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# MAPS™ LTE X2 Interface Emulator

LTE X2 Application Protocol Interface Emulation

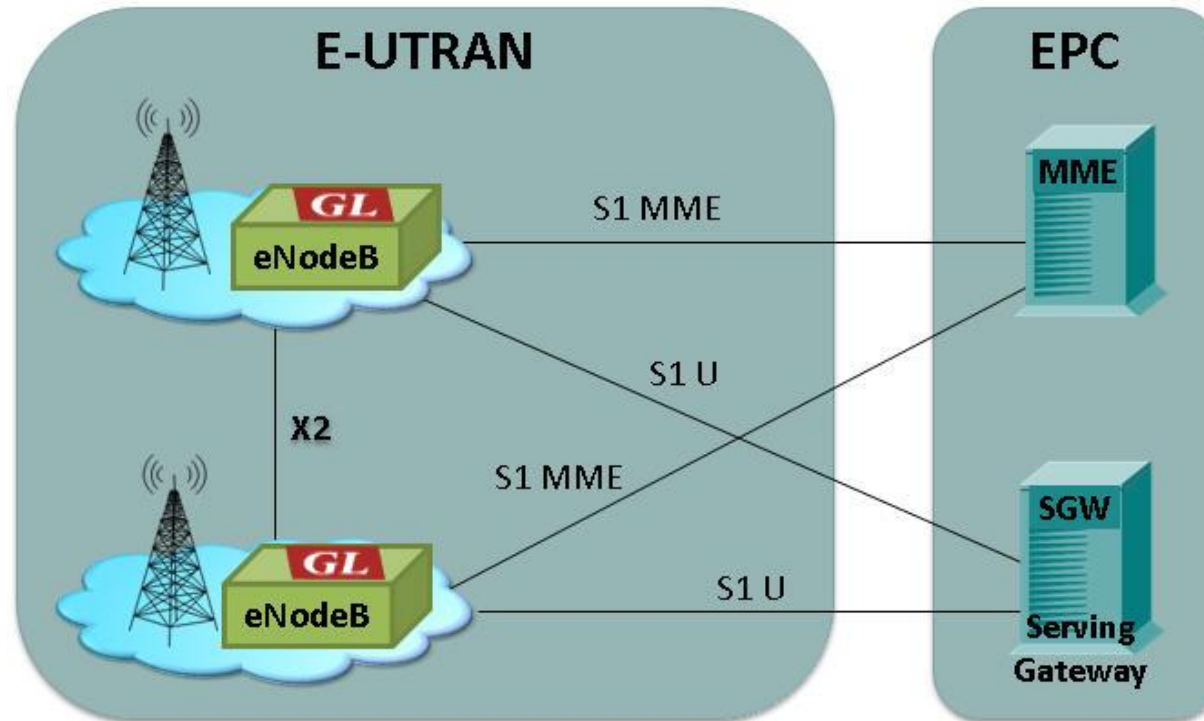
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818 West Diamond Avenue - Third Floor, Gaithersburg, MD 20878  
Phone: (301) 670-4784 Fax: (301) 670-9187 Email: [info@gl.com](mailto:info@gl.com)  
Website: <https://www.gl.com>

# MAPS™ LTE X2-AP Architecture



 MAPS™ X2AP in LTE network

# Main Features

- Setup a virtual real-time network simulating 4G-LTE network elements using 'MAPS™ 4G Wireless Lab Suite'
- Simulate two eNodeB elements in LTE X2-AP interface
- Supports LTE Control plane
- Generates hundreds of UE signaling (Load Testing)
- Generates and process X2-AP (valid and invalid) messages
- Supports Mobility Management, Load Management, Reporting of General Error Situations, Re-setting X2, Setting up the X2, and eNodeB Configuration Update procedures
- Insertion of impairments to create invalid messages
- Supports LTE Conformance designed with 50+ test cases as per 3GPP TS 36.243 Specification

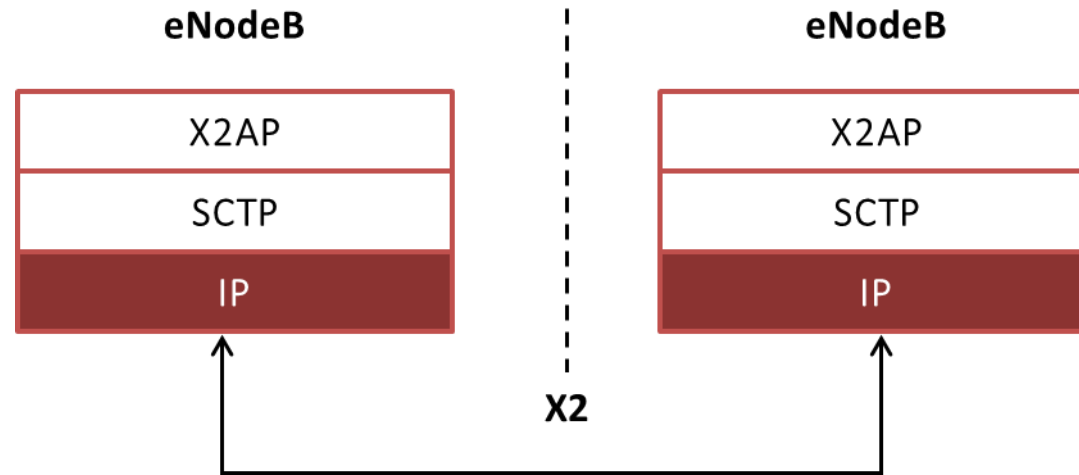
# Applications

- Complete analysis and simulation capability on par with any protocol tester in the market
- Provides fault insertion, and erroneous call flows testing capability
- Functional testing, Regression testing and Conformance testing of network elements
- Ready scripts make testing procedure simpler, less time consuming and hence time to market products
- Simulate Thousands of Smartphones (UEs) powering up and down
- Authenticate and confirm security procedures
- QoS requests for greater or lesser bandwidth
- Temporary addressing management for mobility and security

# Functions

- **Mobility Management** - This enables the serving eNodeB to move the specified UE responsibility to a target eNodeB
- **Load Management** - procedure to report resource status, overload indications and current traffic loading between the eNodeBs
- **Reporting of General Error Situations** - procedure to report general error situations
- **Re-setting /Setting the X2** – procedure to setup or reset X2 interface by exchanging the necessary information between the eNodeBs
- **eNodeB Configuration Update** - procedure to update the application level data required for the eNodeBs to interoperate in the network

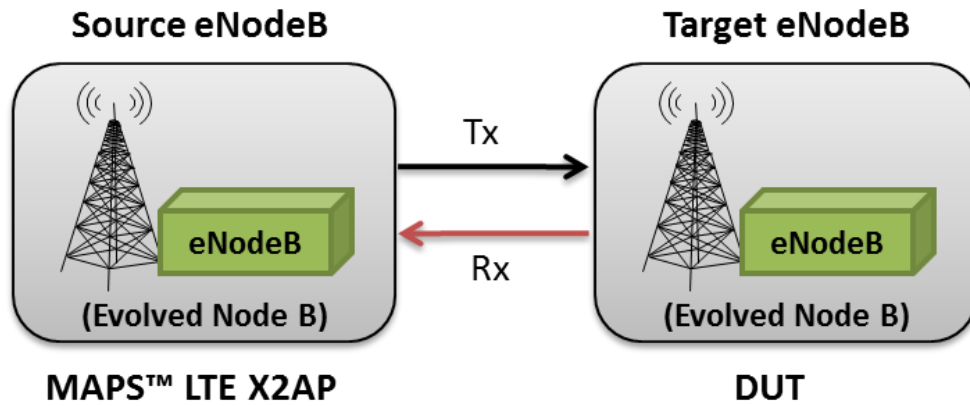
# Protocol Standards



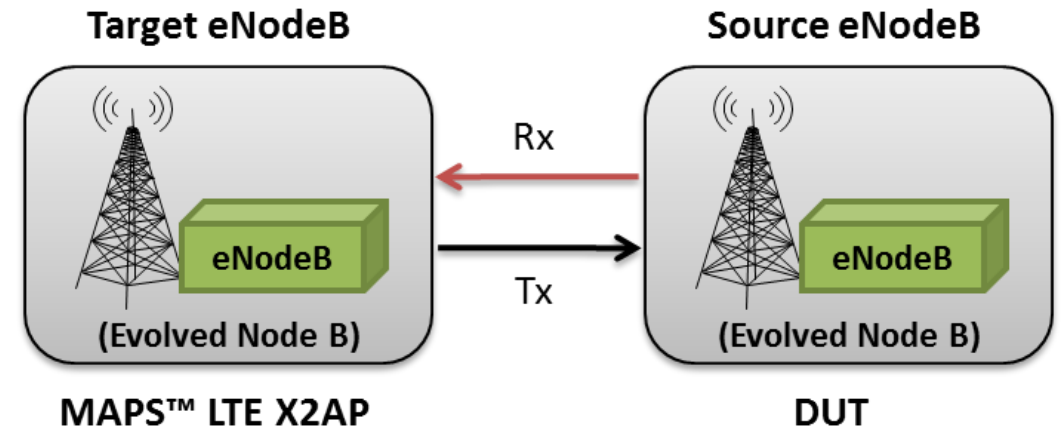
Supported Protocols	Standard / Specification Used
X2 Application Protocol (X2-AP)	3GPP TS 36423-900
SCTP	RFC 4960
Non-Access-Stratum (NAS)	3GPP TS 24.301 V9.0.0 (2009-09)

# LTE X2AP Call Scenario

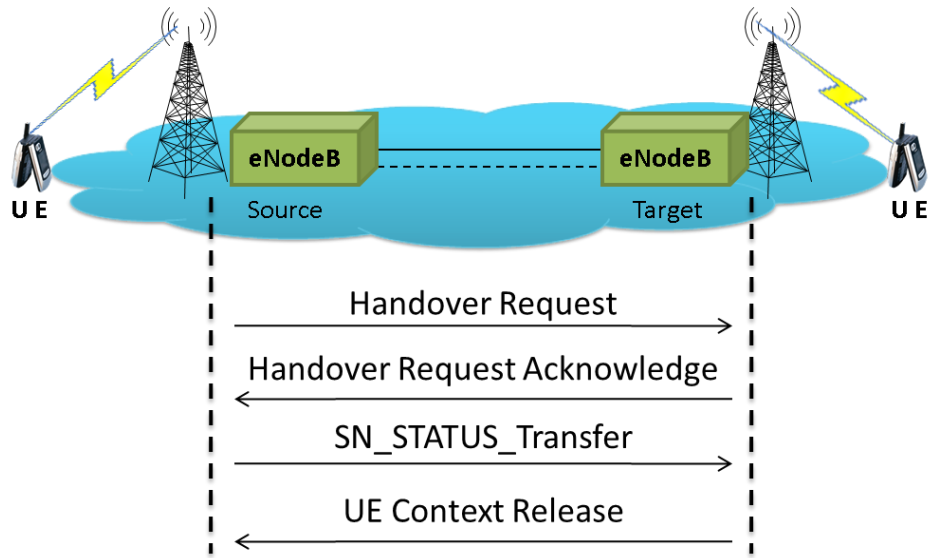
MAPS™ LTE X2AP Configured as Source eNB



MAPS™ LTE X2AP Configured as Target eNB

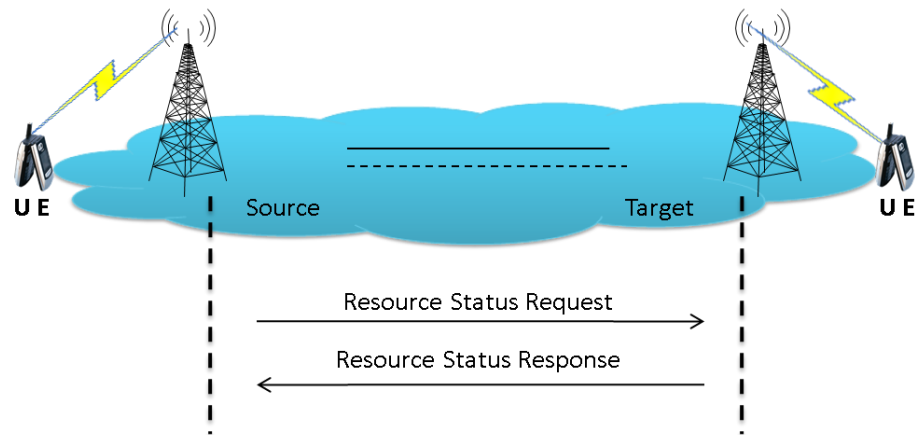


# X2AP Interface Procedures



## Mobility Management

- Handover Preparation
- SN Status Transfer
- UE Context Release
- Handover Cancel



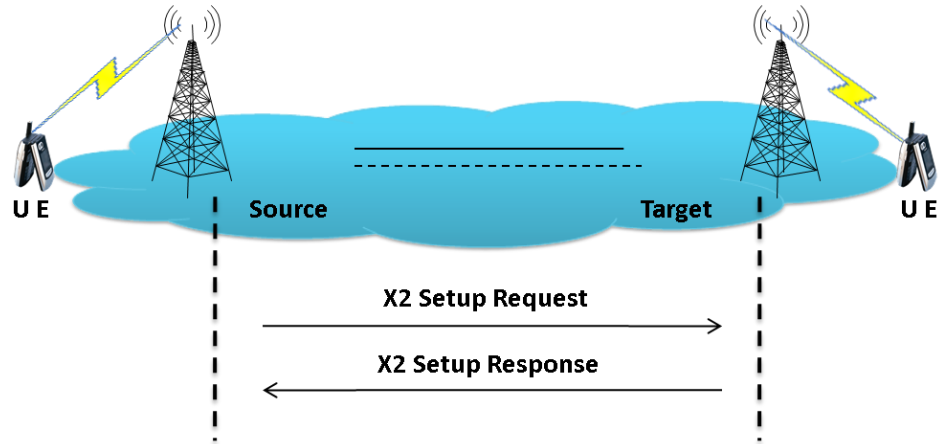
## Load Management

- Load Indication
- Resource Status Reporting Initiation
- Resource Status Reporting

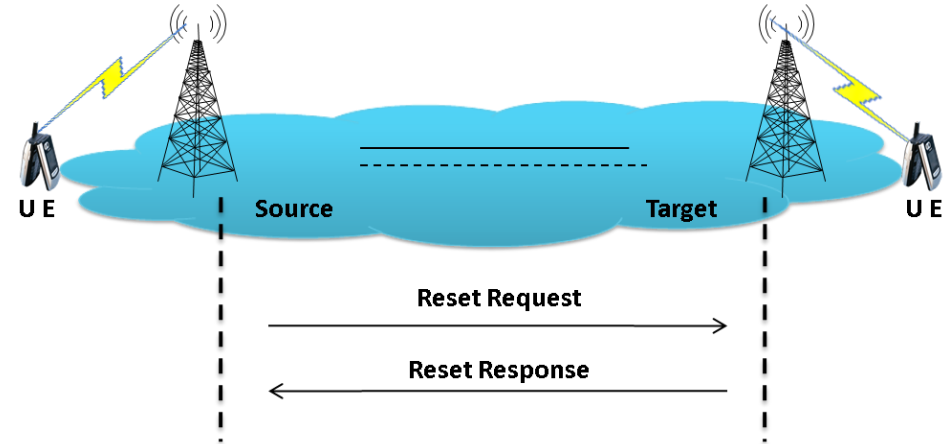


# X2AP Interface Procedures

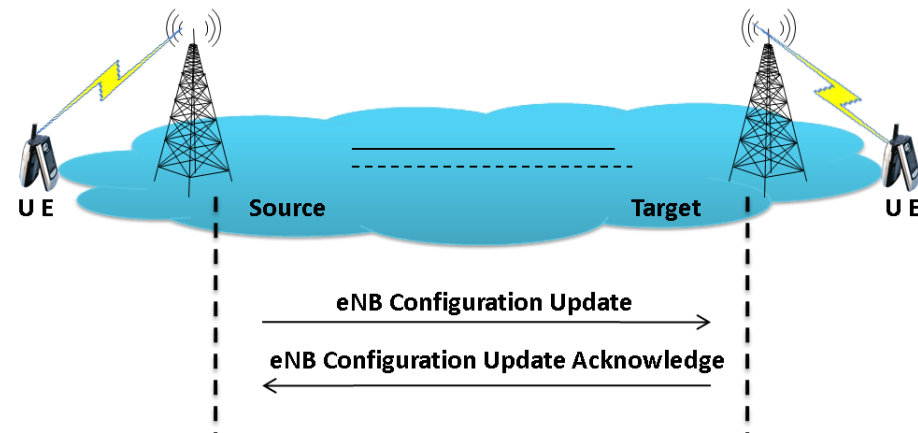
## Resetting the X2



## Setting up the X2



## eNB Configuration Update



# Call Generation

## Call Generation (Source eNodeB)

GL MAPS (Message Automation Protocol Simulation) eNodeB (LTE X2 3GPP) - [Call Generation - CallGenDefault]

Configurations Emulator Reports Editor Debug Tools Windows Help

Sr No	Script Name	Profile	Call Info	Script Execution	Status	Events	Event...	Result	Total Iterations	Completed Iterations
1	X2APSessionController.gls	SourceENBProfile0001	eNBCellID:0x0301E602	Start	UE-Context-Rel	None		Pass	1	1
2	X2APSessionController.gls	SourceENBProfile0002		Start		None		Unknown	1	0
3	X2APSessionController.gls	SourceENBProfile0003		Start		None		Unknown	1	0
4	X2APSessionController.gls	SourceENBProfile0004		Start		None		Unknown	1	0
5	X2APSessionController.gls	SourceENBProfile0005		Start		None		Unknown	1	0
6	X2APSessionController.gls	SourceENBProfile0006		Start		None		Unknown	1	0
7	X2APSessionController.gls	SourceENBProfile0007		Start		None		Unknown	1	0

Add Delete Insert Refresh Start Start All Stop Stop All Abort Abort All

Save Column Width Show Latest

Source-eNodeB Target-eNodeB

```

sequenceDiagram
    participant S as Source-eNodeB
    participant T as Target-eNodeB
    S->>T: HandoverRequest 15:21:29.609000
    T-->S: HandoverRequestAcknowledge 15:21:29.906000
    S->>T: SNStatusTransfer 15:21:29.908000
    T-->S: UEContextRelease 15:21:29.926000
    
```

Find

```

===== X2AP Layer =====
X2AP-PDU = CHOICE
Extensibility Marker = 0
Choice Index = 0
Procedure Code = INTEGER
Contents = 0 id-handoverPreparati
Criticality = ENUMERATOR
Contents = 0 reject(0)
Value = Open Type
Length = 124
Extensibility Marker = 0
ProtocolIE-Container = SEQUENCE OF
Iteration Count = 6
ProtocolIE-Container = Instance 0
ProtocolIE-ID = INTEGER
Contents = 10 id-Old-eNB-UE-X2AP-;
Criticality = ENUMERATOR
Contents = 0 reject(0)
Value = Open Type
Length = 2
Old-eNB-UE-X2AP-ID = INTEGER
    
```

Scripts Message Sequence Event Config Script Flow

Initialisation Errors Error Events Captured Errors Link Status Up=1 Down=0

# Call Generation and Reception

## Call Reception (Target eNodeB)

The screenshot displays the MAPS (Message Automation Protocol Simulation) eNodeB (LTE X2 3GPP) - [Call Reception] interface. The interface is divided into several sections:

- Table of Script Execution Results:**

Sr No	Script Name	Profile	Call Info	Script Execution	Status	Events	Eve...	Results
1	Check_SCTP_Status.gls			Stop	Monitoring SCTP Status	None		Pass
2	GlobalProceduresHandler.gls		eNBID: 0x0401E602	Stop	X2-Setup-Responded	LoadIndication		Pass
3	X2APSessionController.gls		eNBCellID: 0x0401E602	Completed	UE-Context-Released: Handover-Completed	None		Pass

**Message Sequence Diagram:**

The diagram shows the interaction between Source-eNodeB and Target-eNodeB. The messages and their timestamps are:

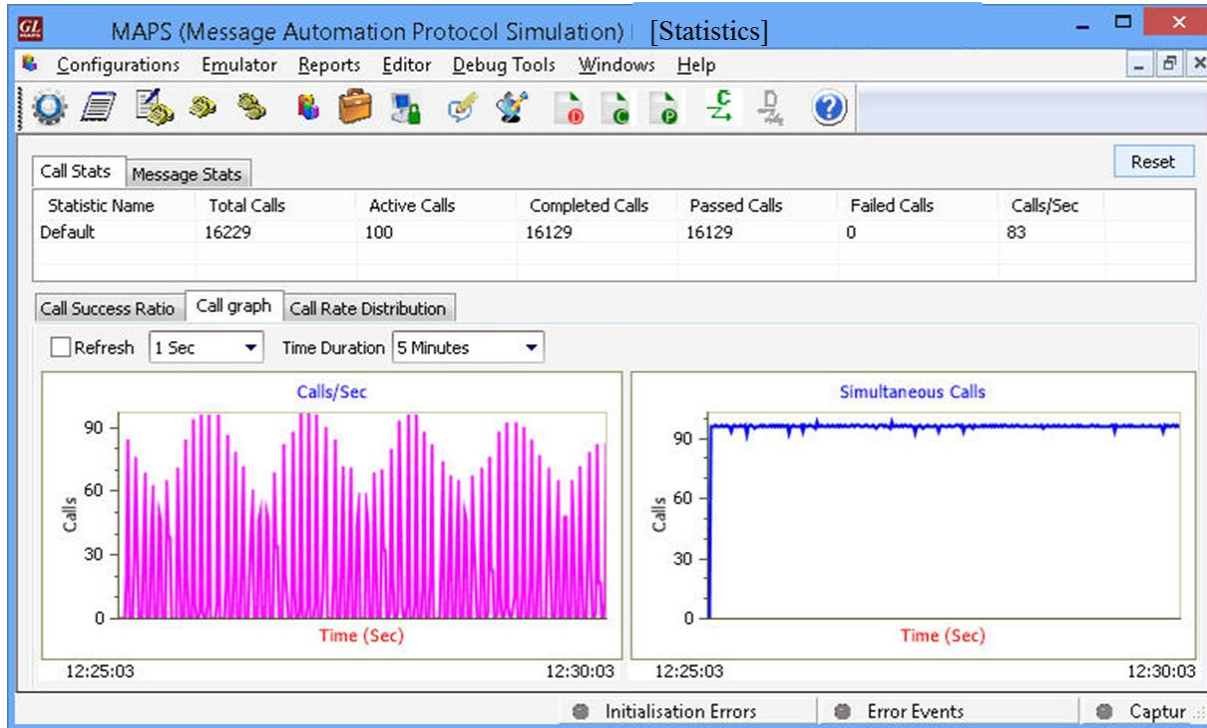
- HandoverRequest (Source-eNodeB to Target-eNodeB) at 15:21:29.808000
- HandoverRequestAcknowledge (Target-eNodeB to Source-eNodeB) at 15:21:29.839000
- SNStatusTransfer (Source-eNodeB to Target-eNodeB) at 15:21:29.917000
- UEContextRelease (Target-eNodeB to Source-eNodeB) at 15:21:29.917000

**X2AP Layer Analysis:**

```
X2AP Layer
=====
X2AP-PDU = CHOICE
Extensibility Marker = 0
Choice Index = 0
Procedure Code = INTEGER
Contents = 0 id-handoverPreparation
Criticality = ENUMERATOR
Contents = 0 reject(0)
Value = Open Type
Length = 124
Extensibility Marker = 0
ProtocolIE-Container = SEQUENCE OF
Iteration Count = 6
ProtocolIE-Container = Instance 0
ProtocolIE-ID = INTEGER
Contents = 10 id-Old-eNB-UE-X2AP-ID
Criticality = ENUMERATOR
Contents = 0 reject(0)
Value = Open Type
Length = 2
Old-eNB-UE-X2AP-ID = INTEGER
Contents = 2
ProtocolIE-Container = Instance 1
```

# Call Statistics and Event Log

## Call Statistics



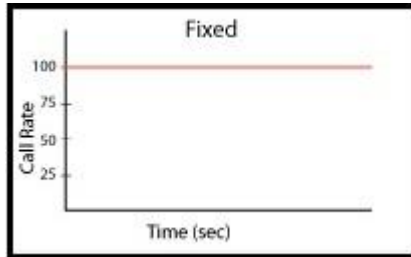
## Event Log

Date/Time	Call Trace Id	Script Id	Captured Events
2013-1-17 15:17:41.236000	2	ProtScriptId_3804857120-4968	HandoverRequested
2013-1-17 15:17:41.236000	2	ProtScriptId_3804857120-4968	Old eNodeB Id ::3
2013-1-17 15:17:41.236000	2	ProtScriptId_3804857120-4968	Handover Cause value ::0
2013-1-17 15:17:41.236000	2	ProtScriptId_3804857120-4968	ERAB ID::1
2013-1-17 15:17:41.236000	2	ProtScriptId_3804857120-4968	Uplink GTP tunnel endpoint::0x23232323
2013-1-17 15:17:41.236000	2	ProtScriptId_3804857120-4968	HandoverAcknowledged
2013-1-17 15:17:41.252000	2	ProtScriptId_3804857120-4968	SN_STATUS_Transfered
2013-1-17 15:17:41.252000	2	ProtScriptId_3804857120-4968	Handover Completed Successfully

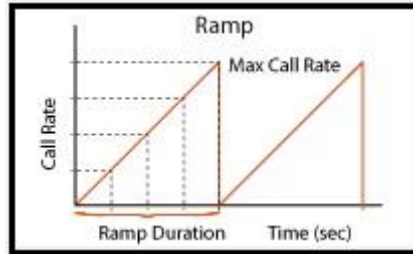
# Load Generation

- Stability/Stress and Performance testing using Load Generation
- Different types of Load patterns to distribute load
- User can load multiple patterns for selected script
- User configurable Test Duration, CPS, Maximum and Minimum Call Rate etc

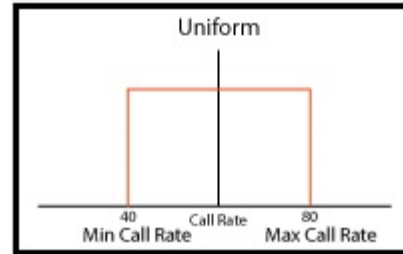
**Fixed**



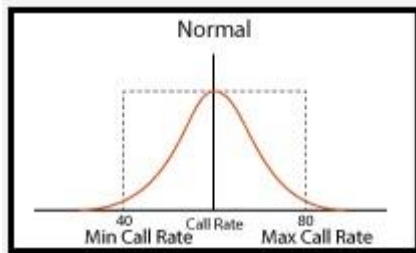
**Ramp**



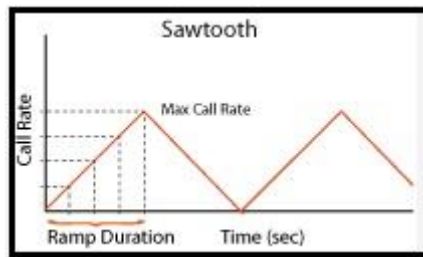
**Uniform**



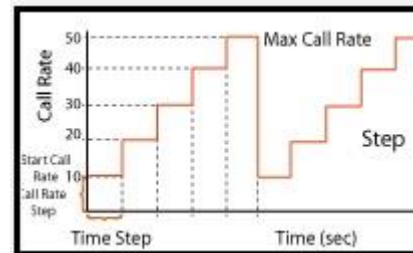
**Normal**



**Saw-tooth**



**Step**



The screenshot shows the 'Load Generation - LoadGendefault' window. It features several configuration options: 'Total Calls To Generate' (set to \*), 'Max Active Calls' (set to 2000), and a checked 'Unique Distributions Per Script' option. There are checkboxes for 'Multi Distributions' and 'Exclusive Profiles'. A 'Statistical Distribution' dropdown is set to 'Fixed', and the 'Call Rate' is set to 100. Below these are two tables: 'Scripts' (containing 'X2APSessionController') and 'Profile' (listing profiles from SourceENBProfile0001 to SourceENBProfile00010). At the bottom, there are 'Add' and 'Delete' buttons for both tables, and a 'Stop Time' section with 'Days', 'Hours', and 'Minutes' dropdowns, and 'Start' and 'End' time fields.

# Testbed Configuration

MAPS (Message Automation Protocol Simulation) eNodeB (LTE X2 3GPP) - [Testbed Setup - Target\_eNB]

Configurations Emulator Reports Editor Debug Tools Windows Help

Config	Value
ENB Configurations	
Traffic Adapter Index	3
eNB	1
eNB 1	
eNodeB IP Address	192.168.13.125
eNodeB Traffic IP Address	192.168.16.120
SCTP Mode	Server
GTP Port For Traffic	2152
eNodeB Id	401E6
eNodeB Name	eNB01
MME Group ID	1234
MME Code	02
PLMN Id	
Mobile Country Code	450
Mobile Network Code	80
Tracking Area Code	0001
Location Area Code	65001
Served Cell Information	
Target eNodeB Parameters	
Target eNodeB	1
Target eNodeB 1	
Target eNodeB IP Address	192.168.13.120
Target eNodeB Port	36422
Source eNodeB Port	36422
GTP Port for Traffic	2152
Target PLMN ID	
Mobile Country Code	001
Mobile Network Code	01
Served Cell Information	
SGW Traffic IP Address	192.168.13.124
Gateway Address	192.168.12.1
Subnet Mask	255.255.255.0
Traffic	Disable
Traffic Type	MobileTraffic
End User Configuration	TargetUE_Profiles.xml

\_AdapterIndex  
Enter Integer  
3

Start Edit

Initialisation Errors Error Events Captured Errors

# Profile Configuration

MAPS (Message Automation Protocol Simulation) eNodeB (LTE X2 3GPP) - [Profile Editor - TargetUE\_Profiles]

Configurations Emulator Reports Editor Debug Tools Windows Help

TargetENBProfile0001

#	Profiles [Edit-F2]	Config	Value	Enable
1	TargetENBProfile0001	TargetENBProfile0001		<input checked="" type="checkbox"/>
2	TargetENBProfile0002	IMSI	001013012041631	
3	TargetENBProfile0003	EUTRAN Cell ID	401E602	
4	TargetENBProfile0004	Target eUTRAN Cell ID	301E602	
5	TargetENBProfile0005	Authentication Parameters		
6	TargetENBProfile0006	Key	00112233445566778899aabbccddeeff	
7	TargetENBProfile0007	Operator Variant Parameter Type	OPc	
8	TargetENBProfile0008	OP	01020304050607080910111213141516	
9	TargetENBProfile0009	OPc	01020304050607080910111213141516	
10	TargetENBProfile0010	SQN	000000000079	
		Handover Information		
		UE Context Information		
		UE Aggregate Maximum Bit Rate		
		UE Aggregate Maximum BitRate DL	1000	
		UE Aggregate Maximum BitRate UL	1000	
		E RAB ID	5	
		QoS Class Identifier	6	
		Handover Preparation Cause	handover-desirable-for-radio-reasons	
		Handover Preparation Failure Cause	cell-not-available	
		Handover Cancel Cause	trelocprep-expiry	
		SN Status Information		
		Uplink PDCP SN	144	
		Uplink HFN	550	
		Downlink PDCP SN	366	
		Downlink HFN	345	
		EndUserAddress	192.168.1.84	
		Mobile Traffic Parameters		
		TCP Server Ip	192.168.12.9	
		TCP port for HTTP	80	
		Transmission Type	Once	
		Start File Count	1	
		Traffic File Name	www.etsi.org	
		File Count For Concurrent Or Sequential	3	
		File Playback Count	1	
		TxFile For Once Transmission From List	1	

Insert Delete Clear

Add Insert Delete Properties

Initialisation Errors Error Events Captured Errors Link Status Up=0 Down=0

# Incoming Call Handler Configuration

Incoming Call Handlers Configuration - default

Message Name	Script Name
ResourceStatusRequest	GlobalProceduresHandler.gls
<b>HandoverRequest</b>	<b>X2APSessionController.gls</b>
X2SetupRequest	GlobalProceduresHandler.gls
ResetRequest	GlobalProceduresHandler.gls
ENBConfigurationUpdate	GlobalProceduresHandler.gls
LoadInformation	GlobalProceduresHandler.gls

Scripts

- X2APSessionController.gls

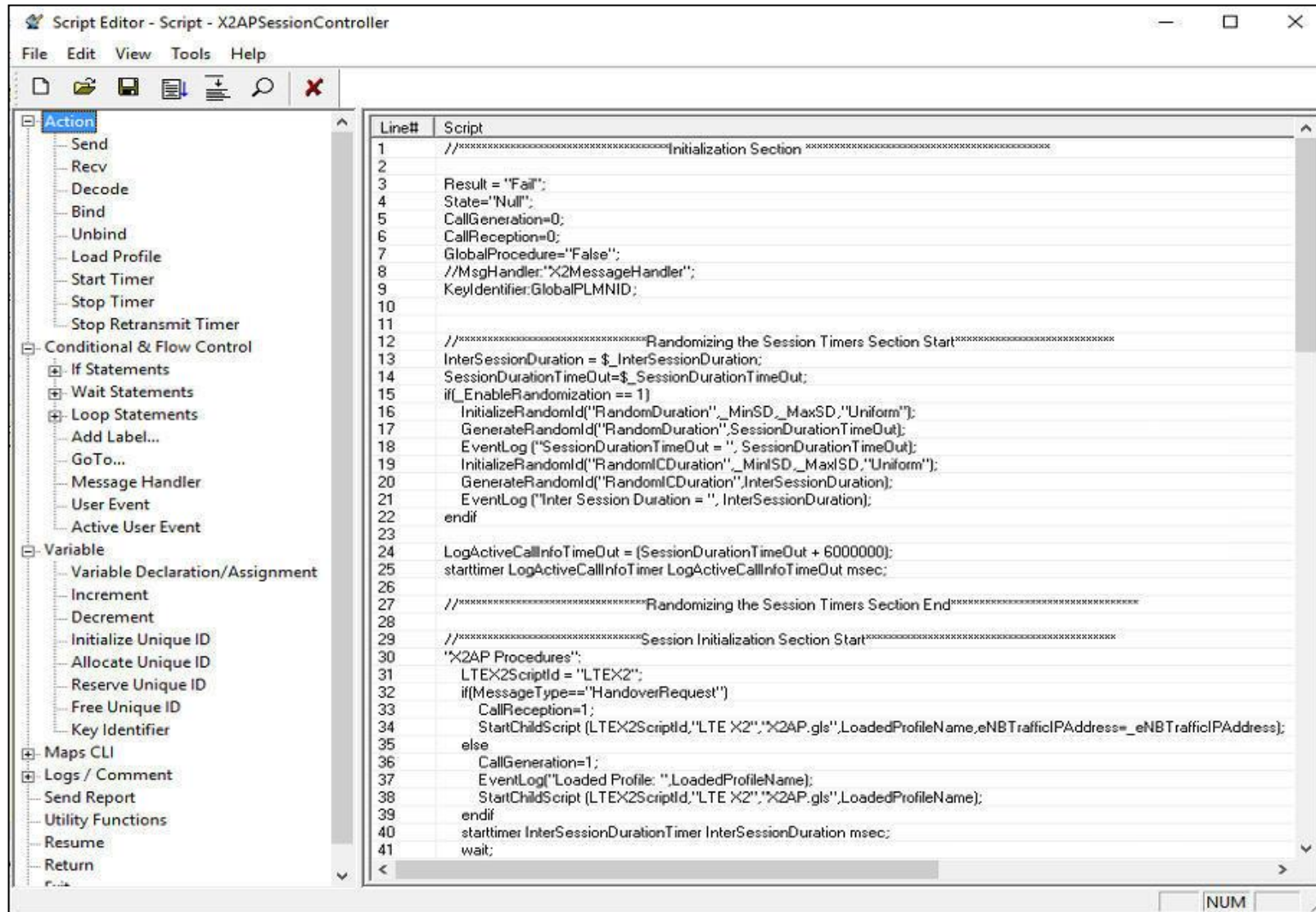
Sequence  
 Random

Up  
Down

Add Delete Clear Scripts Add Delete



# Customizations - Call Flow (Scripts)



Script Editor - Script - X2APSessionController

File Edit View Tools Help

Action

- Send
- Recv
- Decode
- Bind
- Unbind
- Load Profile
- Start Timer
- Stop Timer
- Stop Retransmit Timer
- Conditional & Flow Control
  - If Statements
  - Wait Statements
  - Loop Statements
  - Add Label...
  - GoTo...
  - Message Handler
  - User Event
  - Active User Event
- Variable
  - Variable Declaration/Assignment
  - Increment
  - Decrement
  - Initialize Unique ID
  - Allocate Unique ID
  - Reserve Unique ID
  - Free Unique ID
  - Key Identifier
- Maps CLI
- Logs / Comment
  - Send Report
  - Utility Functions
  - Resume
  - Return

Line#	Script
1	//***** Initialization Section *****
2	
3	Result = "Fail";
4	State="Null";
5	CallGeneration=0;
6	CallReception=0;
7	GlobalProcedure="False";
8	//MsgHandler:"X2MessageHandler";
9	KeyIdentifier:GlobalPLMNID;
10	
11	
12	//*****Randomizing the Session Timers Section Start*****
13	InterSessionDuration = \$_InterSessionDuration;
14	SessionDurationTimeOut=\$_SessionDurationTimeOut;
15	if(_EnableRandomization == 1)
16	InitializeRandomId("RandomDuration",_MinSD,_MaxSD,"Uniform");
17	GenerateRandomId("RandomDuration",SessionDurationTimeOut);
18	EventLog ("SessionDurationTimeOut = ", SessionDurationTimeOut);
19	InitializeRandomId("RandomCDuration",_MinSD,_MaxSD,"Uniform");
20	GenerateRandomId("RandomCDuration",InterSessionDuration);
21	EventLog ("Inter Session Duration = ", InterSessionDuration);
22	endif
23	
24	LogActiveCallInfoTimeOut = (SessionDurationTimeOut + 6000000);
25	starttimer LogActiveCallInfoTimer LogActiveCallInfoTimeOut msec;
26	
27	//*****Randomizing the Session Timers Section End*****
28	
29	//*****Session Initialization Section Start*****
30	"X2AP Procedures";
31	LTEX2ScriptId = "LTEX2";
32	if(MessageType=="HandoverRequest")
33	CallReception=1;
34	StartChildScript (LTEX2ScriptId,"LTE X2","X2AP.gls",LoadedProfileName,eNBTrfficiIPAddress=_eNBTrfficiIPAddress);
35	else
36	CallGeneration=1;
37	EventLog("Loaded Profile: ",LoadedProfileName);
38	StartChildScript (LTEX2ScriptId,"LTE X2","X2AP.gls",LoadedProfileName);
39	endif
40	starttimer InterSessionDurationTimer InterSessionDuration msec;
41	wait;

NUM

# Customizations - Protocol Messages

The screenshot shows the 'Message Editor - HandOverRequest' window. The interface includes a menu bar (File, View, Direction, Tools, Help) and a toolbar with icons for file operations and help. The main area is divided into two panes. The left pane shows a tree view of the message structure:

- X2AP
  - X2AP-PDU
    - InitiatingMessage
      - Procedure Code
      - Criticality
      - ProtocolIE-Container
        - ProtocolIE-Field
          - ProtocolIE-ID
          - Criticality
          - Old-eNB-UE-X2AP-ID
        - ProtocolIE-Field
          - ProtocolIE-ID
          - Criticality
        - cause

The right pane shows a dropdown menu with the selected value: `id-handoverPreparation = 0`.

Below the panes is a hex dump area with the following content:

```
----- X2AP Layer -----  
X2AP-PDU = CHOICE  
Extensibility Marker = 0  
Choice Index = 0  
Procedure Code = INTEGER  
Contents = 0 id-handoverPreparation  
Criticality = ENUMERATOR  
Contents = 0 reject(0)  
Value = Open Type  
Length = 122  
Extensibility Marker = 0  
ProtocolIE-Container = SEQUENCE OF  
Iteration Count = 6  
ProtocolIE-Container = Instance 0  
ProtocolIE-ID = INTEGER  
Contents = 10 id-Old-eNB-UE-X2AP-ID  
Criticality = ENUMERATOR  
Contents = 0 reject(0)  
Value = Open Type  
Length = 2  
Old-eNB-UE-X2AP-ID = INTEGER  
Contents = 2
```

The status bar at the bottom indicates 'Ready' and a 'NUM' button.

# Customizations - Statistics and Reports

MOS, R-Factor

Packet Loss

Packets Discarded

Duplicate Packets

Out-Of-Sequence

Packets

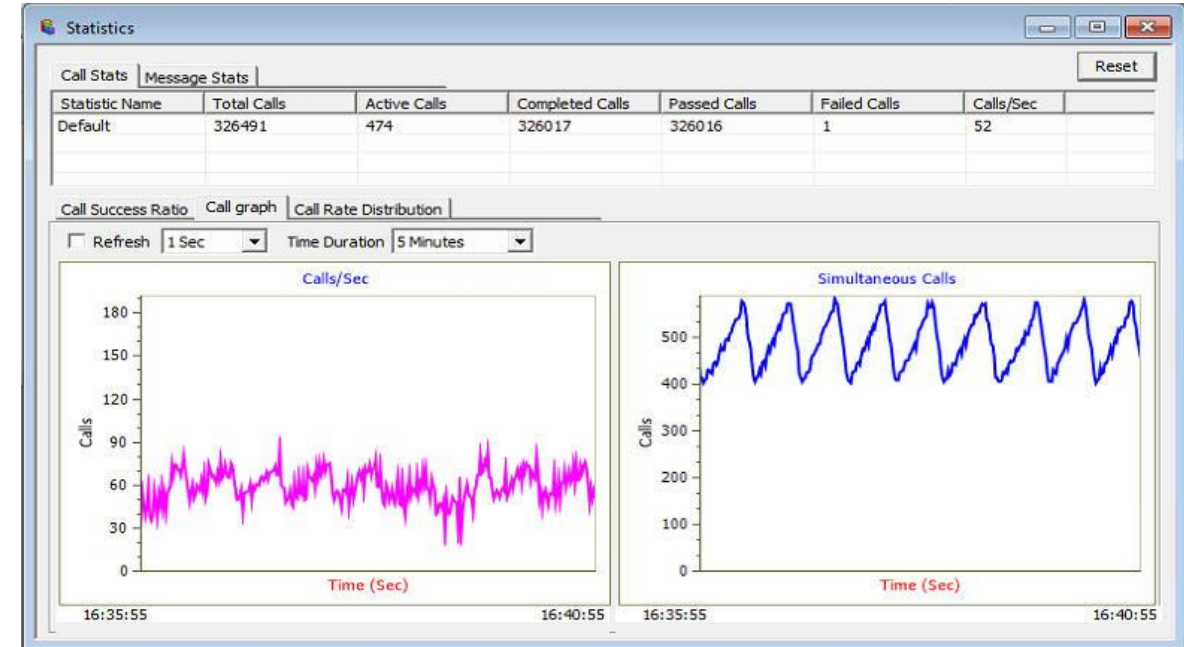
Jitter Statistics

User Defined Statistics - VoiceQualityStats

Packet Stats

Name	Values
Active RTP Sessions	1987
Completed RTP Sessions	1548093
Sessions With Zero Receive Traffic	0
MOS Score Stats	0
Sessions with Mos ( 5.0 - 4.0 )	612618 [39%]
Sessions with Mos ( 4.0 - 3.0 )	852971 [55%]
Sessions with Mos ( 3.0 - 2.0 )	73446 [4%]
Sessions with Mos ( < 2.0 )	9058 [0%]
Total RTP Packet Sent	4485008797
Total RTP Packet Received	4481760883
Packet-Loss Stats	0
Total PacketLoss	4072 [0%]
Sessions with Zero Packet-Loss	1534967 [99%]
Sessions with Packet-Loss(<1%)	13126 [0%]
Sessions with Packet-Loss(1% - 5%)	0 [0%]
Sessions with Packet-Loss(5% - 10%)	0 [0%]
Sessions with Packet-Loss(>10%)	0 [0%]
Packet-Discarded Stats	0
Total PacketDiscarded	3738934 [0%]
Sessions with Zero Packet-Discard	1464299 [94%]
Sessions with Packet-Discard(<1%)	41479 [2%]
Sessions with Packet-Discard(1% - 5%)	37232 [2%]
Sessions with Packet-Discard(5% - 10%)	4843 [0%]
Sessions with Packet-Discard(>10%)	240 [0%]
Packet-Duplicate Stats	0
Total Duplicate Packet	0 [0%]
Sessions with Zero Duplicate Packets	1539942 [99%]
Sessions with Duplicate Packets(<1%)	0 [0%]
Sessions with Duplicate Packets(1% - 5%)	0 [0%]
Sessions with Duplicate Packets(5% - 10%)	0 [0%]
Sessions with Duplicate Packets(>10%)	0 [0%]
Packet-Out Of Sequence Stats	0 [0%]
Total Out Of Sequence Packet	0 [0%]
Sessions with Zero OOS Packets	1539942 [99%]
Sessions with OOS Packets(<1%)	0 [0%]
Sessions with OOS Packets(1% - 5%)	0 [0%]
Sessions with OOS Packets(5% - 10%)	0 [0%]
Sessions with OOS Packets(>10%)	0 [0%]
Jitter Stats	0
Sessions with Jitter( < 1 msec)	1450779 [93%]
Sessions with Jitter( < 5 msec)	93031 [6%]
Sessions With Jitter( < 10 msec)	4841 [0%]
Sessions With Jitter(>= 10 msec)	350 [0%]

Insert Add Delete Edit



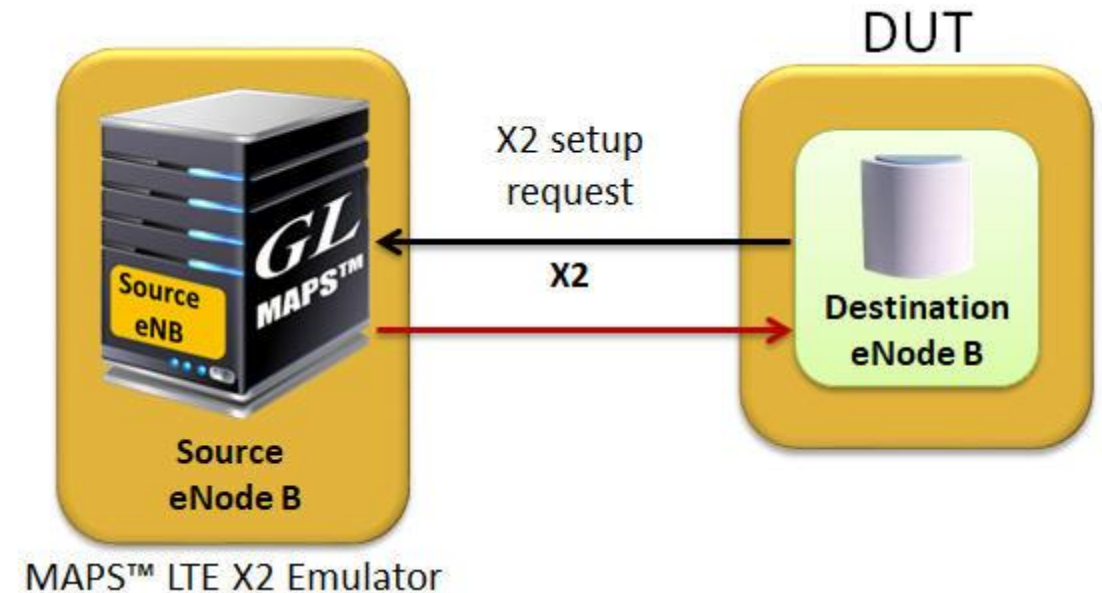
Call Stats provide a running tabular log of system level stats, tracked stats include: Total Calls, Active Calls, Completed Calls, Passed Calls, Failed Calls, Instantaneous Calls/Sec

# LTE-X2 Conformance Suite

MAPS™ LTE X2 emulator can be configured as **Source eNodeB** connected to DUT (Target eNodeB). The conformance script can simulate various procedures conforming success/failure test cases and automating the entire Target eNodeB (DUT) testing.

Following are the supported test cases -

- Handover Test Case
  - Handover success
  - Handover failure (invalid GTP-TEID, duplicated E-RAB ID)
- Load Indication (send load to and receive load from target eNodeB)
- Error Indication (send error to and receive error from target eNodeB)
- X2 Setup
  - X2 Setup Success
  - Setup failure and resend setup
- Configuration update
  - Send/receive configuration update
  - Configure update success after re-send
  - Resend Configuration update after failure
  - Response Configuration update failure



# LTE-X2 Conformance Suite

## X2 Setup Success Conformance

Sr No	Script Name	Profile	Call Info	Script Execution	Status	Monitoring SCTP Status	Events	Event	Results
1	Check_SCTP_Status.gls			Stop		Monitoring SCTP Status	None		Pass
2	GlobalProceduresHandler.gls		eNBID: 0x01A2E001	Stop		X2Setup-Responded	LoadIndication		Pass

## X2 Setup Failure Cause Conformance

Sr No	Script Name	Profile	Call Info	Script Execution	Status	Monitoring SCTP Status	Events	Event	Results
1	Check_SCTP_Status.gls			Stop		Monitoring SCTP Status	None		Pass
2	GlobalProceduresHandler.gls			Completed		X2 Setup Failure	None		Fail

```

X2AP Layer
-----
X2AP-PDU = CHOICE
Extensibility Marker = 0
Choice Index = 0
Procedure Code = INTEGER
Contents = 6 id-x2Setup
Criticality = ENUMERATOR
Contents = 0 reject(0)
Value = Open Type
Length = 55
Extensibility Marker = 0
ProtocolIE-Container = SEQUENCE OF
Iteration Count = 3
ProtocolIE-Container = Instance 0
ProtocolIE-ID = INTEGER
Contents = 21 id-GlobalENB-ID
Criticality = ENUMERATOR
Contents = 0 reject(0)
Value = Open Type
Length = 5
Extensibility Marker = 0
Preamble = 0
pLMN-Identity = OCTET STRING
000C MCC = 001
000D MNC = 01
eNB-ID = CHOICE
Extensibility Marker = 0
Choice Index = 1
home-eNB-ID = BITSTRING
Contents = 0301E602
ProtocolIE-Container = Instance 1
    
```

**THANK YOU**