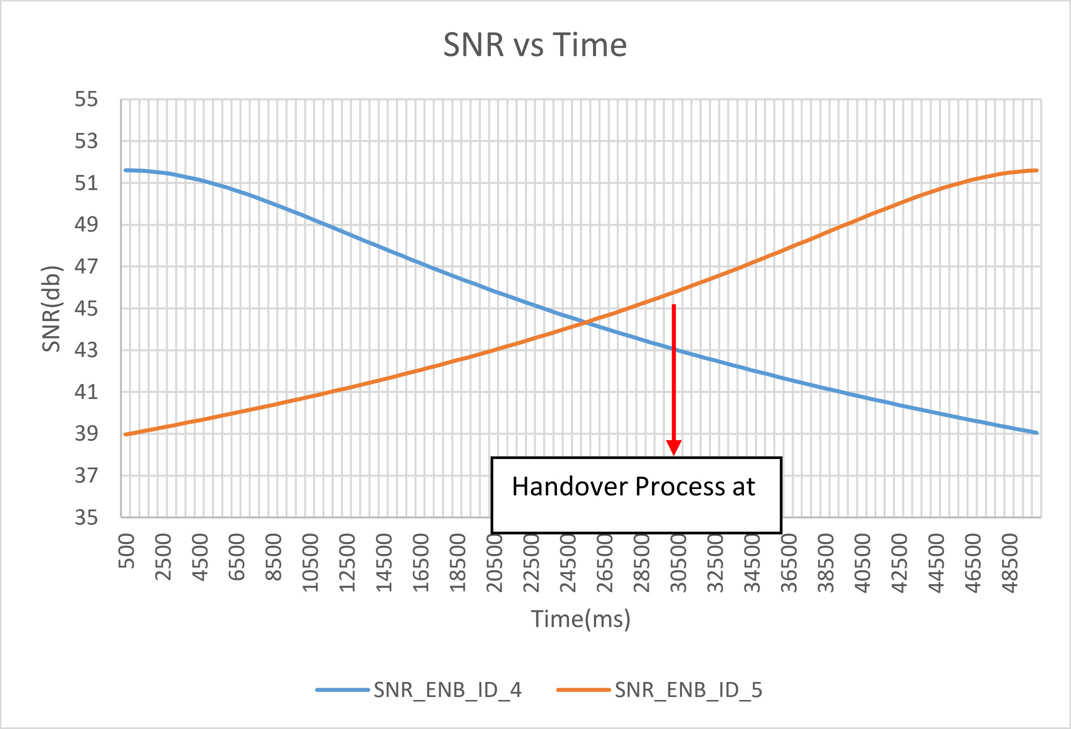


UE_ID	Time	SNR_ENB_	SNR_ENB_ID_5	
6	500000	51.60512	38.96413	
6	1000000	51.59759	39.04661	
6	1500000	51.57506	39.12985	
6	2000000	51.53778	39.21383	

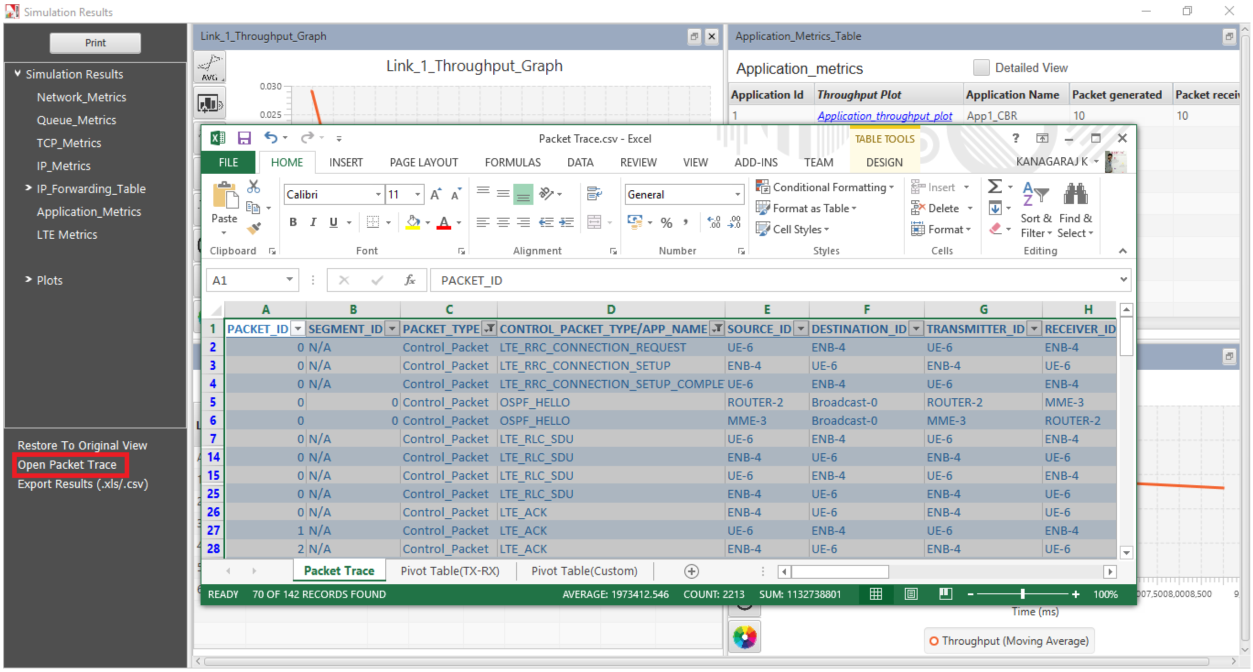
3. Handover occurs when SNR difference between two ENBs is equal to 3 db. So for this scenario find in the graph the time value when SNR_ENB_5-SNR_ENB_4 measured is equal to 3 db.
4. This is the time value at which handover occurs.

Result

Handover occurs when difference between SNR measured by two ENB is equal to 3 db. In below chart Handover occurs when Difference value is equal to 3 on y axis which is between 30.5 sec and 31 sec.



The packet trace file can be accessed from the results window to understand the various packets involved in the handover process.



Application_metrics

Application Id	Throughput Plot	Application Name	Packet generated	Packet recei
1	Application throughput plot	App1_CBR	10	10

A1 PACKET_ID

	A	B	C	D	E	F	G	H
1	PACKET_ID	SEGMENT_ID	PACKET_TYPE	CONTROL_PACKET_TYPE/APP_NAME	SOURCE_ID	DESTINATION_ID	TRANSMITTER_ID	RECEIVER_ID
2	0	N/A	Control_Packet	LTE_RRC_CONNECTION_REQUEST	UE-6	ENB-4	UE-6	ENB-4
3	0	N/A	Control_Packet	LTE_RRC_CONNECTION_SETUP	ENB-4	UE-6	ENB-4	UE-6
4	0	N/A	Control_Packet	LTE_RRC_CONNECTION_SETUP_COMPLE	UE-6	ENB-4	UE-6	ENB-4
5	0	0	Control_Packet	OSPF_HELLO	ROUTER-2	Broadcast-0	ROUTER-2	MME-3
6	0	0	Control_Packet	OSPF_HELLO	MME-3	Broadcast-0	MME-3	ROUTER-2
7	0	N/A	Control_Packet	LTE_RLC_SDU	UE-6	ENB-4	UE-6	ENB-4
14	0	N/A	Control_Packet	LTE_RLC_SDU	ENB-4	UE-6	ENB-4	UE-6
15	0	N/A	Control_Packet	LTE_RLC_SDU	UE-6	ENB-4	UE-6	ENB-4
25	0	N/A	Control_Packet	LTE_RLC_SDU	ENB-4	UE-6	ENB-4	UE-6
26	0	N/A	Control_Packet	LTE_ACK	ENB-4	UE-6	ENB-4	UE-6
27	1	N/A	Control_Packet	LTE_ACK	UE-6	ENB-4	UE-6	ENB-4
28	2	N/A	Control_Packet	LTE_ACK	ENB-4	UE-6	ENB-4	UE-6

Packet Trace | Pivot Table(TX-RX) | Pivot Table(Custom)

READY 70 OF 142 RECORDS FOUND AVERAGE: 1973412.546 COUNT: 2213 SUM: 1132738801 100%

As UE moves from one position to another it sends measurement report to each ENB in range. As it moves SNR received by each ENB keeps on changing based on distance between ENB and UE. If the difference between SNR received by new ENB to that of old ENB to which it is connected gets greater than 3 decibel than at that point handover occurs.

Related Article links:

How to Implement Time to Trigger (TTT) used in LTE Handover Modelling?

How to vary the Handover Margin in LTE?