BLACK BOOK

Long Term Evolution - Access

ixia
A Keysight Business

Our goal in the preparation of this Black Book was to create high-value, high-quality content. Your feedback is important to help guide our future books.

If you have comments regarding how we could improve the quality of this book, or suggestions for topics to be included in future Black Books, contact us at ProductMgmtBooklets@ixiacom.com.

Your feedback is greatly appreciated!

Contents

How to Read this Book

The book is structured as several standalone sections that discuss test methodologies by type. Every section starts by introducing the reader to relevant information from a technology and testing perspective.

Each test case has the following organization structure:

Overview	Provides background information specific to the test case.
Objective	Describes the goal of the test.
Setup	An illustration of the test configuration highlighting the test ports, simulated elements and other details.
Step-by-Step Instructions	Detailed configuration procedures using Ixia test equipment and applications.
Test Variables	A summary of the key test parameters that affect the test's performance and scale. These can be modified to construct other tests.
Results Analysis	Provides the background useful for test result analysis, explaining the metrics and providing examples of expected results.
Troubleshooting and Diagnostics	Provides guidance on how to troubleshoot common issues.
Conclusions	Summarizes the result of the test.

Typographic Conventions

In this document, the following conventions are used to indicate items that are selected or typed by you:

- **Bold** items are those that you select or click on. It is also used to indicate text found on the current GUI screen.
- *Italicized* items are those that you type into fields.

Dear Reader

Ixia's Black Books include network, application, and security test methodologies that will help you become familiar with new technologies and the key testing issues associated with them.

The Black Books are primers on technology and testing. They include test methodologies to verify device and system functionality and performance. The methodologies are universally applicable to any test equipment. Step-by-step instructions use Ixia's test platforms and applications to demonstrate the test methodology.

Our library of Black Books includes twenty-two volumes that cover key technologies and test methodologies:

Volume 1 – Network Security

Volume 2 – Application Delivery

Volume 3 – QoS Validation

Volume 4 – Voice over IP

Volume 5 – Video over IP

Volume 6 – LTE Access

Volume 7 – LTE Evolved Packet Core

Volume 8 – Carrier Ethernet

Volume 9 – IPv6 Transition Technologies

Volume 10 – Converged Data Center

Volume 11 –Converged Network Adapters

Volume 12 – Network Convergence Testing

Volume 13 –Ethernet Synchronization

Volume 14 – Advanced MPLS

Volume 15 – MPLS-TP

Volume 16 – Ultra Low Latency (ULL) Testing

Volume 17 – Network Impairment

Volume 18 – Test Automation

Volume 19 – 802.11ac Wi-Fi Benchmarking

Volume 20 – SDN/OpenFlow

Volume 21 – Audio Video Bridging

Volume 22 – Automotive Ethernet

These Black Books are available in Ixia's online Resources Library.

We are committed to helping our customers build and maintain networks that perform at the highest level, ensuring end users get the best application experience possible. We hope this Black Book series provides valuable insight into the evolution of our industry, and helps customers deploy applications and network services—in a physical, virtual, or hybrid network configurations.

Bethany Mayer, Ixia President and CEO

Long Term Evolution Access

Test Methodologies

This document covers the Long Term Evolution (LTE) Access wireless technology. The document presents a general overview of LTE technology market followed by key test scenarios for an eNode B. This Blackbook introduces both the Ixia IxLoad Access and IxCatapult Access products. LTE Evolved Packet Core (EPC) is detailed in its own Black Book.

LTE Overview

The Third Generation Partnership Project (3GPP) conducted the "Evolved UTRA and UTRAN" study, finalized in September 2006, to define the long term evolution (LTE) of the 3GPP wireless access technology. A parallel study known as system architecture evolution (SAE) defined the evolution of the wireless core network.

Important objectives of LTE include:

- Reduced latency
- Higher data rates
- Faster connection times
- Improved system capacity
- Improved system coverage
- Reduced operator cost

In order to achieve these objectives, 3GPP defines a new radio interface and evolved radio access network architecture. LTE provides users with an always-on IP connectivity service.

SAE defines the evolved packet core (EPC) network architecture for LTE. The EPC simplifies connectivity with 3GPP and 3GPP2 technologies as well as Wi-Fi and fixed line broadband networks.

The LTE access network, which consists of base stations known as evolved Node Bs (eNode Bs), is known as the evolved universal terrestrial radio access network (E-UTRAN). The evolved packet system (EPS) consists of E-UTRAN combined with an EPC.

LTE Requirements and 3GPP Evolution

The 3GPP release 8 specifications define new requirements for LTE technology. Some of these requirements are:

- Scalable bandwidth
    - 1.4, 3.0, 5.0, 10.0, 15.0, and 20 MHz bandwidths in both uplink and downlink directions
- Operation in both paired and unpaired spectrum (FDD and TDD modes)
- Significantly increased peak data rates, scaled according to the size of the bandwidth allocation:
    - Downlink peak data rate of 300 Mbps with a 20 MHz downlink bandwidth when using a 4x4 multiple-input multiple-output (MIMO) antenna configuration
    - Uplink peak data rate of 75 Mbps with a 20 MHz uplink bandwidth when using a single-input single-output (SISO) antenna configuration
    - Uplink peak data rate of 150 Mbps with a 20 MHz uplink bandwidth when using multi-user MIMO
- Improved system performance
    - A two- to four-fold increase in performance in downlink bit rates compared with basic Release 6 system high speed downlink packet access (HSPDA) when using a maximum of two transmit antennas at the eNode B and two receive antennas at the user equipment (UE).

- A two- to three-fold increase in performance in uplink bit rates compared with basic Release 6 system enhanced dedicated channel (E-DCH) when using a single transmit antenna at the UE and two receive antennas at the eNode B.
- Significantly reduced control plane latency
  - Transition time of less than 100ms from a camped state to an active state (excluding downlink paging delay and non-access stratum (NAS) signaling delay).
- Control plane capacity
  - At least 200 users per cell must be supported in an active state with spectrum allocations of up to 5 MHz and at least 400 users per cell with spectrum allocations greater than 5 MHz.
- Significantly reduced user plane latency
  - User plane latency of less than 5ms in an unloaded condition (a single user with a single data stream) and a small IP packet size (0 byte payload) calculated as the one-way transit time between the access network edge node and the UE at the IP layer in both the uplink and downlink directions.
- Interwork with other wireless technologies
  - GSM and UMTS
  - CDMA2000 1xRTT and high rate packet data (HRPD)

The 3GPP Release 9 specification baseline was set in the December 2009 specification release. Release 9 is now being adopted by eNode B manufacturers.

Key new features available in Release 9 are as follows:

- Multicast, MCH, eMBMS support
- Home eNode Bs, Femtocells and Picocells
- Emergency Bearer Services
- UE Positioning with Positioning Reference Signals
- Transmission Mode 8, a Beam Forming mode extending TM7 under 2x2 MIMO
- DCI Format 2B

Release 9 NAS protocol updates include messages for the following:

- Uplink/Downlink Generic NAS Transport
- Notification
- NF Capability
- LSC (Location Services)

Release 9 RRC protocol updates include messages for the following:

- Proximity
- UE Information
- MBMS
- SIBs 12,13
- UE CMAS

The evolution of 3GPP mobile technology for FDD and TDD modes is shown in Table 1.

Table 1. Evolution of 3GPP FDD and TDD Technology

FDD evolution	TDD evolution	3GPP release	Network rollout year	Peak DL data rate	Peak UL data rate	Latency (round trip)
WCDMA	TD-SCDMA	Release 99/4	2003/2004	384 kbps	128 kbps	150 ms
HSDPA/HSUPA	TD-HSDPA	Release 5/6	2005/2006 (HSDPA) 2007/2008 (HSUPA)	14 Mbps	5.7 Mbps	100 ms
HSPA+	TD-HSUPA	Release 7	2008/2009	28 Mbps	11 Mbps	50 ms
LTE and HSPA+	TD-LTE and TD-HSPA+	Release 8	2010	LTE: 150 Mbps (2x2 MIMO and 20 MHz bandwidth) HSPA+: 42 Mbps	LTE: 75 Mbps; HSPA+: 11 Mbps	LTE: 10 ms
LTE Advanced		Study item initiated		High mobility: 100 Mbps Low mobility: 1Gbps		

The LTE Market

Informa predicts a dramatic increase in the use of advanced mobile applications, such as mobile browsing and video, and predicts that mobile video traffic will grow by a factor of 30 by 2012. In fact, mobile video traffic could overtake voice traffic by 2011. Since the design, rollout and operation of mobile networks has always been driven by voice, the future dominance of data traffic will have a significant impact on the design of future mobile networks.

In voice dominated networks, in the past revenue has closely been correlated with traffic, but in data dominated networks this relationship is not true because the value to application users is no longer proportional to data volume.

In data dominated networks, to remain profitable the per bit cost must be reduced for operators, as shown in Figure 1. One way to do this is to optimize the network by moving from a voice traffic oriented architecture to a data traffic oriented architecture such as LTE.

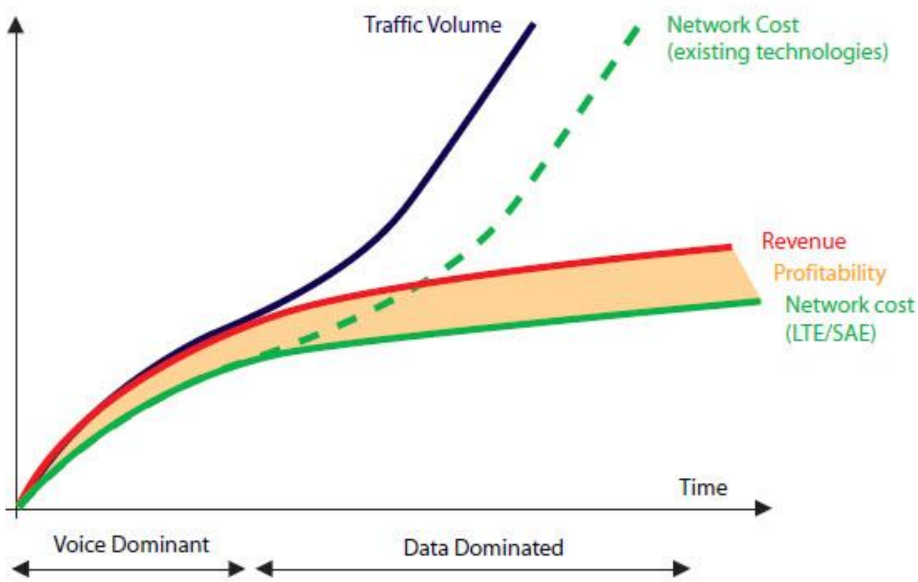


Figure 1. Divergence between Traffic Volume and Revenue over Time (Source: Nokia Siemens Networks)

LTE promises to deliver the massive capacity required for the shift in mobile traffic patterns from voice to data and video at a lower cost compared to previous 3GPP technologies. Analysys Mason, in a study presented to the UMTS Forum in 2008, estimated that dual band 10 MHz (2x10 MHz) deployment of 10,000 eNode Bs would provide a significant increase in downlink capacity over a comparable 3GPP HSPA deployment, as shown in Figure 2. According to the Analysys Mason study, the cost per megabit could drop by a factor of three in going from HSPA (2x5 MHz) to LTE (2x5 MHz).

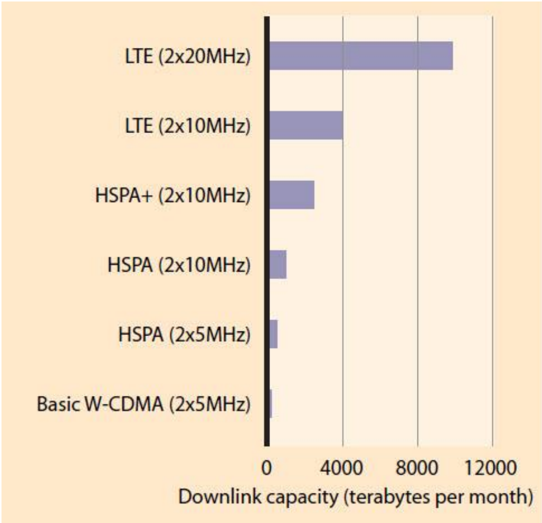


Figure 2. Estimated Network Capacities for a Typical 10,000 Base Station Deployment (Source: Analysys Mason, 2008)

LTE offers a number of upgrade paths for operators of 3GPP and non-3GPP networks, as shown in Figure 3. LTE is the next step on the roadmap of 3GPP cellular systems that includes GSM, GPRS, EDGE, UMTS (WCDMA) and HSPA. LTE also fulfills the goal of harmonious coexistence with legacy circuit switched systems through the EPC, as shown in Figure 3.

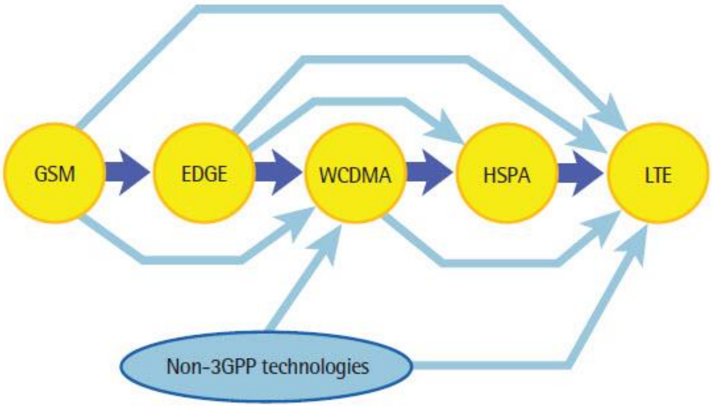


Figure 3. Upgrade Paths to LTE (Source: UMTS Forum, *Towards Global Mobile* Broadband, 2008)

Infonetics explains that the LTE infrastructure market is expected to grow at a compound annual growth rate of 56% to $5 billion by 2013, driven by E-UTRAN deployment during this period (see Figure 4). The market for E-UTRAN is expected to reach $4.7 billion by 2013, while the market for EPC is expected to reach $350 million by the same time.

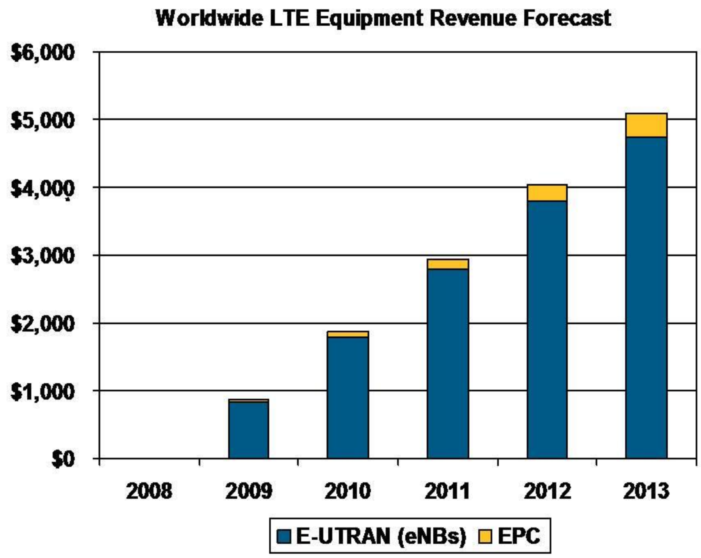


Figure 4. Worldwide LTE Equipment Revenue Forecast (Source: Infonetics, *Infrastructure and Subscribers*, April 2009); Note: eNode B has been abbreviated as eNB in the figure

In addition, according to Infonetics, the number of LTE subscribers could exceed 72 million by 2013, largely split between the Asia Pacific and North American regions. NTT Docomo, KDDI, Verizon Wireless and AT&T are expected to deploy the technology during this time frame. Europe is expected to lag behind because it is deploying HSDA+ in the interim between HSDA and LTE, as shown in Figure 5.

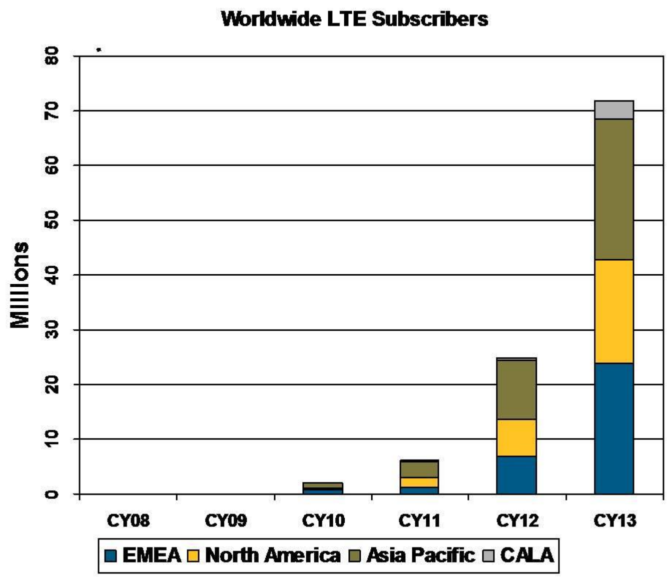


Figure 5. Worldwide LTE Subscribers (Source: Infonetics, *Infrastructure and Subscribers*, April 2009)

Technical deployments of LTE are expected in the last half of 2009 and commercial offerings are expected between 2010 and 2012.

The Global Mobile Suppliers Association (GSA) conducted a study of LTE commitments worldwide. The study was released on August 26, 2009. The study shows growing support and commitment to LTE as the next broadband technology. Verizon Wireless and NTT Docomo are scheduled to introduce commercial LTE service in the U.S. and Japan, respectively, in 2009-2010 and 2010. In 2010, an additional eleven carriers are expected to launch LTE services in Canada, Japan, Norway, South Korea, Sweden and the U.S. According to the GSA study, it is anticipated that by the end of 2012 at least 31 carriers located in 14 countries will have launched LTE services.

EPS Architecture

Compared to the UMTS and GSM architectures that preceded it, LTE reduces the number of network elements and eliminates the circuit-switched domain. The LTE architecture defines the evolved packet system (EPS) as a combination of the IP-based core network and LTE access system. The EPS consists of the E-UTRAN and the EPC, as illustrated in Figure 6. The EPC is the LTE core network and the E-UTRAN is the LTE access network. The E-UTRAN consists of E-UTRAN Node B (eNode B) network elements.

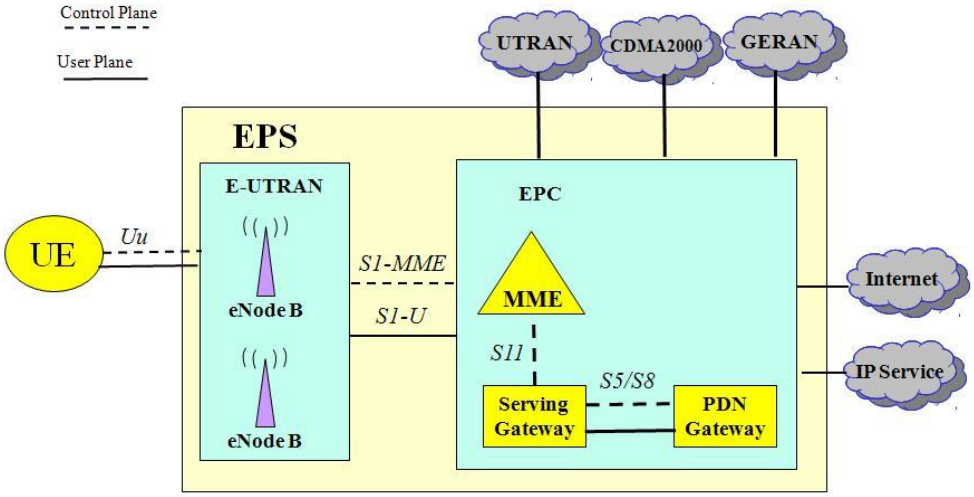


Figure 6. EPS Architecture

The EPC contains the following:

- Mobility management entity (MME)—terminates control plane signaling between the EPC and the UE as well as between the EPC and the E-UTRAN. The MME also contains bearer management functions and inter-core network mobility to other access networks such as UTRAN (UMTS) and GERAN (GSM) or to other MME.
- Serving gateway (S-GW)—a gateway that terminates the EPC user plane interface towards the E-UTRAN. For each UE associated with the EPS, there is a single S-GW.
- Packet data network (PDN) gateway (PDN-GW)—a gateway that terminates the user plane interface towards a PDN. There is a PDN-GW for each PDN accessed by the UE. The eNode B is a much more complex network element than its counterparts, the Node B in UMTS and the BTS in GSM, as it operates without a central controller (RNC or BSC). The functions of the central controller is performed by the eNode B itself in LTE, elevating the critical role of the base station in the LTE architecture.

An eNode B interconnects with other eNode Bs over the X2 interface and to the EPC over the S1 interface. The S1 interface is composed of the S1-MME control plane interface to the MME and the S1-U user plane interface to the S-GW. The Uu interface defines the radio interface between the eNode B and the user equipment (UE).

In the EPC the S5 (non-roaming) or S8 (roaming) reference point lies between S-GW and PDN-GW. The S11 interface reference point is defined between MME and S-GW.

QoS Control in the EPS

The units of QoS control in the EPS are the EPS bearer between the PDN-GW (sometimes denoted as P-GW) and the UE, and the E-UTRAN radio access bearer (E-RAB) between the S-GW and the UE. Each packet flow mapped to the same EPS bearer receives identical bearer-level packet forwarding treatment and is assigned the same QoS class. Provisioning of different packet forwarding treatments to different packet flows requires the establishment of separate bearers.

Each QoS class and UE IP address combination requires a separate bearer, and each UE IP address is associated with a single access point name (APN). The APN is a reference used to identify a PDN to which the UE may connect. The APN itself is a name that may be used in a DSN query to resolve the IP address of the appropriate PDN-GW. One bearer, known as the default bearer, remains established throughout the lifetime of the PDN connection. Additional EPS bearers, known as dedicated bearers, may be established to the same APN, but with different QoS classes, and are also associated with the same UE IP address. A single UE may connect to multiple APNs and hence may be assigned multiple UE IP addresses.

The indicator of QoS class throughout the EPS is the QoS Class Indicator (QCI). The QCI is a scalar that is associated to each individual bearer assigned to a UE. It establishes, for each network node, the QoS parameters and forwarding handling of the packets within each data flow. The delay budget, packet error loss rate and priority are all characteristics of a flow derived from the QCI associated bearer carrying the data flow. The 3GPP has defined the specific set of supported QCIs, and this QoS classes to be used in the EPS.

These QCI values are shown in Table 2.

Table 2. Standard QCI values

QCI	Resource Type	Priority	Packet Delay Budget	Packet Error Loss Rate	Example Services
1	GBR	2	100 ms	10-2	Conversational Voice
2		4	150 ms	10-3	Conversational Video (Live Streaming)
3		3	50 ms	10-3	Real Time Gaming
4		5	300 ms	10-6	Non-Conversational Video (Buffered Streaming)
5	Non-GBR	1	100 ms	10-6	IMS Signaling
6		6	300 ms	10-6	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
7		7	100 ms	10-3	Voice, Video (Live Streaming) Interactive Gaming
8		8	300 ms	10-6	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.
9		9			

The EPS supports the following types of bearer:

- guaranteed bit rate (GBR)
- non-guaranteed bit rate (non-GBR)

A GBR bearer is permanently assigned network resources at the time of its establishment or modification by the admission control functions resident in the EPS, for example the eNode B. If the traffic carried over a GBR bearer conforms to the QoS assigned to it, congestion related packet losses are expected to be rare. Congestion related packet loss on a non-GBR bearer, however, would not be unexpected.

UE Characteristics

The UE category is a parameter that defines a set of UE uplink and downlink capabilities. The eNode B learns the UE category by using the radio resource control (RRC) UE capability transfer procedure. The 3GPP defines UE categories 1 to 5, assigning each category a different set of fixed capabilities. Based on 3GPP TS 36.306 V8.2.0, the LTE UEs support a wide range of uplink and downlink maximum throughputs and antenna configurations, as shown in Table 3. In addition, each LTE UE has category independent capabilities.

Table 3. Access Characteristics of LTE UE Categories

UE Category	Maximum Downlink Throughput (Mbps)	Maximum Uplink Throughput (Mbps)	Downlink Antenna Configuration	Highest Order Uplink Modulation Scheme
Category 1	10	5	SISO	16 QAM
Category 2	50	25	2x2 MIMO	16 QAM
Category 3	100	50	2x2 MIMO	16 QAM
Category 4	150	50	2x2 MIMO	16 QAM
Category 5	300	75	4x4 MIMO	64 QAM

The ability to support the full range of UE capabilities is needed for both functional and load testing. In load testing situations, the ability to vary the mix of UE capabilities possessed by the simulated or actual UEs is especially advantageous. Radio test tools should support each UE category as well as the full range of category independent UE capabilities.

E-UTRAN Overview

eNode B functions are summarized below:

- Radio resource management, including the following:
    - Radio bearer control
    - Radio admission control
    - Connection mobility control
    - Scheduling of uplink and downlink radio resources
- Data stream compression and encryption
- MME selection from an MME pool when the UE registers with the EPS
- Routing of user plane data to the assigned S-GW
- Scheduling and transmission of paging messages over the radio interface
- Scheduling and transmission of broadcast information over the radio interface
- Scheduling and transmission of earthquake and tsunami information (ETWS) over the radio interface
- Configuration of measurement reporting by the UE for mobility and scheduling
- Measurement of uplink radio signals

LTE Antenna Transmission Schemes

LTE supports the following antenna configurations in the downlink:

- Single input single output (SISO)—a single transmit antenna and a single receive antenna.
- 2x2 multiple input multiple output (2x2 MIMO)—two transmit antennas and two receive antennas.
- 4x4 multiple input multiple output (4x4 MIMO)—four transmit antennas and four receive antennas.

Both 2x2 MIMO and 4x4 MIMO are multi-antenna configuration schemes that utilize the multipath phenomenon that produces constructive and destructive interference at the receiver. Having multiple antennas at the sender and receiver establishes one radio path between each transmit and receive antenna. Each receiver antenna receives a linear combination of the data streams transmitted from each transmit antenna. When the transmit antennas transmit different data streams, the receiver must derive the original data streams from the received data streams. In the case of 2x2 MIMO this problem reduces to a set of two equations and two unknowns, while in the case of 4x4 MIMO the problem reduces to a set of four equations and four unknowns.

In the downlink, LTE applies orthogonal frequency division multiple access (OFDMA) multiplexing. OFDMA is a multiuser version of orthogonal frequency division multiplexing (OFDM). OFDM breaks down the available bandwidth into many narrower subcarriers that are used to transmit the data in parallel streams. Each subcarrier is modulated with a quadrature amplitude modulation (QAM) scheme, one of quadrature phase shift keying (QPSK), 16QAM or 64QAM, to convert the bits to be transmitted to symbols. In OFDMA, users are allocated specific numbers of subcarriers for predetermined lengths of time. These resources are called physical resource blocks (PRBs) in the LTE specifications and have both a time and frequency dimension. PRBs are allocated to users by a scheduling function located at the eNode B.

LTE applies several of the following multi-antenna transmission schemes to the downlink:

- Spatial multiplexing—sends different transmission streams through each transmit antenna to achieve capacity gain.
- Transmit diversity—sends a single transmission stream through each transmit antenna to achieve diversity gain.
- Beam forming—sends a single transmission stream through each transmit antenna to achieve power or antenna gain.

LTE downlink transmission schemes are characterized as either open-loop or closed-loop. Open-loop schemes do not require information about the channel conditions at the transmitter. Open-loop configurations are characterized by lower performance, lower complexity and lower signaling overhead. Closed-loop schemes, on the other hand, optimize data reception by application of signal processing prior to transmission by utilizing some knowledge of channel information at the transmitter.

In the downlink, spatial multiplexing is utilized to map multiple modulation symbol streams to a single UE using the same PRBs. Spatial multiplexing is used to increase data rates by transmitting different data streams over different transmit antennas. Spatial multiplexing of the MIMO resource is known as single-user MIMO (SU-MIMO) when the MIMO resource is assigned to a single UE. LTE employs both open-loop and closed-loop spatial multiplexing in the downlink. LTE also supports a technique known as multi-user MIMO (MU-MIMO) that allows the eNode B to spatially multiplex different modulation symbol streams to different UEs over the same time-frequency resources.

A technique known as transmit diversity maps a single data stream onto either two (2x2 MIMO) or four layers (4x4 MIMO). Each transmitter transmits different versions of the same signal, providing the receiver with multiple copies of the transmitted signal. Transmit diversity is an effective strategy to combat instantaneous fading and can be used to extend coverage or enhance the effective QoS. In LTE, open-loop transmit diversity blindly transmits different versions of the same signal through different transmit antennas in order to provide spatial diversity. Transmit diversity reduces the variability of the signal to interference and noise ratio (SINR) seen by the UE.

LTE also employs a closed-loop version of transmit diversity known as codebook-based beam forming in the downlink. This type of beam forming applies codebook-based pre-coding to the transmitted signals sent over each antenna to adjust the phases of the signals so that they add constructively at the receiver. This technique confines the transmission to a narrow beam, as opposed to transmit diversity, which distributes the transmission evenly over the whole sector. This is useful when a UE is at the edge of a cell because it increases the SINR received by the UE.

In the uplink, LTE employs single carrier frequency division multiuser (SC-FDMA). SC-FDMA is a multi-carrier multiplexing scheme that essentially applies a discrete Fourier transform (DFT) to a pre-coded OFDMA signal where the modulation symbols have been mapped to consecutive OFDM carriers. SC-FDMA is used in the uplink rather than OFDMA because it achieves a better (lower) peak-to-average power ratio.

In the uplink, LTE supports SISO and MU-MIMO configurations. Multi-stream transmission is not supported in the UE, but in the uplink version of MU-MIMO they can share uplink resources. In the case of uplink MU-MIMO, the eNode B allocates the same time and frequency resources to several UEs, and each UE transmits over its own single antenna.

Radio Interface

Layer 2 of the radio interface is divided into the following sublayers:

- Medium access control (MAC)
- Radio link control (RLC)
- Packet data convergence protocol (PDCP)

At layer 3 of the radio interface are the radio resource control (RRC) sublayer and the non-access stratum (NAS) sublayer.

The layer 1 or physical (PHY) layer of the radio interface is divided into six downlink and three uplink channels.

The downlink physical channels are as follows:

- Physical broadcast channel (PBCH)
- Physical control format indicator channel (PCFICH)
- Physical downlink control channel (PDCCH)
- Physical hybrid ARQ indicator channel (PHICH)
- Physical downlink shared channel (PDSCH)
- Physical multicast channel (PMCH)

The uplink physical channels are as follows:

- Physical uplink control channel (PUCCH)
- Physical uplink shared channel (PUSCH)
- Physical random access channel (PRACH)

MAC

The MAC sublayer supports the following functions:

- Maps logical channels to transport channels
- Multiplexes MAC SDUs from one or more logical channels into transport blocks (TBs) which are delivered to the physical layer for transport
- Demultiplexes TBs received from the physical layer into MAC SDUs for delivery onto different logical channels to the RLC sublayer
- Reports scheduling information
- Provides error correction using hybrid automatic repeat request (HARQ)
- Uses dynamic scheduling to provide priority handling between UEs
- Provides priority handling between logical channels of individual UEs at the eNode B
- Provides priority handling between logical channels at the UE
- Selects between transport formats

RLC

The RLC sublayer provides the following three services to the PDCP sublayer:

- Transparent mode (TM) data transfer
- Unacknowledged mode (UM) data transfer
- Acknowledged mode (AM) data transfer

The RLC sublayer supports the following functions:

- Transfer of PDCP protocol data units (PDUs)

- Error correction of AM data transfer using automatic repeat request (ARQ)
- Concatenation, segmentation, and reassembly of RLC service data units (SDUs) undergoing UM or AM data transfer
- Re-segmentation RLC data PDUs (AM data transfer)
- Reorder RLC data PDUs received out-of-sequence (UM and AM data transfer)
- Detection and discard of duplicate RLC PDUs (UM and AM data transfer)
- RLC re-establishment
- RLC error detection and recovery

PDCP

The PDCP sublayer supports the following functions:

- Transfer of user plane and control plane upper layer PDUs
- Robust header compression (ROHC)
- In-sequence delivery of upper layer PDUs for RLC AM
- Detection and discard duplicate PDCP PDUs for RLC AM
- Retransmit PDCP SDUs at handover for RLC AM
- Cipher user plane and control plane
- Integrity protection of control plane
- Uplink timer-based SDU discard

Radio Interface Protocol Stacks

The radio interface protocol stack of the eNode B is divided into user plane and control plane protocol stacks.

The radio interface user plane protocol stack consists of the PDCP, RLC and MAC layer 2 protocols and the PHY layer 1 protocol, as shown in Figure 7.

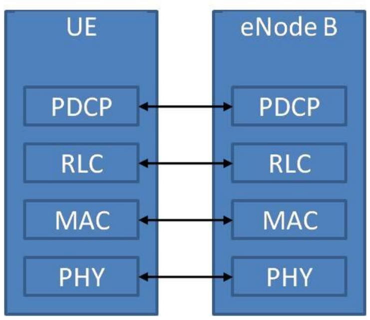


Figure 7. Radio Interface Protocol Stack – User Plane

The radio interface control plane protocol stack adds the NAS and RRC protocols to the layer 2 protocols used in the user plane protocol stack. The NAS protocol is terminated in the MME of the EPC and provides EPS bearer management, authentication, ECM-IDLE mobility handling, ECM-IDLE paging origination, and security control. ECM-IDLE is the idle state of EPS connection management (ECM). The RRC protocol terminates in the eNode B of the E-UTRAN and provides broadcast, paging, RRC connection management, radio bearer control, mobility, and UE measurement and control functions.

Figure 8 shows the radio interface control plane protocol stack.

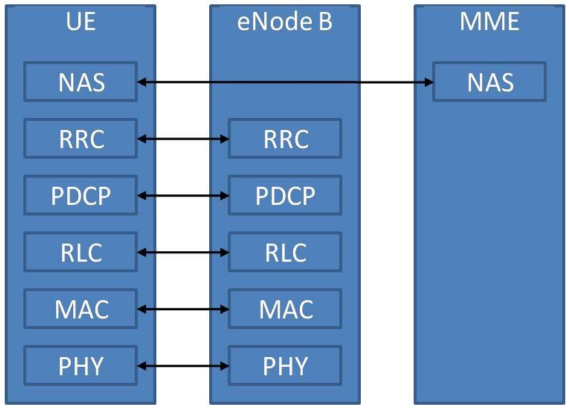


Figure 8. Radio Interface Protocol Stack – Control Plane

S1 Interface Protocol Stacks

The S1 user plane interface (S1-U) is defined between the eNode B and the S-GW and provides non-guaranteed delivery of user plane PDUs between the two network elements. The user plane protocol stack is shown in Figure 9 and consists of the GPRS tunneling protocol user (GTP-U), UDP and IP protocols.

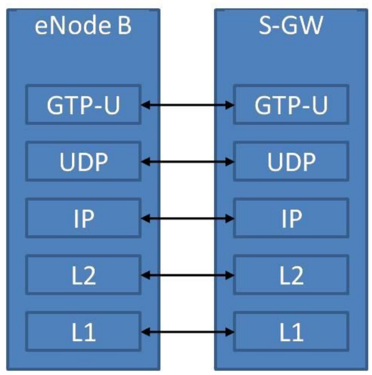


Figure 9. S1-U Interface Protocol Stack

The S1 control plane interface (S1-MME) is defined between the eNode B and the MME. The S1 application protocol (S1-AP) is transported over the SCTP protocol, which runs over the IP protocol and provides reliable transport.

The S1-MME protocol stack is shown in Figure 10. The S1-AP protocol transports NAS messages between the UE and the EPC over the S1-MME interface.

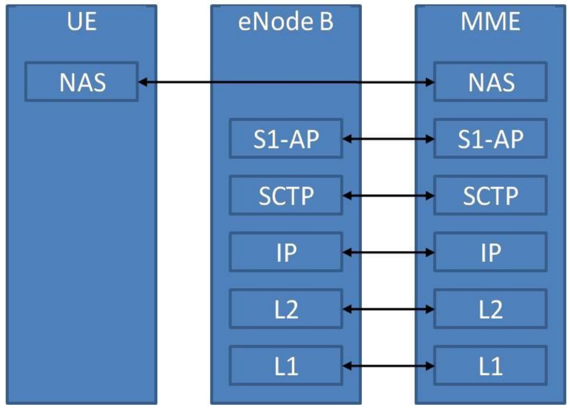


Figure 10. S1-MME Protocol Stack

X2 Interface Protocol Stacks

The X2 user plane interface is defined between eNode Bs and provides non-guaranteed delivery of user plane PDUs. The transport stack uses the GTP-U, UDP and IP protocols. The X2 interface user plane protocol stack is shown in Figure 11 and is identical to the S1-U protocol stack.

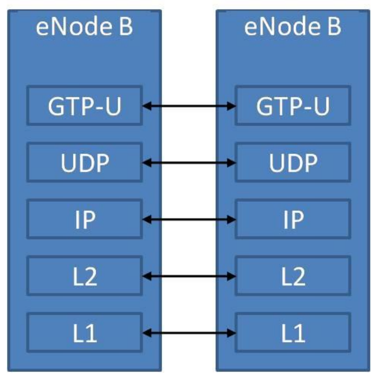


Figure 11. X2 User Plane Protocol Stack

The X2 control plane interface is defined between two eNode Bs of the E-UTRAN. The X2 application protocol (X2-AP) is used to provide mobility support to UEs in the ECM-CONNECTED state and to handle load management between adjacent cells. The X2 control plane transport stack consists of SCTP and IP. Each X2 control plane instance has its own SCTP association.

The X2 control plane protocol is shown in Figure 12.

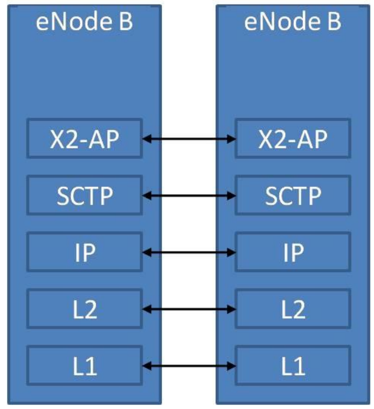


Figure 12. X2 Interface Control Plane Protocol Stack

E-UTRAN Mobility

Handover is a procedure handled by E-UTRAN that maintains a call while a user transitions from one cell to another. Handovers generally occur when the UE is near the edge of coverage and a failed handover often results in a dropped call. LTE only supports a very fast break-before-make hard handover procedure. In a break-before-make handover the UE only has connectivity to a single cell at a time. The soft and softer make-before-break handover procedures used in UMTS systems have been eliminated in LTE in order to simplify the procedures and reduce the need for extra radio and backhaul resources. LTE introduces the X2 interface that provides connectivity between source and target base stations during an intra-E-UTRAN handover. Introduction of the X2 interface reduces load on the EPC and makes the handover procedure faster, reducing the likelihood of failure.

Handover procedures are defined for UEs in the ECM-CONNECTED state. Several types of handover procedures are defined by LTE:

- Intra-eNode B handover between sectors of the same eNode B.
- Inter-eNode B handover between eNode Bs:
    - With MME relocation.
    - Without MME relocation, but with S-GW relocation.
    - With neither MME relocation nor S-GW relocation.
- E-UTRAN to UTRAN inter-radio access technology (inter-RAT) handover.
- UTRAN to E-UTRAN inter-RAT handover.
- E-UTRAN to GSM EDGE radio access network (GERAN) A/Gb mode inter-RAT handover.
- GERAN A/Gb mode to E-UTRAN inter-RAT handover.
- E-UTRAN to high rate packet data (HRPD) inter-RAT handover.
- E-UTRAN to cdma2000 1xRTT inter-RAT handover.

The inter-eNode B handover without MME and S-GW relocation is shown in Figure 13. The case illustrated assumes that IP connectivity is present between the S-GW and both source and target eNode Bs and also requires the presence of the X2 reference point between the eNode Bs. Part of the handover command information comes from the target eNode B and is passed to the UE by the source eNode B, which passes all information necessary to complete the handover to the UE. The UE will then access the target eNode B using a contention-free RACH procedure if a dedicated RACH preamble is available. During the execution of the handover procedure, user plane packets are forwarded from the source eNode B to the target eNode B. When the UE has connected to the target eNode B, downlink data that has been forwarded to the target eNode B is delivered to the UE.

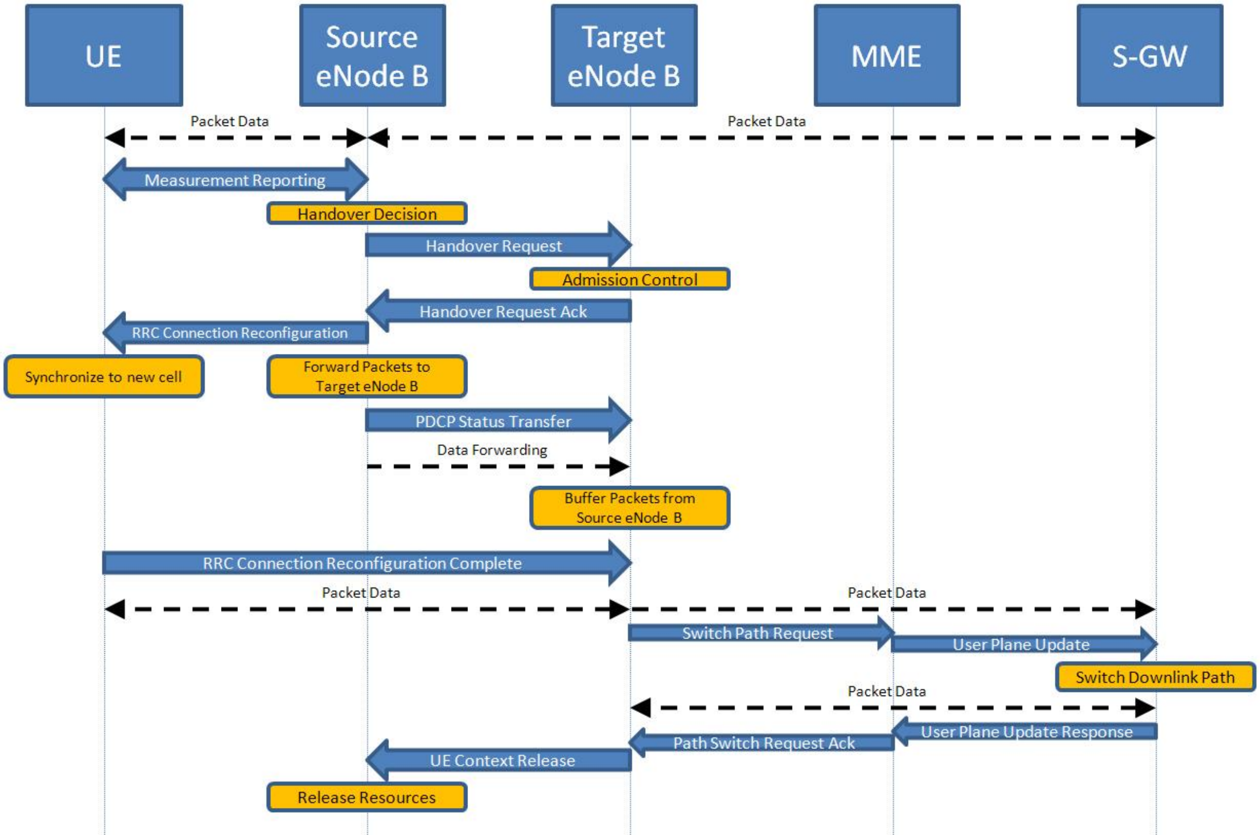


Figure 13. Inter eNode B Handover without MME Relocation

The eNode B Scheduler

The LTE eNode B contains an entity called the packet scheduler that is very complex and resides in the MAC layer. This scheduler performs scheduling decisions for each UE every TTI (Transmission Time Interval). The primary functionality of this scheduler is to allocate limited resources to the UEs being serviced by an eNodeB.

Due to the limited signaling resources, subcarriers are allocated collectively. On the downlink, subcarriers are grouped into a Resource Block (RB). Two consecutive RBs make an SB (Scheduling Block), which is the smallest resource unit that a scheduler can assign to a UE. The duration of the SB is one TTI. The Scheduler decides other transmission parameters including modulation and coding scheme for those PRBs assigned to a UE, and this procedure is called *link adaptation*.

These transmission parameters are transmitted through the Physical Dedicated Control Channel (PDCCH) to a UE. The overall scheduling goal is to maximize the cell capacity while maintaining the minimum Quality of Service (QoS) requirements for the services.

The scheduling decision is made on a per-UE basis even if this UE may have several different data flows. Usually, a UE has a control plane data flow for Radio Resource Control (RRC) protocol and one or more user plane flows for its own traffic data.

The scheduler interacts very closely with HARQ (Hybrid Automatic Repeat request) manager, because it is responsible for scheduling retransmissions. At each TTI, the scheduler should decide whether to send a new transmission or a pending HARQ transmission to a scheduled UE. The Scheduler takes various inputs to make decisions on resource allocation.

For downlink scheduling, Channel Quality Indicator (CQI) feedback from a UE would be one of the most important inputs. For uplink scheduling, measurement through Sounding Reference Signal (SRS), Buffer Status Report (BSR) and Power Headroom Report (PHR) would be essential inputs.

Typically, the LTE scheduler would have combined functionality of frequency domain scheduling and time domain scheduling. A brief explanation of each scheduling type is given in the next two sections.

Frequency Domain Packet Scheduler (FDPS)

Frequency domain scheduling is the most powerful technique for LTE systems to ensure broadband use. FDPS exploits the frequency selectivity which would be experienced differently by each UE. That is, FDPS schedules UEs only on those PRBs with high channel quality while trying to avoid other PRBs with lower channel quality. This procedure is depicted in the following figure.

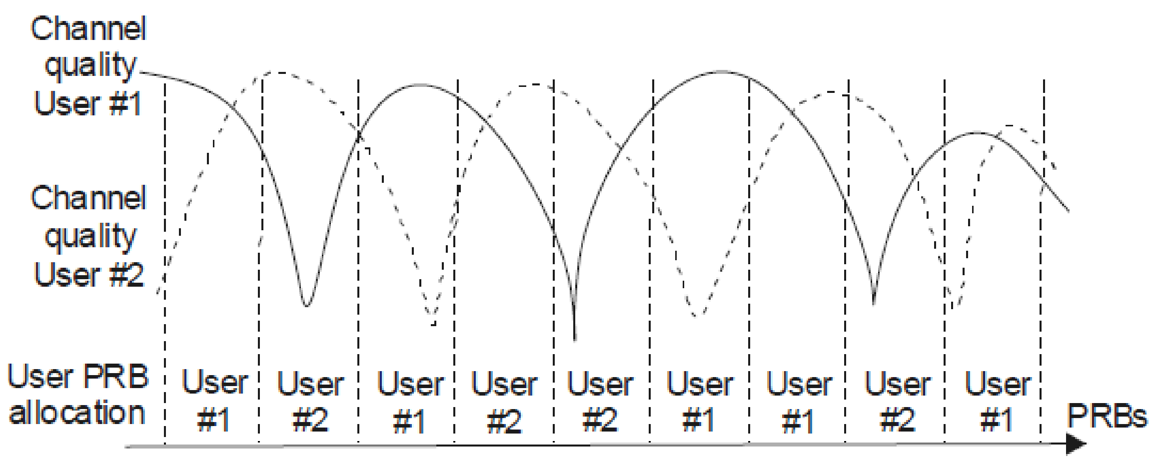


Figure 14. Frequency Domain Scheduling

The system capacity gain, which could be provided by exploiting the frequency selectivity by the FDPS, is called *scheduling gain, multi-user gain,* or *multi-user diversity gain*. The frequency selectivity would be dependent on the radio channel's coherence bandwidth, which is typically smaller than the system bandwidth in most of the cellular systems.

Time Domain Packet Scheduler (TDPS)

As the FDPS exploits the frequency domain selectivity, time domain packet scheduling exploits time domain selectivity. However, if the mobile speed gets higher, then the fading rate would become higher accordingly, and it would be difficult for the TDPS since it depends on the CQI report to track the fading. Also transmit or receive antenna diversity work against time diversity, the overall gain by TDPS would be also reduced. Thus, typically, the gain by TDPS would be relatively small in LTE since multiple antenna technology is a standard feature and, in most of the cases, it uses large bandwidth.

Testing the eNode B Scheduler

Typical multi-user scheduling algorithms such as *proportional fair* could also be employed in an LTE system. However, the scheduler itself is implementation-specific, and each eNodeB vendor will have its own proprietary algorithm for the scheduler.

Once implemented, as with other functions in the system, it has to be fully verified and optimized.

The following figure shows the interaction which a downlink (DL) scheduler could have with other functional entities in the system.

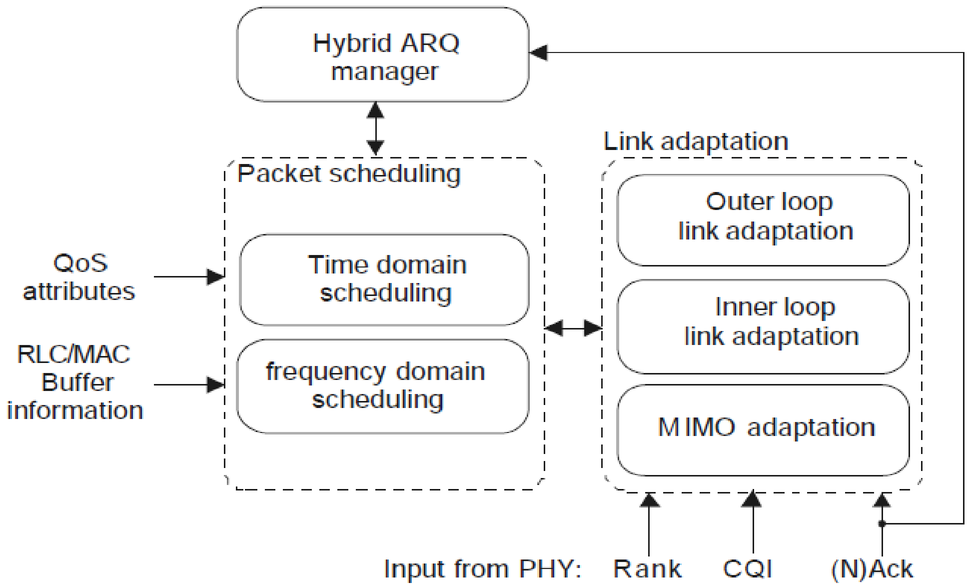


Figure 15. Interaction of Downlink Scheduler with Other Entities

When testing the scheduler, it is necessary to have a testing environment where the scheduler could be fully exposed to possible scenarios which it may face in the real world such as stressed conditions, multiple UEs, practical measurements, reporting, and reference signals. With predetermined simulation conditions, the system capacity which depends on the scheduler algorithm could be measured and analyzed to optimize the scheduler functionality. As an example, typical use cases for an eNodeB scheduler test are as follows:

- Testing the eNodeB's scheduling commitment to QoS with variables such as the number of UEs, QoS, and traffic profiles.

- Testing scheduling capability under varying numbers of UEs with a variety of channel conditions. Especially, the testing of scheduling and link adaption when all UEs are highly mobile with rapidly varying channel quality.
- Testing of expected UE usage scenarios with cell edge UEs, cell center UEs, highly mobile UEs, UEs in hand-over situation, and also other situations expected in the real world.
- Confirmation of eNode B operation at certain BERs under certain signal-to-noise (SNR) levels.

eNode B Testing Challenges

Some key challenges to testing the eNode B are:

- Meeting performance requirements
- Supporting the Uu radio interface
- QoS/QoE conformance on an all-IP platform
- Interoperating with other wireless technologies
- Verifying eNodeB scheduler operation

The importance of testing eNodeB radio interface access stratum, non-access stratum signaling, user plane data transfer and air interface security are discussed further. In addition, it is important to consider the advantages of wraparound testing, and to consider the type of UE simulator to be employed when testing the eNodeB.

Radio Interface Access Stratum (AS)

In UMTS, access network functionality is split between base station and the radio network controller (RNC). The AS largely terminates at the RNC, allowing radio interface AS protocols and operation to be largely tested over the Iub interface that connects the UMTS base station and the RNC.

In contrast, in LTE, the network termination of the LTE AS is completely contained within the new eNodeB network element. LTE has no interface comparable to the Iub; therefore testing must include the Uu radio interface. Figure 14 compares the AS of UMTS and LTE access networks.

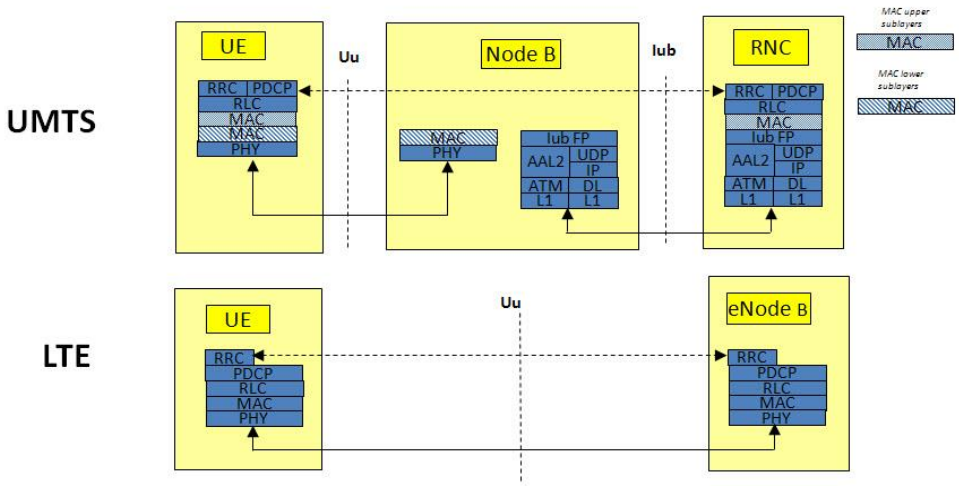


Figure 16. Comparison of UMTS and LTE Access Stratum (AS)

The LTE AS consists of the RRC, PDCP, RLC, MAC and PHY protocol layers. Functional testing of lower layers (*e.g.*, PHY, and sometimes MAC and RLC) can proceed without higher layers. However, any UE simulator providing a complete eNodeB testing solution needs to implement the entire AS protocol stack and provide a means to analyze the full protocol stack, in order to measure performance and analyze problems adequately.

Non-Access Stratum (NAS) Signaling Transport

Figure 15 shows the NAS signaling and AS protocol stacks in the UE, eNode B and enhanced packet core (EPC). NAS procedures provide mobility management and session management between the UE and the EPC, including procedures to handle EPS bearer contexts.

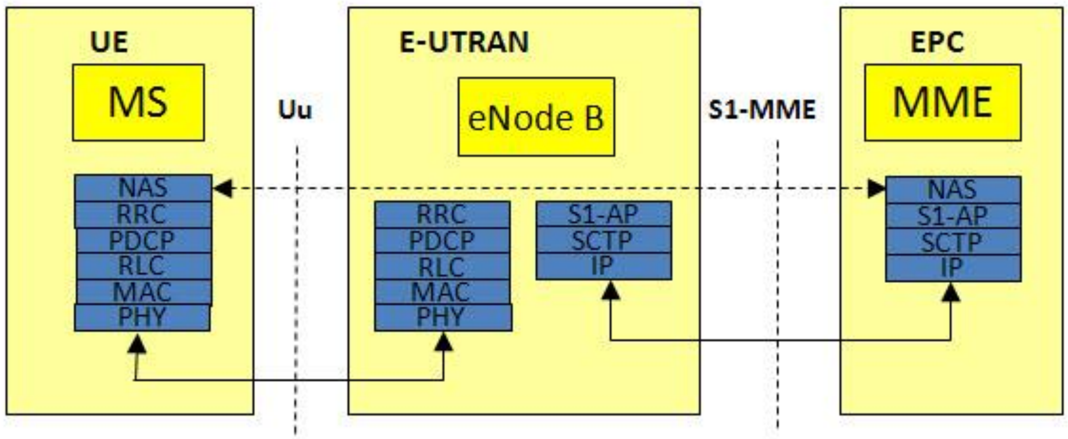


Figure 17. NAS Signaling Protocol Stacks

The LTE core network, also known as the EPC, connects directly to the eNode B over the S1 interface. UEs and the EPC exchange non-access stratum (NAS) signaling over Uu and S1 interface connections provided by the eNode B, but the eNode B itself does not process NAS signaling.

As long as NAS control streams can be accurately simulated, and the EPC is not involved in the test, a NAS protocol implementation may not be needed to test the radio interface.

However, users will find the inclusion of NAS protocol state machines and signaling protocols in UE simulation tools useful for the following reasons:

- They allow the system to accumulate accurate control plane statistics for each session
- They allow NAS layer timeout and error conditions caused by eNode B delay or message loss to be flagged by the simulator
- They allow assessment of the impact of eNodeB load test conditions on signaling
- They facilitate the understanding and easy modification of NAS message content and call flow sequences by the user

User Plane Data

Compared to UMTS, LTE provides increased data throughput, improved network performance and more stringent latency requirements. UE simulators need to support user plane test data streams representative of the great variety of services supported by LTE at high data rates and over sufficient UE connections to fully load and stress the eNode B.

Some goals of eNodeB user plane load testing are:

- Incrementing voice, video and data traffic streams until eNodeB capacity is reached

- Verifying that bearer traffic is properly prioritized over the radio interface
- Accurately measuring eNodeB performance characteristics
- Assessing the ability of the eNodeB to maintain QoS commitments for each traffic stream, both guaranteed bit rate (GBR) and non-GBR.
- Evaluating the quality of experience (QoE) delivered by the eNodeB by providing evaluative tools such as perceptual evaluation of speech quality (PESQ) for voice service.

UE simulators use internal traffic generation tools to send and receive user plane frames for data services, video and voice applications. They coordinate user bearer connections with NAS and RRC signaling. Additionally, they can provide Ethernet connections that allow application clients and servers to provide actual application data.

Figure 18 shows the application and AS protocol stacks in the UE, eNodeB, EPC and application server.

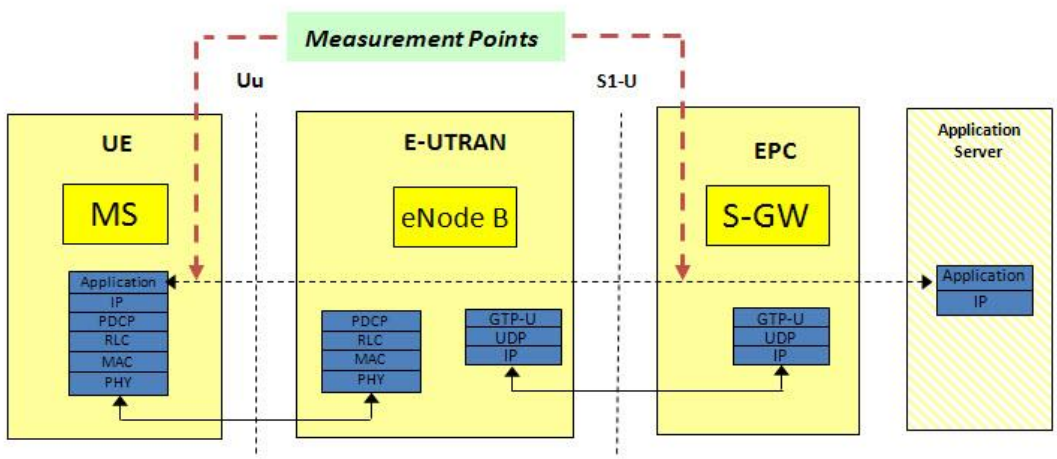


Figure 18. Application Transport Protocol Stack

Radio Interface Access Stratum Security

Simulated UEs need to support and verify the processor intensive security and compression treatment for signaling and user plane traffic over the radio interface. The packet data convergence protocol (PDCP) protocol of the access stratum (AS) provides the radio interface security mechanisms used between the UE and the eNodeB. PDCP ciphers user plane frames and control plane RRC messages. PDCP also subjects RRC messages to integrity checking. For AS security to work properly, security key material used by each UE must match the security key material provided to the eNodeB by the EPC over the S1 interface or the source eNodeB over the X2 interface. Coordination of the security keys used by the UE and eNodeB is a challenge that UE simulation tools need to solve.

With ciphering and integrity checking being such processor-intensive tasks, the load on the eNodeB can be especially high given the large number of UEs to which it can be connected. In order to provide meaningful results, load and performance testing of the eNodeB needs to done under a rigorous security regimen that fully exercises the ciphering and integrity checking capabilities of the eNodeB.

Advantages of Wraparound Testing

Many eNodeB functions and procedures can only be verified using wraparound testing equipment in which all eNodeB interfaces are connected to test equipment. At layer 3, signaling between the UE and eNodeB on the Uu interface is tightly coupled with intra-E-UTRAN signaling on the X2 interface and signaling between the eNodeB and the EPC on the S1 interface. This tight coupling makes testing any one interface in isolation difficult, if not impossible. The preferred approach is to use an integrated set of wraparound test procedures that simultaneously exercises and coordinates all eNodeB interfaces.

Wraparound testing provides a complete testing solution for each eNode B interface by:

- Exercising each eNodeB interface
- Measuring response time
- Recording eNode B response details
- Determining resultant test actions in conjunction with the configured test script

Wraparound testing verifies eNode B user plane connections by:

- Applying a variety of realistic user plane traffic flows against each interface.
- Coordinating each user plane flow according to the signaling exchanged with the eNodeB.
- Verifying the content of the user plane traffic flows sent by the eNodeB.
- Exercising control of user plane frames at both source and sink.
- Measuring the quality of service (QoS) and quality of experience (QoE) delivered for each traffic flow.

Use of a core network simulator can offer great test advantages to the user by eliminating the need for expensive EPC network elements.

LTE Radio Interface Test Devices

UE simulators eliminate the need for physical UE banks. UE simulator tools, as opposed to banks of actual UE devices, allow the implementation of easily designed tests that can be preprogrammed, are repeatable, and are controlled with scripts. UE simulators allow individual parameters within each layer of the UE protocol stack to be controlled by a script, and can inject failures into the various layers to force retransmission and timeout behavior by the eNodeB. UE simulators bring advanced performance tools to detect and analyze problems from the viewpoint of the individual UE as wel as the overall network.

LTE radio interface test devices either simulate or utilize actual UE devices. UE simulator test tools can be roughly divided further into two classes, functional test oriented and load test oriented:

- Actual UE device/bank of UEs: often placed in phone cabinets, a method that enables control of many UEs from a single point of control. Use of actual UEs offers the certainty of real rather than simulated entities, but creates a system that is difficult to program, connect and control.
- Functional test UE simulator: functional UE simulators are well-suited to the functional testing of AS transport and physical layers but are not easily scalable to adequately stress the E-UTRAN, both in terms of the number of UEs and in terms of the aggregate data rate.
- Multi-UE load test UE simulator: multi-UE load simulators are designed to simulate large numbers of UEs and provide heavy load traffic conditions. These systems are cost-effective, particularly when extended to multiple UEs.

Establishing the LTE First Call

The 3GPP specifications for LTE were frozen on Dec. 2008, but only deemed stable in March 2009. Therefore, most telecom equipment manufacturers (TEMs) are planning to deploy LTE between six months and a year; they are currently working on a tight schedule to validate their eNodeB functionality based on the last specifications changes, and sometime based on proprietary implementations.

A critical step in validating eNodeB functionality is the establishment of the first LTE call. This first step is not only challenging due to the complexity associated with bringing up the radio interface and the transport layers, but it is very important in establishing early technical credibility for their customers the mobile carriers.

The success of the first call establishment depends not only on selecting the right test equipment, but also on test methodology. It is critical that every step of the procedure be performed meticulously by observing test results at well-defined checkpoints.

Ixia Products for Testing LTE Access

Ixia provides IxLoad LTE Access UE simulation:

- IxLoad Access
  - Designed for service validation of an eNodeB
  - Based on the IxLoad product for its traffic capabilities & ease-of-use
  - Extensive Real Traffic capabilities with QoE analysis

IxLoad Access Test Cases

The following test cases demonstrate how to successfully configure and complete Uu interface test scenarios against a real eNodeB using the IxLoad multi-UE simulator.

- Single UE attach with user plane data traffic
- Multi UE 1000 UE attach with user plane data traffic
- Multiple UE ranges, multiple user plane activities
- Voice over LTE (VoLTE)

Test Harness

In order to simulate UEs we use an XM platform with XCellon Ultra-NP (or NG) card and a XAir card. The Xair is a state-of-the-art sector card, which can support up to 1000 RRC Connected UEs (with traffic).

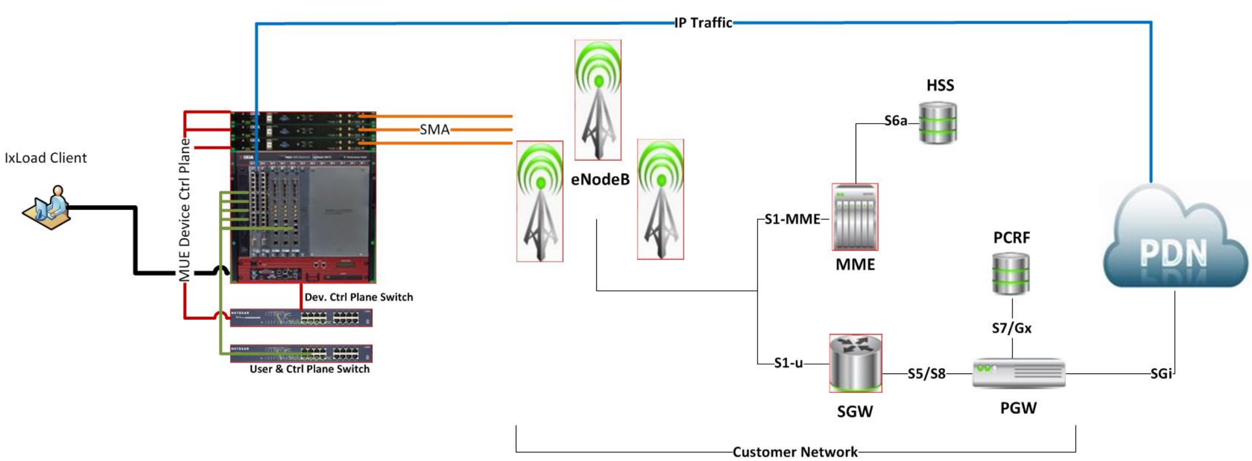


Figure 19. Test Setup

The XM platform simulates higher layers – NAS, RRC, PDCP, and the Xair simulates – RLC, MAC, and PHY.

Xair Ports

Figure 20. Xair

1. 4 CPRI ports - The Xair consists of 4 CPRI ports, out of which only 1 is currently used. Plug the provided transceiver (SFP) into the first CPRI port and connect it to the Radio Head using the supplied multi-mode CPRI cable.
2. Timing input/output – The Xair comes complete with inband time synchronization, therefore a clock source is no longer required. However, there are input and output ports for 10Mhz clock source in case a clock source is desired.
3. Ethernet ports – Port 1 is used for device management, connecting to the Device Control Plane switch. Port 2 is test traffic port, connecting to the User & Control plane switch and running the RLC, MAC and PHY layers.

Xair Bring-up Procedure

1. Stop any running IxServer process on XM/XG Chassis
2. Install IxOS version recommended for IxLoad LTE Access support
3. If this is the first time you are bringing up an Xair on this chassis,
   a. Go to C:\Program Files\Ixia\IxOS\<version>\IxCatapult\t600srv
   b. Double-click start_t600service.bat to install it as a service

Note: This has to be done once, not for every IxOS release.

Xair Internals

- Xair gets its IP from t600service running on XM/XG Chassis
- When IxServer is started,
  - Xair boots up

- Gets an IP through DHCP
- Downloads firmware from latest install (IxOS-IxCatapult) directory in C:/tftpboot

▪ Key directory – **C:\tftpboot**

- Contains t600service log file
- Firmware directories
- The log file should indicate which firmware got selected for download (in case of multiple installs)
- Do check once & confirm it's the right firmware

▪ Xair card architecture

- Freescale Power Architecture based processor –multi-core with 8 cores. Default mode is to use 6 cores.
- You can login to 4080 (PQ3) and capture vectors (autovec and vectool supported)
- Directory structure is similar
- Due to multi-core in the 4080, there are multiple instances of lte_scs, one master and rest slaves

Xair Reset

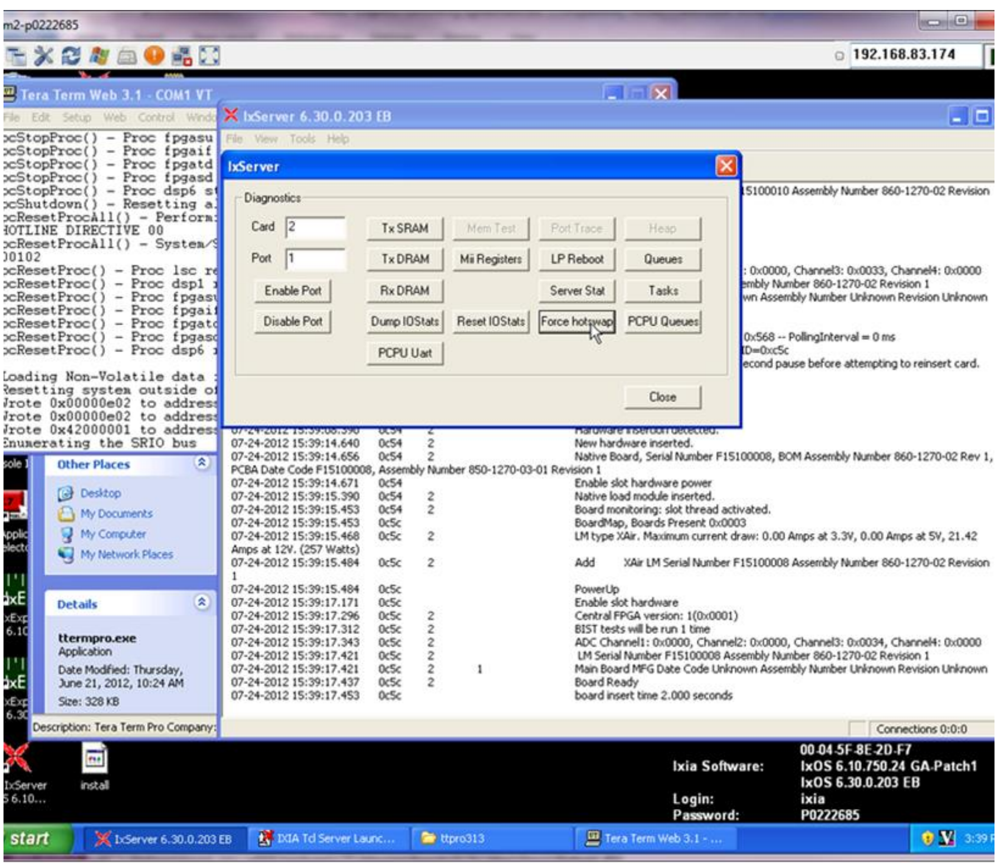


Figure 21. Xair Hotswap - Reset

- From IxServer Tools Menu
- Select Diagnostics A dialogue box will open
- Enter the card slot #
- Select the“Force Hotswap” button
- You will see the IxServer window show the removal of the XAir card and the reinsertion/configuration

Test Case 1: Single UE Attach with User Plane Data Traffic

Overview

IxLoad MUE Simulator can simulate multiple UEs and model their behavior. However when we start testing, the first test case is generally a single UE test. This allows us validate the setup as well as the basic connectivity.

Objective

Configure a 1 UE test with HTTP traffic activity and objective of 10Mbps throughput, to sustain traffic for 3 mins.

Setup

Refer to Figure 1 - Test Setup XAir for more information on setup.

Step-by-step Instructions

To achieve this test case, perform the following tasks:

1. Start IxLoad.
2. Create a new rxf file – this should happen automatically.

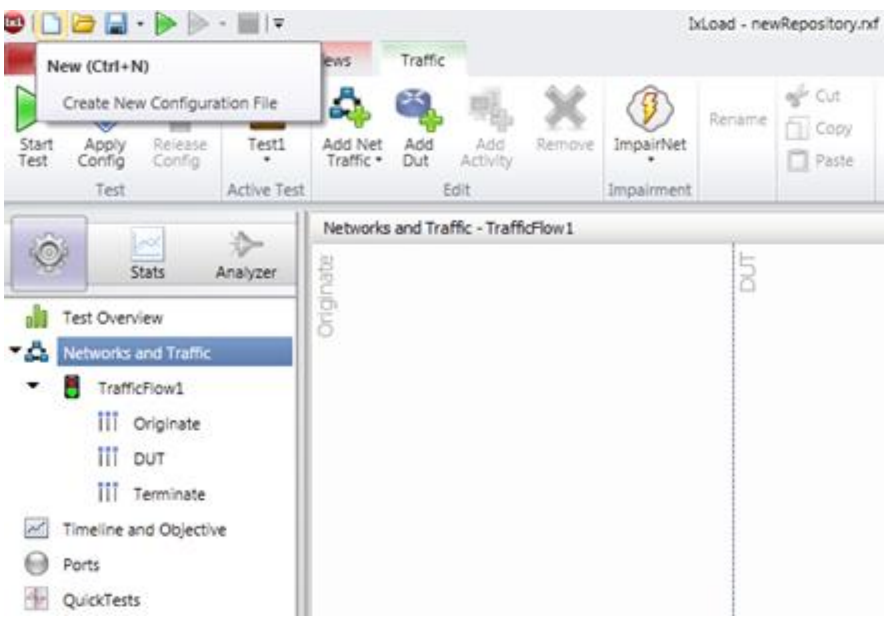


Figure 22. New LTE UE configuration

3. Add a new NetTraffic activity to **Originate**. This activity will now be configured to simulate Multiple UEs.

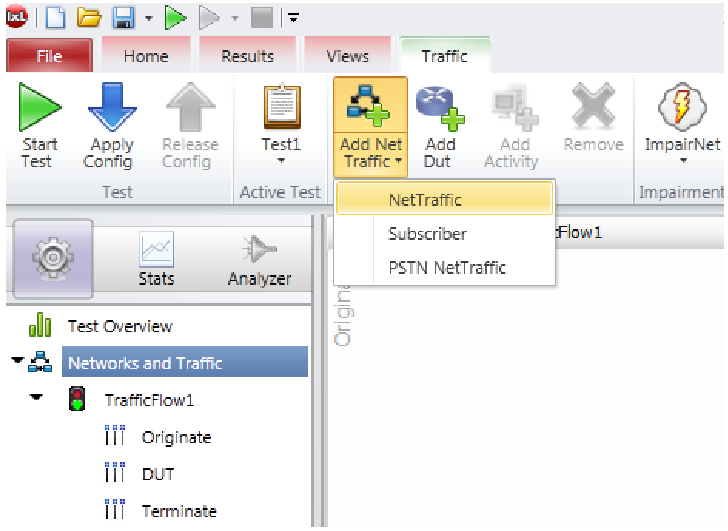


Figure 23. New NetTraffic

Each NetTraffic activity has a Network layer and L4-L7 Traffic Layer configuration. The LTE UEs are configured in Network layer.
Click the newly added NetTraffic activity and add LTE UE stack.

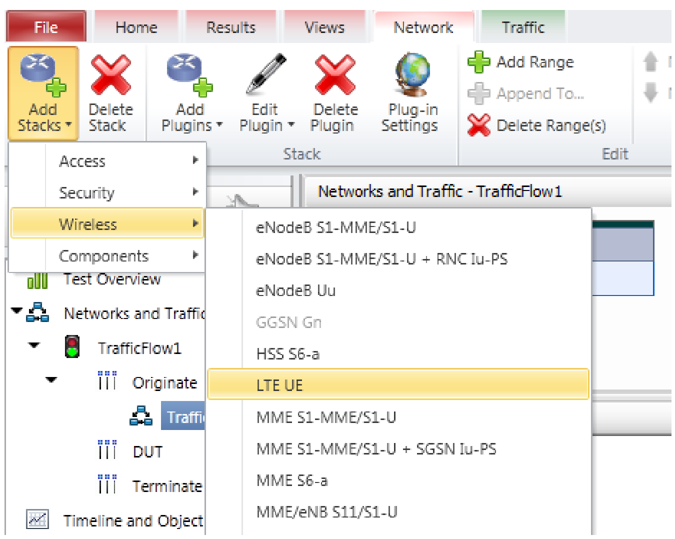


Figure 24. New LTE UE stack

4. Click **Delete Stack** to select and remove the default IP stack.

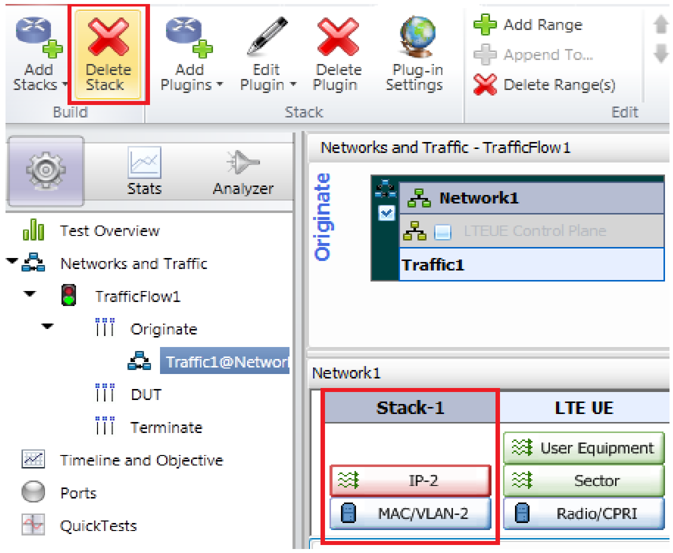


Figure 25. Delete IP stack

5. Before configuring the LTE UE stack, make sure to set global network/plugin wide settings applicable for this test case.
In the IxLoad client application, click **Network**, and then **Plug-in Settings**.

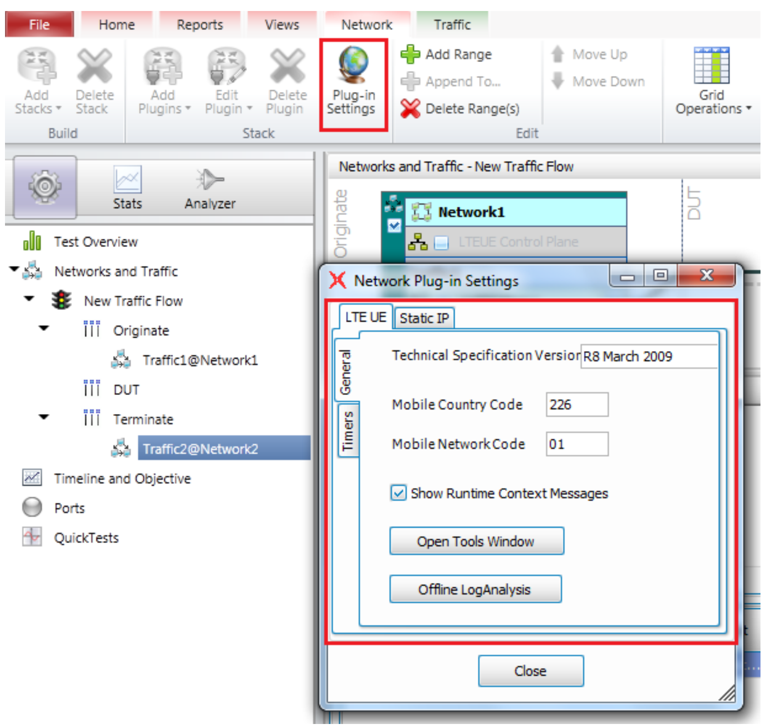


Figure 26. Global Settings

Click the **LTE UE** tab. Enter appropriate value for **Mobile Country Code** and **Mobile Network Code** for the systems under test. Also, enter the appropriate **Technical Specification Version** (R8, R9).

Select **Show Runtime Context Messages** check box to view the protocol messages decoded simultaneously during the test. Note that selecting this option may impact the performance of the system depending on the level of logging enabled.

In the **Timers** tab, you can override default guard timers. However, this is not required under normal circumstances.

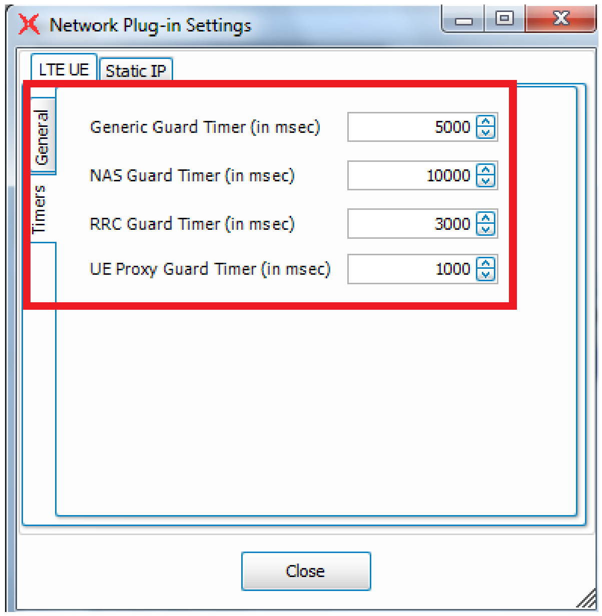


Figure 27. **LTE UE Timers**

6. Configure LTE UE stack. Start with **User Equipment** layout.

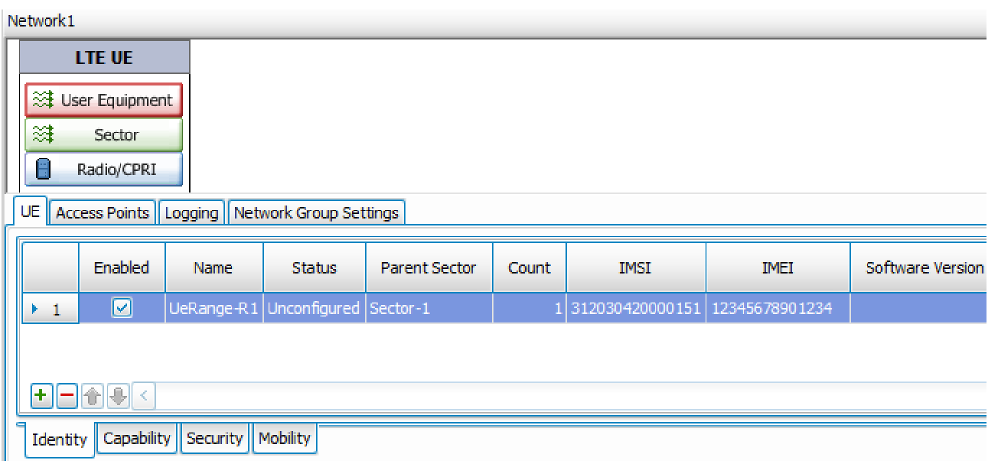


Figure 28. UE range configuration

User Equipment Layout

The **User Equipment** layout contains four tabs, each of which inturn has additional tabs as listed in the following table:

Tab	Description
Identity	Add 1 UE to the configuration. Configure the appropriate values for **IMSI, IMEI,** and **Software Version.** These values identify the subscription and equipment and must match the values configured in the system under test. Select the right **Parent Sector** for this UE range from the list of connected sectors. **Note**: It is better to assign the**Parent Sector** after adding the sectors.
Capability	Here you can configure UE Category, Supported Bands, and options like Tx Antenna Selection and UE Specific Reference Signals. For this scenario, we use default settings.
Security	For each UE-range, corresponding authentication and ciphering/integrity algorithms can be set in this tab. OP and K are authentication keys that are assigned at HSS or AuC. These can be UE specific or same across the range.
Mobility	Being a 1 UE test there is no mobility to be selected for this test.

Access Points Tab

IxLoad 6.0 supports multiple-APNs. Here, you can configure all the APNs that are used by the UEs. Set the **APN Name** and **IP type** to match the EPC configuration.

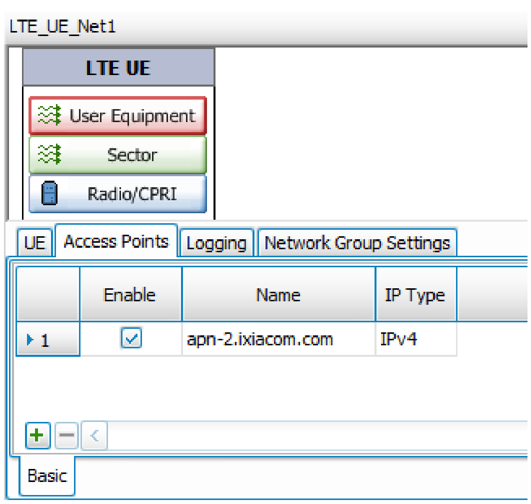


Figure 29. APN Setup

Logging Tab

Select Enable NAS/RRC Messages check box to copy the messages to a file. In this scenario, this check box is selected.

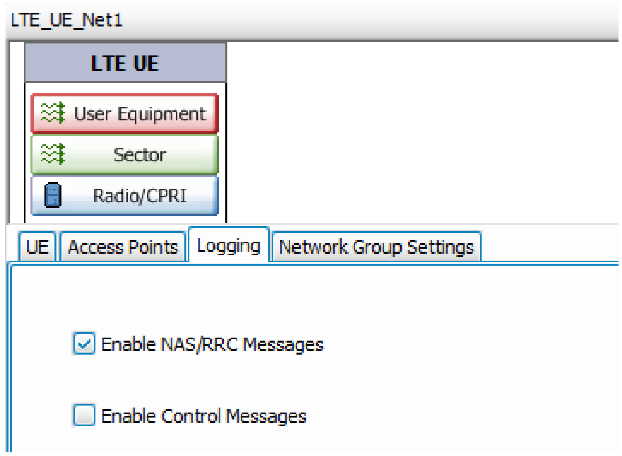


Figure 30. Logging

Network Group Settings Tab

In this tab, you can modify the **Port CPU Log Level**. For this test, select **Error** as the default log in the **Port CPU Log Level** list.

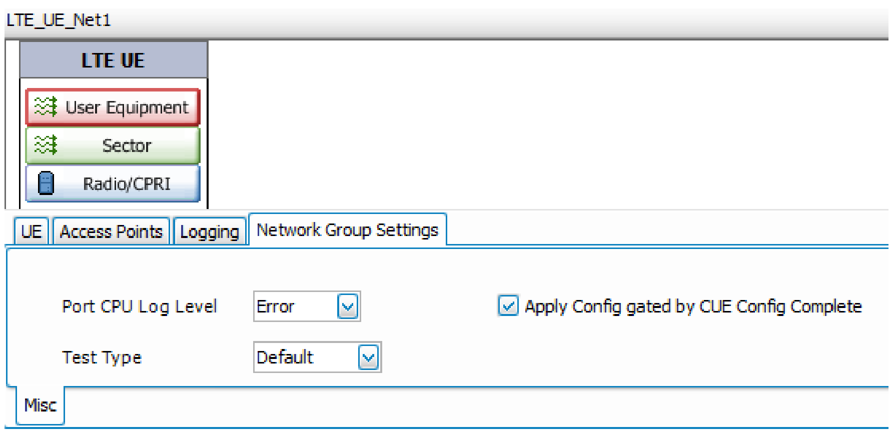


Figure 31. Network Group Settings

Sector layout

The **Sector** layout has five tabs as listed in the following table.

Tab	Description
Sector Info	In this tab, you can automatically discover all sector cards connected to the chassis. Before you discover the sector cards, add the chassis and assign ports. Refer to **Error! Reference source not found.**. Click **Show Sectors** button, to visualize all connected sector. In this example, there is only one sector connected.

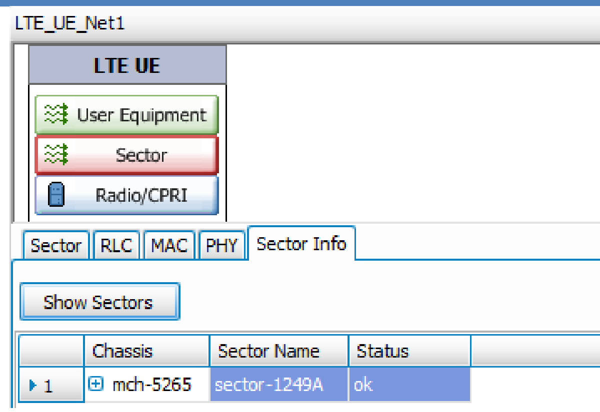
<table>
<tr><th>Tab</th><th>Description</th></tr>
<tr><td></td><td>

Figure 32. Sector Discovery</td></tr>
<tr><td>Sector</td><td>After Auto-Discovery, click + to add a new sector as depicted in the following image. Select a sector from Connected Sector list.

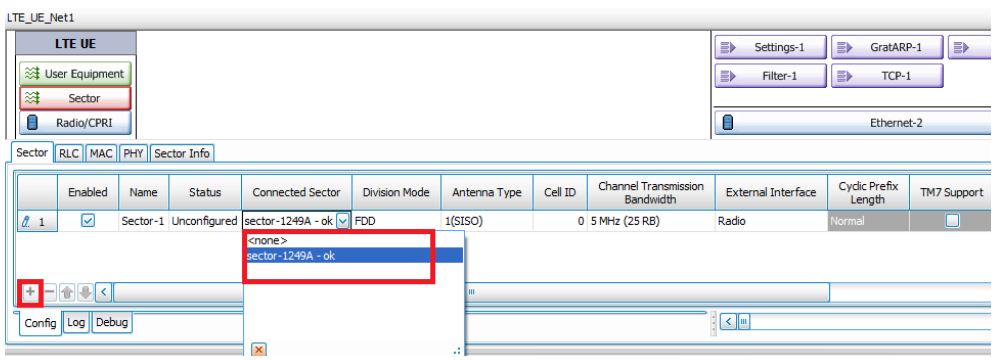


Figure 33. Sector Tab</td></tr>
<tr><td>RLC, MAC and PHY</td><td>These tabs enable lower layer logging options. These options are not required for our test.</td></tr>
</table>

Radio/CPRI layout

Radio Head Info Tab

Just like sector cards, radio heads connected to the chassis can be automatically discovered. To do so, click the **Show Radio Heads** button. After discovery, click **Sector** tab. Before clicking **Show Radio Heads**, refer to **Error! Reference source not found.**.

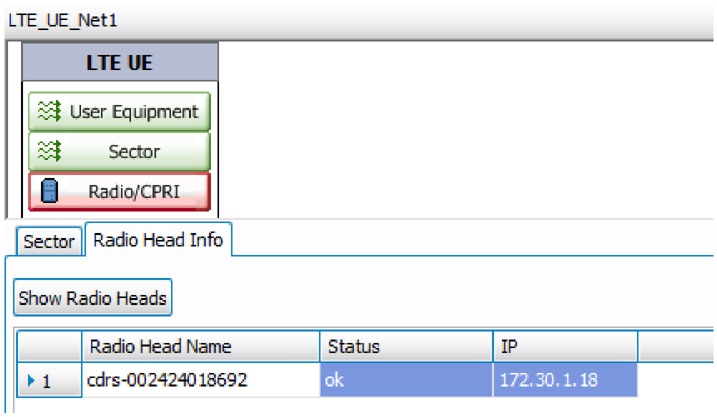


Figure 34. Radio Head Discovery

Sector Tab

For each sector in the test, assign a radio head and set the corresponding center frequency. This needs to match the eNodeB configuration.

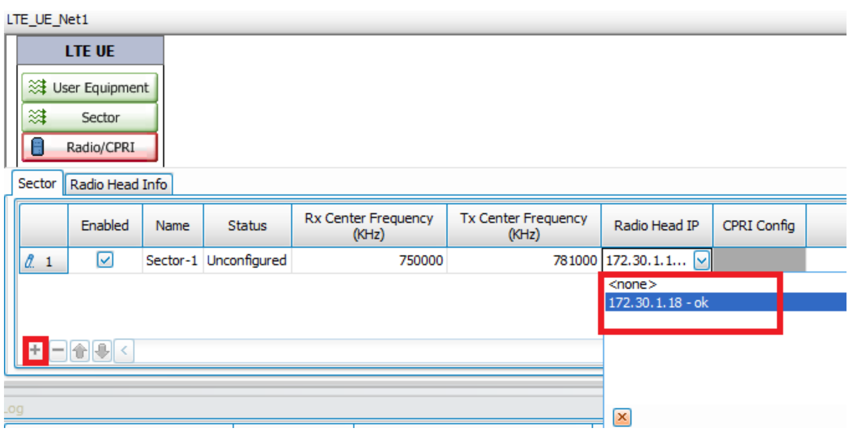


Figure 35. Radio Head Sector Assignment

7. Click the **Settings** button for the network plugin. In the **Interface Behavior** section, click **Create interface with user**, and then select **Teardown interface with user** checkbox. This option is called Dynamic Control Plane, and it is the only supported option as on date.

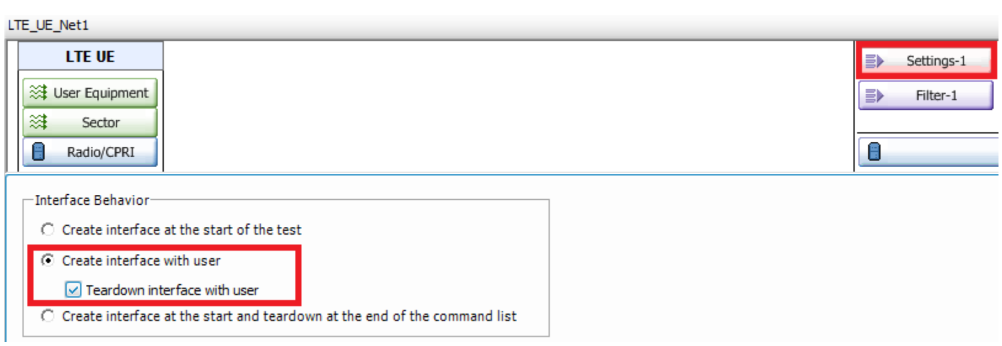


Figure 36. Network Plugin Settings

8. At this point, configuring the Network Layer for the NetTraffic activity is complete. We now move on to configuring L4-L7 Traffic simulated by the UE.
   Add an **HTTP client** activity to the LTE UE NetTraffic. Configure one command in the command list: **GET** the **1024k.html** file, you may enable dedicated bearer based on network support for it. This example does not use dedicated bearer.

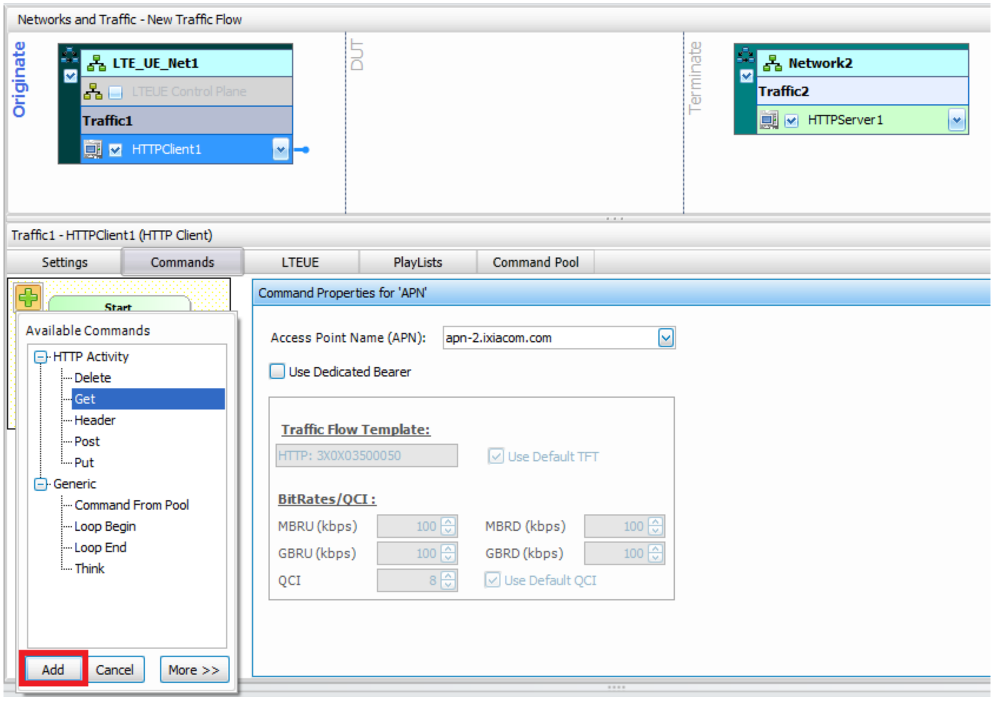


Figure 37. HTTP GET

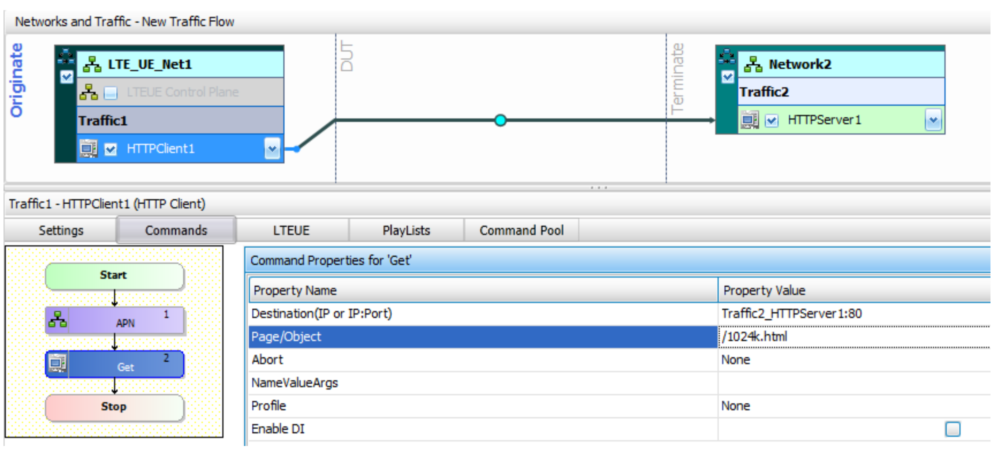


Figure 38. HTTP GET Config

9. In order to generate traffic coming in on SGi interface (HTTP Server), insert **a new NetTraffic** on the **Terminate side**. Configure it to have a range with **1 IP**, using an IP address and gateway that corresponds to EPC SGi interface. This step is optional, if you are simulating against an external L4-L7 server.

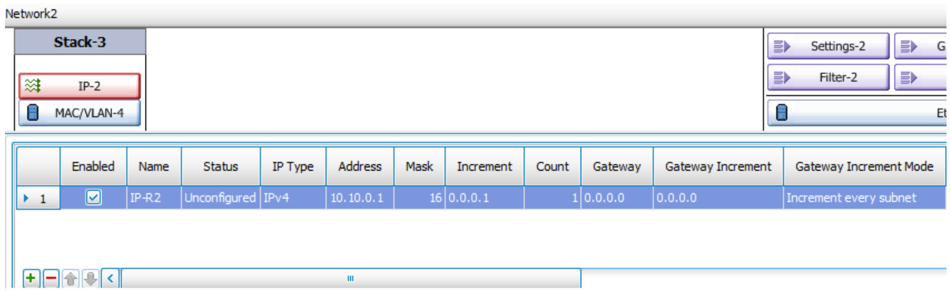


Figure 39. SGi Interface

Timeline and Objective

In this section, we define the L4-L7 traffic activity objectives, which will indirectly drive our network layer objectives.

For this scenario, simulate a UE attaching to the network and generating requests to simulate 10Mbps DL traffic from the cellular network for 3 minutes. In order to achieve this, use an HTTP objective of **Throughput (Mbps)** and **Sustain Time** of 3 minutes.

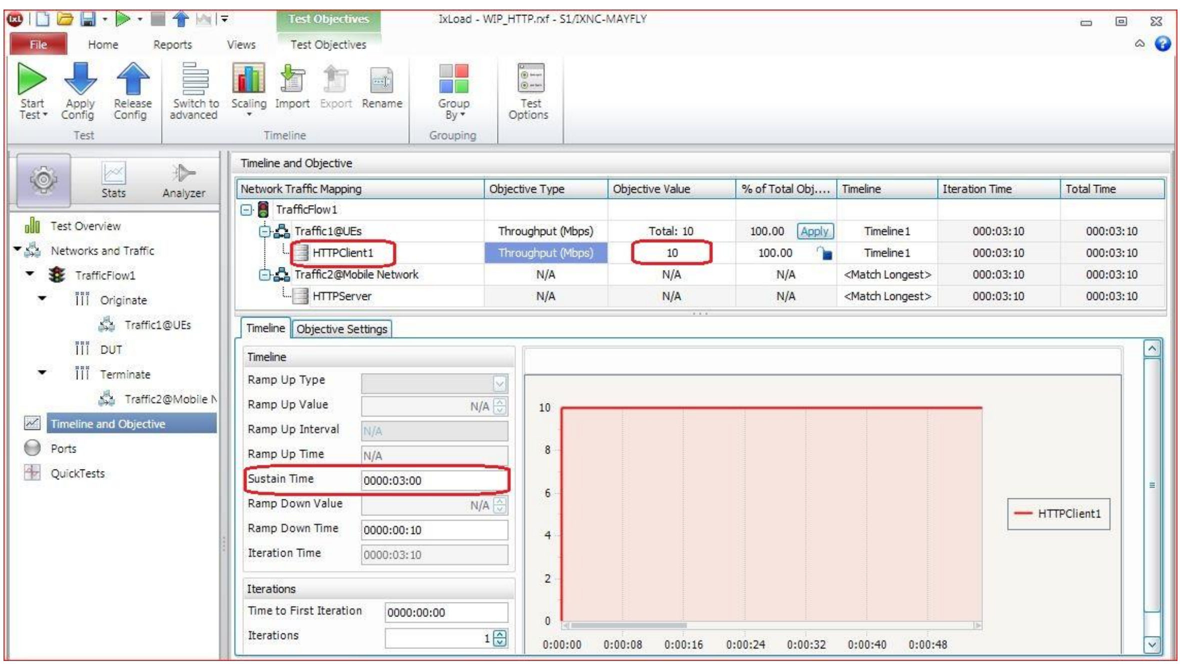


Figure 40. Timeline & Objective

Port Assignment

For LTE UE stack, Port Assignment is among the very first configuration steps. The configuration in this step is used during the Sector and Radio Head auto-discovery.

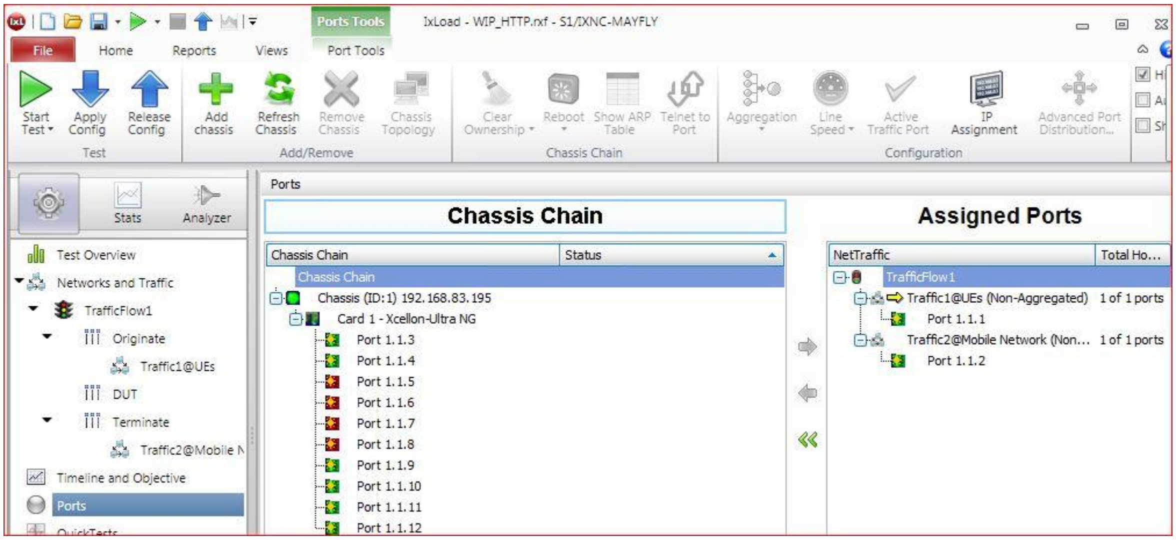


Figure 41. Port Assignment

Test Variables

Refer to the attached RXF for variables used in this test. Many of the settings (like IMSI, cell ID, OP, K, and so on) mustbe updated to suit the network you are simulating against.

Results Analysis

Once the test starts IxLoad automatically switches to Stats view. You can also use the Stats button in the upper-left side of IxLoad client application to enable this view.

One way to analyse stats is to start with Network layer – confirm all UEs have attached correctly; followed by traffic layer – confirm if we are hitting our throughput objective; and finally analyse UEs Quality of Experience.

Network Layer Stats – LTE UE Global

Verify **LTE UE Global** stats to make sure 1 UE has attached suceessfully. If there are failure check for

- RACH Success/Failure
- RRC Success/Failure
- Authentication Success/Failure

There are specific message counters that provide insight into the UE state.

LTE UE Global Stats are organized in 3 categories - System Summary, NAS Messaging, and RRC Messaging counters.

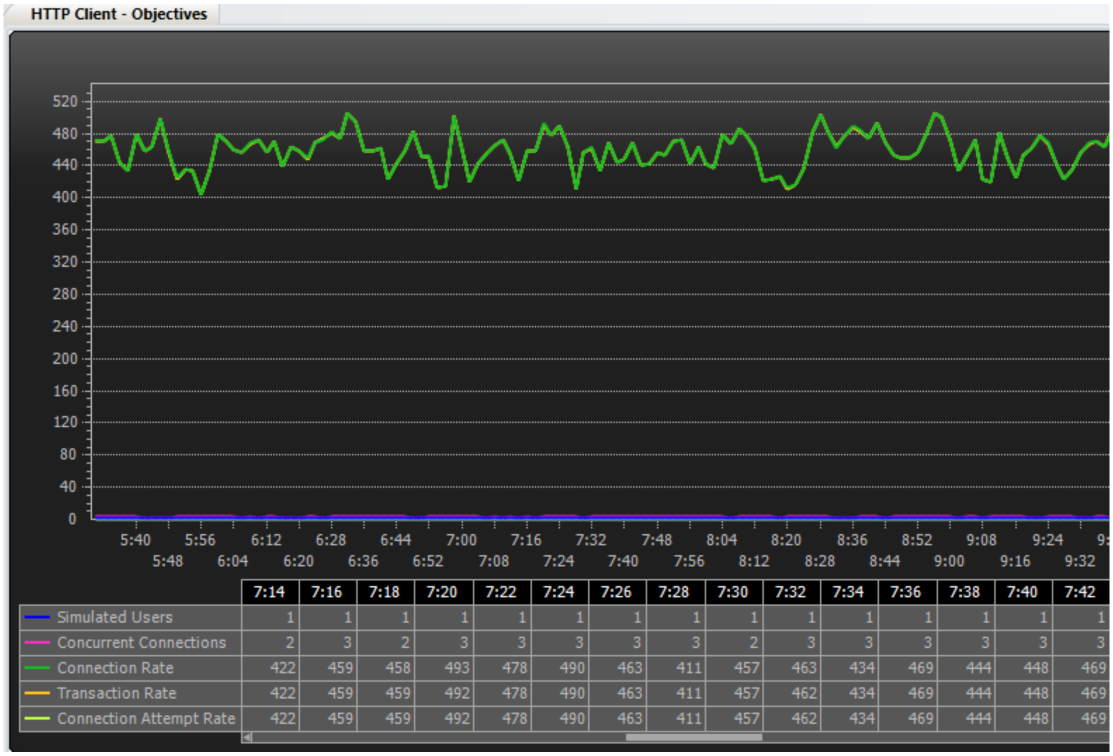
LTE UE - Global - All Ports

	Stat Name	:56	:58	1:00	1:02	1:04	1:06	1:08	1:10
1	LTE UE - Global/All Ports : Cells in BCH Sync	0	0	0	0	0	0	0	0
2	LTE UE - Global/All Ports : Available UEs	1	1	1	1	1	1	1	1
3	LTE UE - Global/All Ports : Current Attached UEs(EMM_REGISTERED)	1	1	1	1	1	1	1	1
4	LTE UE - Global/All Ports : Current Detached UEs(EMM_DEREGISTERED)	0	0	0	0	0	0	0	0
5	LTE UE - Global/All Ports : Current RRC Connected UEs	1	1	1	1	1	1	1	1
6	LTE UE - Global/All Ports : Current RRC IDLE UEs	0	0	0	0	0	0	0	0
7	LTE UE - Global/All Ports : Current APN Connections (Default Bearer)	1	1	1	1	1	1	1	1
8	LTE UE - Global/All Ports : Current Dedicated Bearers	0	0	0	0	0	0	0	0
9	LTE UE - Global/All Ports : ThroughPut UL	0	0	0	0	0	0	0	0
10	LTE UE - Global/All Ports : ThroughPut DL	0	0	0	0	0	0	0	0
11	LTE UE - Global/All Ports : Total Attach Attempts	1	1	1	1	1	1	1	1
12	LTE UE - Global/All Ports : Total Attach Succeeded	1	1	1	1	1	1	1	1
13	LTE UE - Global/All Ports : Total Attach Failed	0	0	0	0	0	0	0	0
14	LTE UE - Global/All Ports : Total Detach Attempts	0	0	0	0	0	0	0	0
15	LTE UE - Global/All Ports : Total Detach Succeeded	0	0	0	0	0	0	0	0
16	LTE UE - Global/All Ports : Total Detach Failed	0	0	0	0	0	0	0	0
17	LTE UE - Global/All Ports : UEs that attempted HO	0	0	0	0	0	0	0	0
18	LTE UE - Global/All Ports : Total HO Attempts	0	0	0	0	0	0	0	0
19	LTE UE - Global/All Ports : Total HO Succeeded	0	0	0	0	0	0	0	0
20	LTE UE - Global/All Ports : Total HO Failed	0	0	0	0	0	0	0	0

Figure 42. LTE UE Global Stats

User plane

Verify *HTTP Client Objectives* to make sure the test is meeting the pre-defined objective – 10Mbps DL traffic rate. These stats must also indicate one simulated user with maximum three concurrent HTTP connections per the default HTTP config.



	7:14	7:16	7:18	7:20	7:22	7:24	7:26	7:28	7:30	7:32	7:34	7:36	7:38	7:40	7:42
Simulated Users	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Concurrent Connections	2	3	2	3	3	3	3	3	2	3	3	3	3	3	3
Connection Rate	422	459	458	493	478	490	463	411	457	463	434	469	444	448	469
Transaction Rate	422	459	459	492	478	490	463	411	457	462	434	469	444	448	469
Connection Attempt Rate	422	459	459	492	478	490	463	411	457	462	434	469	444	448	469

Figure 43. HTTP Client Objective

Quality of experience

The QoE is a subjective definition interpreted based on specific L4-L7 traffic activities.

For instance, HTTP plugin offers the following stats to provide insight into QoE:

- HTTP Latencies – higher latencies imply poor experience for the user
- HTTP Failures – HTTP errors imply poor experience for the user
- TCP Failure – TCP resets and retries imply poor user experience

Below are some sample illustrations depicting the run that may be different for each setup. Analyze these runs as an exercise against the ones in your setup.

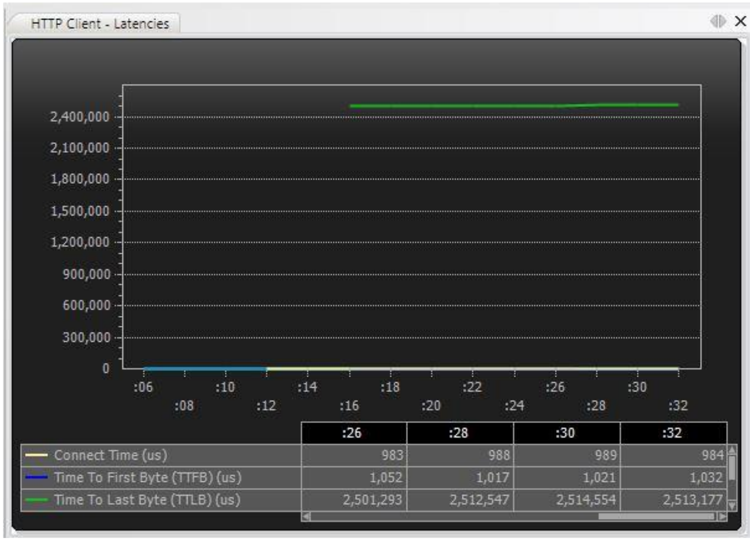


Figure 44. HTTP Latency

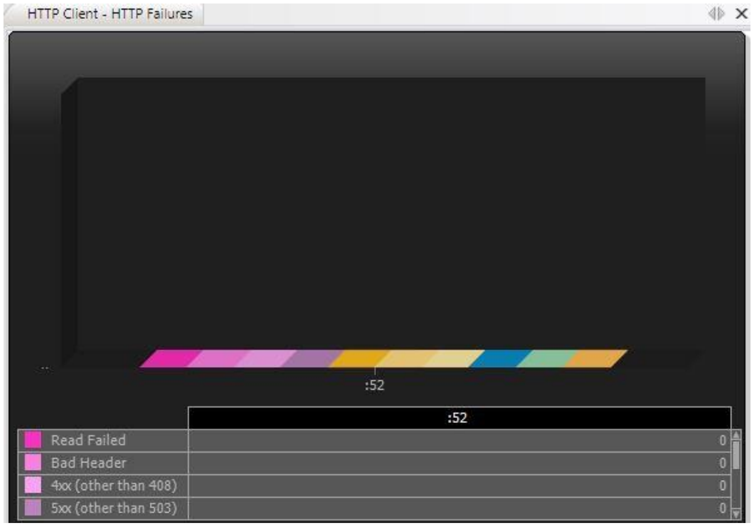


Figure 45. HTTP Failures

Test Case 2: Multi UE, 1000 UEs Configuration

Overview

Successfully simulating a 1 UE test implies that the basic setup and connectivity is alright. Therefore, we can accelerate and try to simulate 1000 UEs with our configuration.

Note: To simulate 1000 UEs you need three sectorcard sets. However, for this example we have simulated 1000 UEs in loop-back mode.

Objective

The objective is to create a test case where 1000 UEs attaching to the network at 10 UEs/sec, followed by 3 minutes of sustain time. Traffic rate remain the same – 10Mbps across 1000 UEs.

Setup

Refer to **Error! Reference source not found.** - **Error! Reference source not found.** for more in formation on setup.

Step-by-step Instructions

Follow the instructions from Scenario 1 to setup a 1 UE test configuration. Using that as a base, modify the following parts of the RXF to simulate 1000 UEs.

1. Click the **User Equipment** layout in order to configure the UEs (subscribers) for the test. Update the UE count from 1 to 1000.
   Note: In order to model subscriber behavior with more granularities, you can possess multiple ranges of UEs. This type of behavior is covered as part of Scenario 3 and 4.

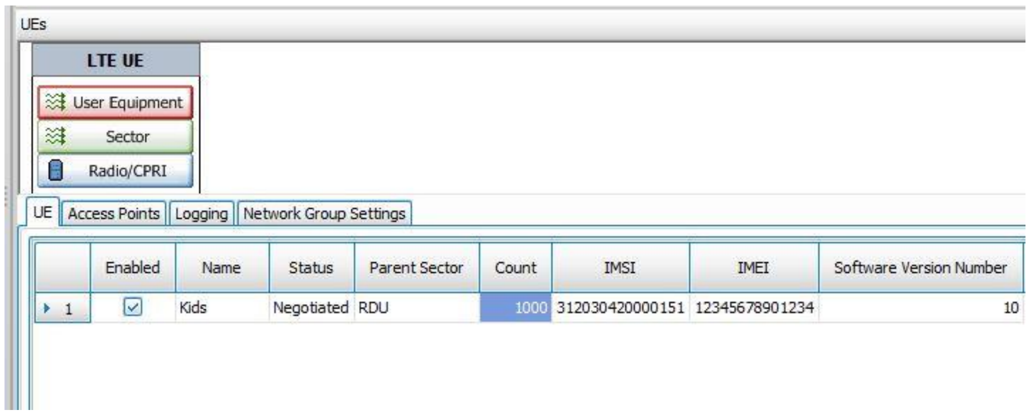


Figure 46. 1000 UE Count

Timeline and Objective

In this section, L4-L7 traffic activity objectives that indirectly drive network layer objectives are defined.

For this scenario, simulate 1000 UEs attaching to the network and generating requests to simulate 10Mbps DL traffic from the cellular network for 3 minutes. In order to achieve this, use an HTTP objective of **Throughput (Mbps)** with a Constraint of 1000 UEs. Set the **Sustain Time** to 3 minutes.

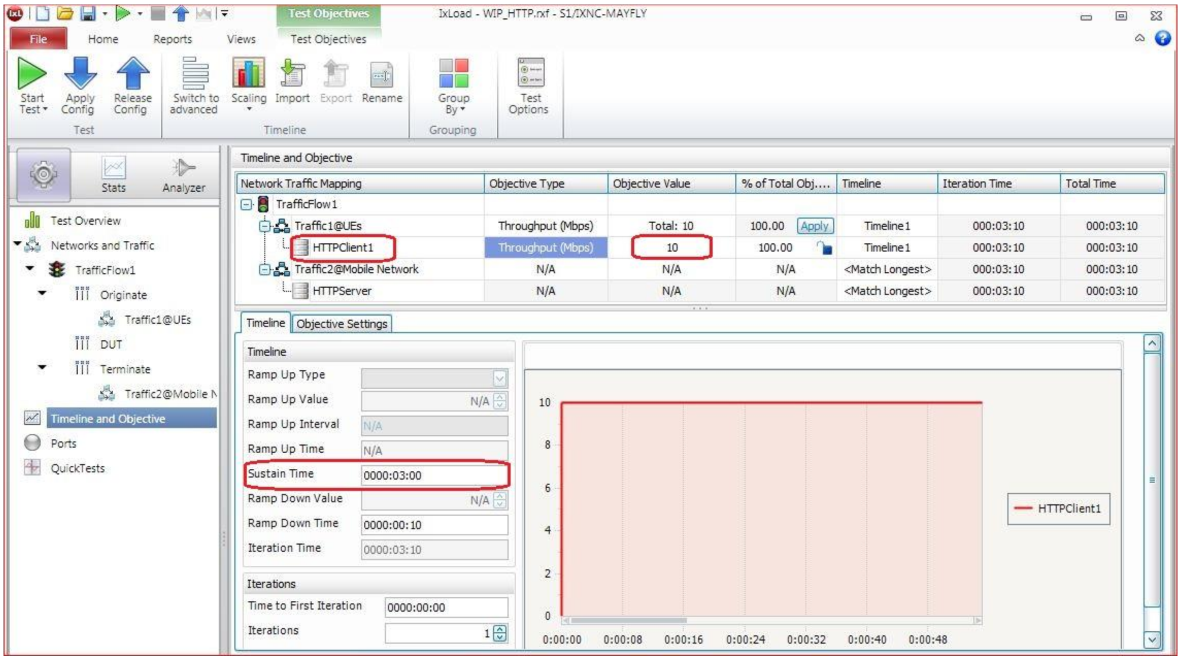


Figure 47. Timeline & Objective

Port Assignment

Refer to **Error! Reference source not found.** from Scenario 1.

Test Variables

Refer to the attached RXF for variables used in this test. Many of the settings (like IMSI, cell ID, OP, K, and so on) must be updated to suit the network you are simulating against.

Results Analysis

Once the test starts, IxLoad automatically switches to Stats view, Use the **Stats** button in the upper-left side of IxLoad client application to enable this view.

One way to analyse stats is to start with Network layer – confirm all UEs have attached correctly; followed by traffic layer – confirm if we are hitting our throughput objective; and finally analyse UEs Quality of Experience.

Network Layer Stats – LTE UE Global

Verify **LTE UE Global** stats to make sure 1000 UEs have attached suceessfully. If there is failure, check for:

- RACH Success/Failure
- RRC Success/Failure
- Authentication Success/Failure

For specific UEs that fail attaches, drill down the stats and retrieve per session stats. You can then filter and sort these per-session stats to specific criteria. Refer to IxLoad manual for more on these features.

LTE UE - Global - All Ports

	Stat Name	15:30	15:32	15:34
1	LTE UE - Global/All Ports : Cells in BCH Sync	0	0	0
2	LTE UE - Global/All Ports : Available UEs	1,000	1,000	1,000
3	LTE UE - Global/All Ports : Current Attached UEs(EMM_REGISTERED)	0	0	0
4	LTE UE - Global/All Ports : Current Detached UEs(EMM_DEREGISTERED)	1,000	1,000	1,000
5	LTE UE - Global/All Ports : Current RRC Connected UEs	0	0	0
6	LTE UE - Global/All Ports : Current RRC IDLE UEs	1,000	1,000	1,000
7	LTE UE - Global/All Ports : Current APN Connections (Default Bearer)	104	104	104
8	LTE UE - Global/All Ports : Current Dedicated Bearers	0	0	0
9	LTE UE - Global/All Ports : ThroughPut UL	0	0	0
10	LTE UE - Global/All Ports : ThroughPut DL	0	0	0
11	LTE UE - Global/All Ports : Total Attach Attempts	1,000	1,000	1,000
12	LTE UE - Global/All Ports : Total Attach Succeeded	998	998	998
13	LTE UE - Global/All Ports : Total Attach Failed	2	2	2

Figure 48. 1000 UE Stats

LTEUE Per Session

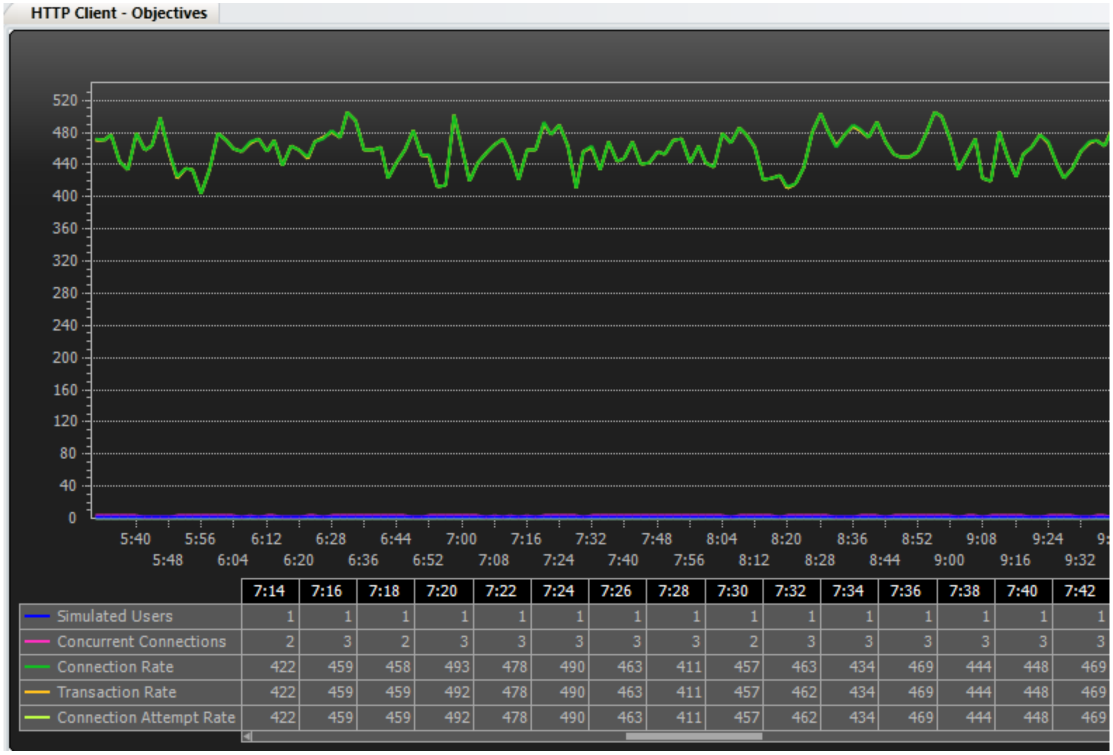
	Stat Name	Total Attach Failed	UE ID	UL Throughput	DL Throughput	EMM State	RRC State
1	192.168.83.195/Card1/Port1 - 000	0	312030420000151	0	0	Deregistered	Idle
2	192.168.83.195/Card1/Port1 - 001	0	312030420000152	0	0	Deregistered	Connected
3	192.168.83.195/Card1/Port1 - 002	0	312030420000153	0	0	Deregistered	Idle
4	192.168.83.195/Card1/Port1 - 003	0	312030420000154	0	0	Deregistered	Connected
5	192.168.83.195/Card1/Port1 - 004	0	312030420000155	0	0	Deregistered	Idle
6	192.168.83.195/Card1/Port1 - 005	0	312030420000156	0	0	Deregistered	Connected
7	192.168.83.195/Card1/Port1 - 006	0	312030420000157	0	0	Deregistered	Idle
8	192.168.83.195/Card1/Port1 - 007	0	312030420000158	0	0	Deregistered	Connected
9	192.168.83.195/Card1/Port1 - 008	0	312030420000159	0	0	Deregistered	Idle
10	192.168.83.195/Card1/Port1 - 009	0	312030420000160	0	0	Deregistered	Connected
11	192.168.83.195/Card1/Port1 - 010	0	312030420000161	0	0	Deregistered	Idle
12	192.168.83.195/Card1/Port1 - 011	0	312030420000162	0	0	Deregistered	Connected
13	192.168.83.195/Card1/Port1 - 012	0	312030420000163	0	0	Deregistered	Idle
14	192.168.83.195/Card1/Port1 - 013	0	312030420000164	0	0	Deregistered	Connected
15	192.168.83.195/Card1/Port1 - 014	0	312030420000165	0	0	Deregistered	Idle
16	192.168.83.195/Card1/Port1 - 015	0	312030420000166	0	0	Deregistered	Connected

1/20 (total rows: 1000) All

Figure 49. Drill Down Per Session

User plane

Verify *HTTP Client Objectives* to make sure the test is meeting the pre-defined objective – 10Mbps DL traffic rate. These stats must also indicate one simulated user with maximum three concurrent HTTP connections per the default HTTP configuration.



	7:14	7:16	7:18	7:20	7:22	7:24	7:26	7:28	7:30	7:32	7:34	7:36	7:38	7:40	7:42
Simulated Users	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Concurrent Connections	2	3	2	3	3	3	3	3	2	3	3	3	3	3	3
Connection Rate	422	459	458	493	478	490	463	411	457	463	434	469	444	448	469
Transaction Rate	422	459	459	492	478	490	463	411	457	462	434	469	444	448	469
Connection Attempt Rate	422	459	459	492	478	490	463	411	457	462	434	469	444	448	469

Figure 50. HTTP Client Objective

Quality of experience

The QoE is a subjective definition interpreted based on specific L4-L7 traffic activities.

For instance, HTTP plugin offers the following stats to provide insight into QoE:

- HTTP Latencies – higher latencies imply poor experience for the user
- HTTP Failures – HTTP errors imply poor experience for the user
- TCP Failure – TCP resets and retries imply poor user experience

Below are some sample illustrations in the run that may be different for each setup. Analyze these runs as an exercise against the ones in your setup.

Figure 51. HTTP Latency

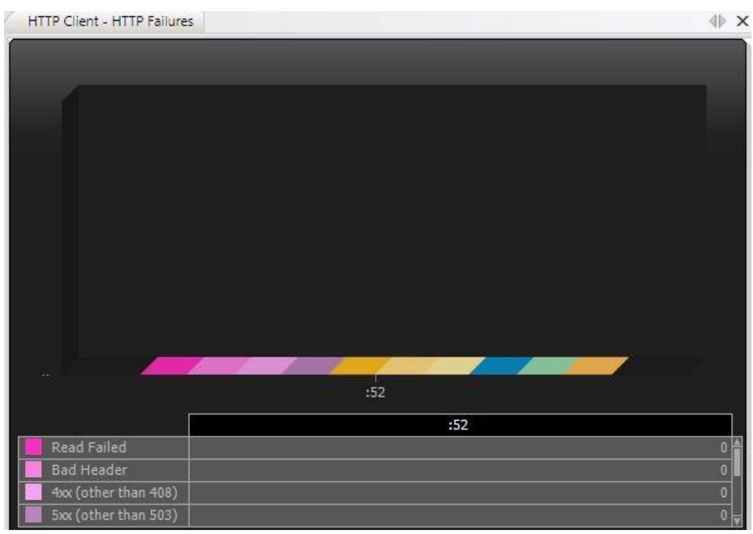


Figure 52. HTTP Failure

Test Case 3: Multiple UE Ranges – Multiple Activities

Overview

The test case demonstrates how to configure IxLoad for scenarios where different ranges of UEs must be emulated on the LTE Uu interface, each running a different L7 activity.

Objective

This test case explains how to run a basic attach scenario using 4 ranges of UEs, each mapped to a different activity type.

Setup

Refer to **Error! Reference source not found.** - **Error! Reference source not found.** for more in formation on setup.

Multiple configuration parameters depend on the network under test; such as IP addresses for the application servers used, UE identifier parameters like IMSI and MSISDN, networking parameters, and so on. These parameters are obtained by knowing the network configuration.

Step-by-step Instructions

To achieve the test case objectives, perform the following tasks:

1. Open already created rxf file from 1 UE attach scenario:

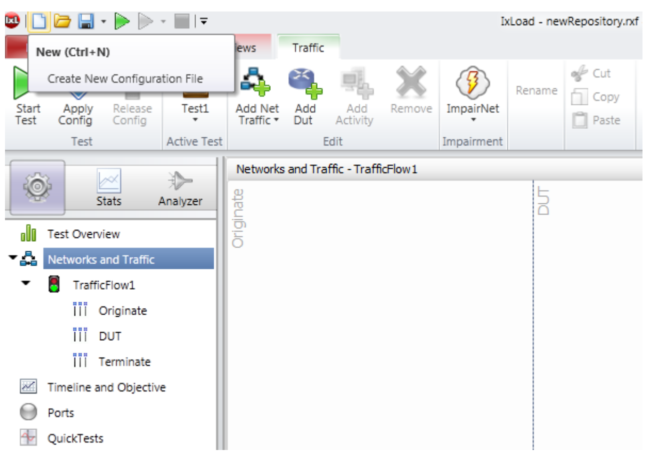


Figure 53. Open LTE UE configuration

UE layer

***UE tab configuration*:**

Add three more UE ranges

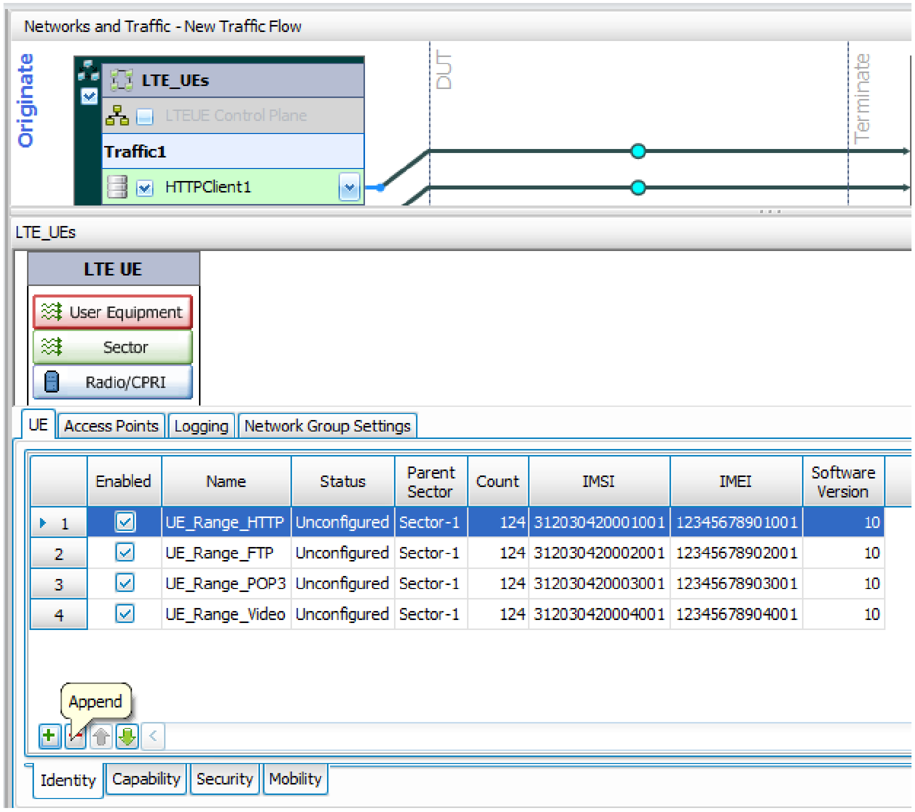


Figure 54. UE ranges configuration

The UE tab contains the following additional tabs:

Tab	Description
Identity	Configure the **Count** value to match the test variables section. For this scenario, use Count set to 124 UEs on each UE range. Configure the appropriate values for **IMSI, IMEI,** and **Software Version.** These values identify the subscription and equipment and must match the values configured in the system under test. All UE ranges use the same **Parent Sector.**
Capability	This scenario uses default settings for UE Category, Supported Bands, and options like Tx Antenna Selection and UE Specific Reference Signals.
Security	In this tab, you can configure parameters related to **USIM** like **OP** preshared-key and supported LTE ciphering LTE Integrity algorithms.

Access Points Tab

Configure the **APN Name** and APN's **IP type** to match the values configured in the system under test. The same APN IPv4 is used for all UE ranges.

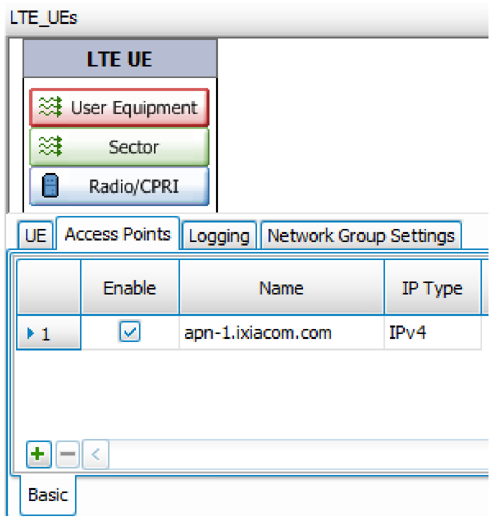


Figure 55. Access Points tab

Logging Tab

For this scenario **NAS/RRC Messages** logging is used.

No changes are needed.

Network Group Settings Tab

For this test the default Error log level is used.

No changes are needed.

Sector Layout

Sector Info Tab

For this scenario all UE ranges will use the same sector.

No changes are needed.

RLC, MAC and PHY Tabs

These tabs enable lower layer logging options. No changes are needed.

Radio/CPRI layout

Radio Head Info Tab

No changes are needed. The same radio head can be used.

Sector Tab

No changes are needed. The same frequency settings can be used.

2. Select the LTE UE stack and add 3 different L7 activities – 1 FTP Client, 1 POP3 Client and 1 IPTV_Video Client.

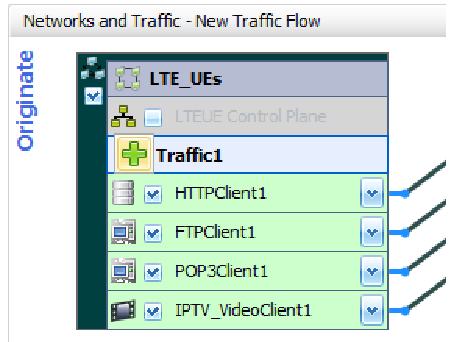


Figure 56. Configure different L7 Activities

3. Select the terminate side and add 3 more L7 servers – 1 FTP, 1 POP3, and 1 IPTV_Video.

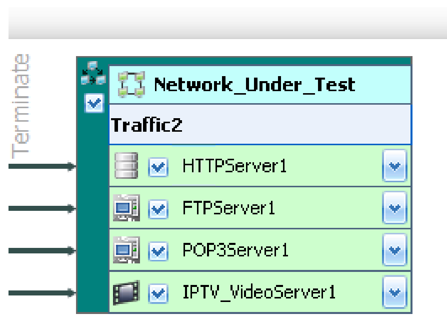


Figure 57. Add L7 Servers

4. Select and configure the IPTV_Video server to provide 124 streams for VoD:

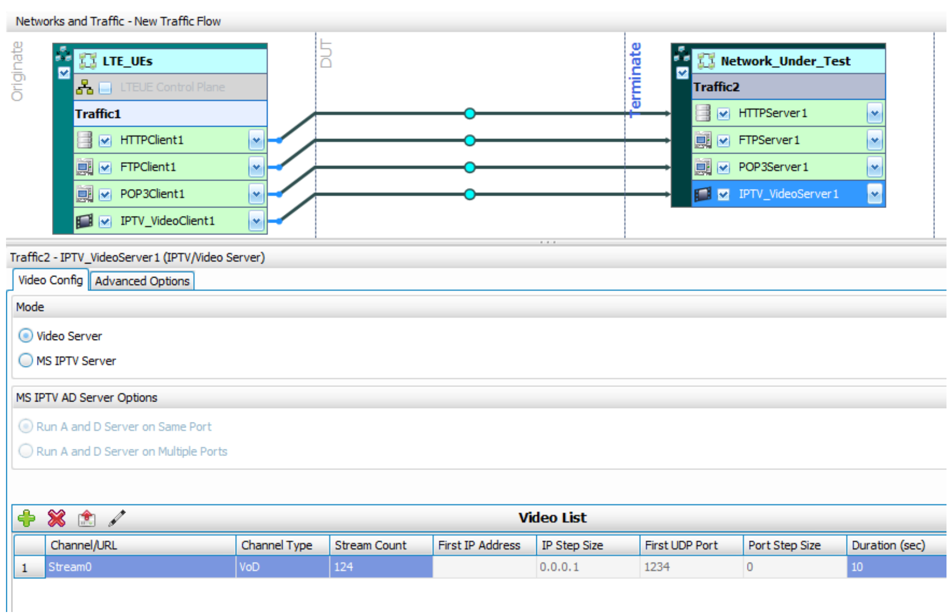


Figure 58. Configure IPTV_Video Server

5. Configure the FTP, POP3, and 1 IPTV clients:

All activities use the same APN, no changes are needed for APN command.

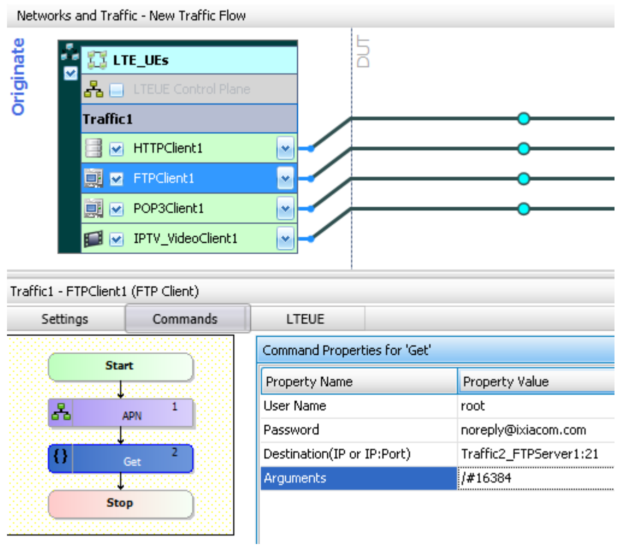


Figure 59. FTP client configuration

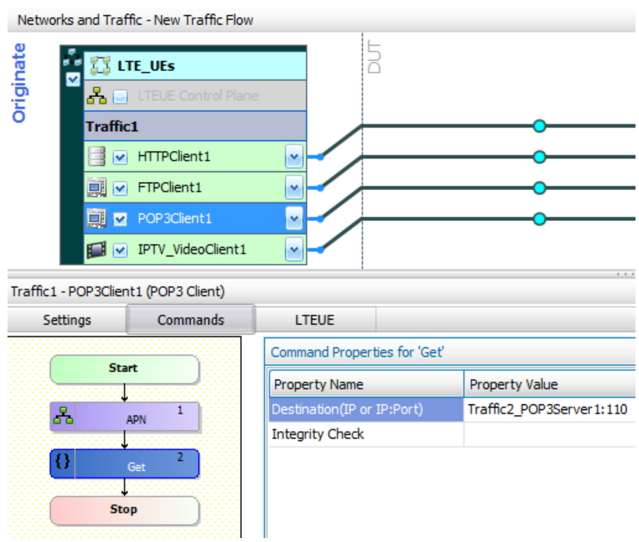


Figure 60. Configure IPTV_Video Server

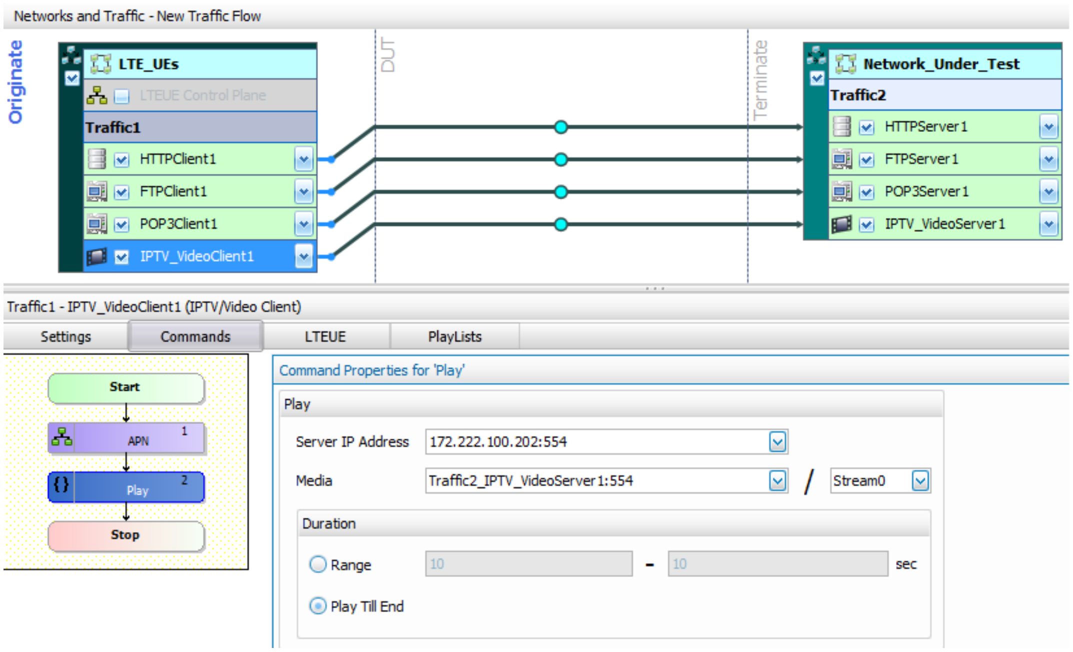


Figure 61. ITPV client configuration

6. Select **Traffic** layer on the LTE_UE stack and map each UE range to one activity.

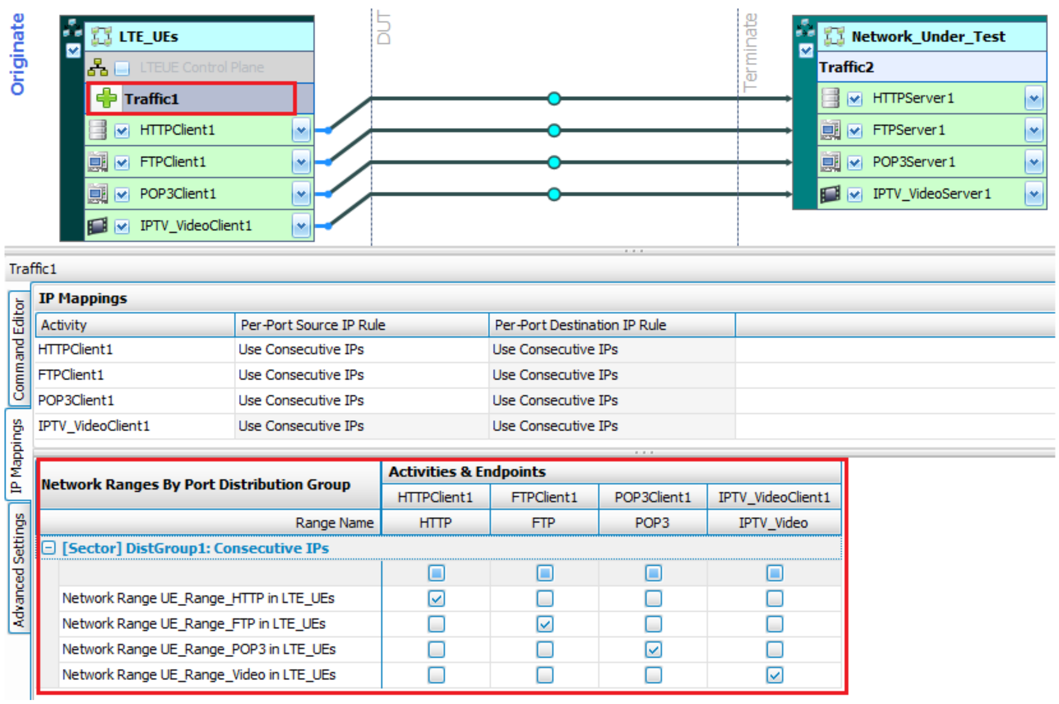


Figure 62. Map UE ranges to L7 activities

Timeline and Objective

In this section we define the L4-L7 traffic activity objectives, which will indirectly drive our network layer objectives.

For this scenario we have to simulate 496 UEs divided in 4 groups. Each group will be attaching to the network and will generate different L7 traffic types for 5 minutes. In order to achieve this we use an objective of “Simulated Users=124” for each HTTP, FTP, POP3 and IPTV_Video activities and a Sustain Time of 5 min.

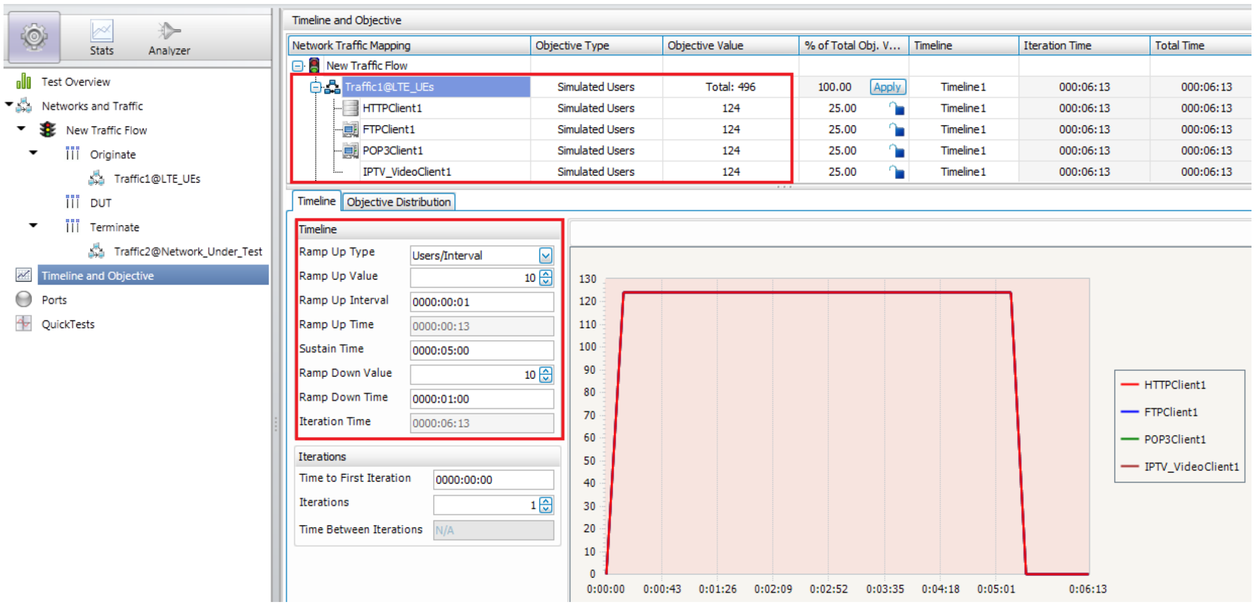


Figure 63. Timeline & Objective

Port Assignment

Refer to **Error! Reference source not found.** from Scenario 1.

Test Variables

Refer to attached RXF for variables used in this test. Many of the settings (like IMSI, cell ID, OP, K etc) will have to be updated to suit the network you are simulating against.

Results Analysis

Once the test is started IxLoad will automatically switch to Stats view, you can also use the Stats button in the upper-left side of IxLoad client GUI to enable this view.

One way to analyse stats is to start with Network layer – confirm all UEs have attached correctly, followed by traffic layer – confirm if we are hitting our test objective and finally analyse UEs Quality of Experience.

Network Layer Stats – LTE UE Global

Verify **LTE UE Global** stats to make sure 496 UEs have attached suceessfully.

If there are failures check for

- RACH Success/Failure
- RRC Success/Failure
- Authentication Success/Failure

For specific UEs that fail attaches, you can also “drill down” stats and retrieve per UE range stats. These per-UE stats can then further be filtered and sorted to specific criteria. Refer to IxLoad manual for more on these features.

LTE UE - Global - All Ports

	Stat Name	3:46	3:48	3:50	3:52	3:54	3:56
1	LTE UE - Global/All Ports : Cells in BCH Sync	0	0	0	0	0	0
2	LTE UE - Global/All Ports : Available UEs	496	496	496	496	496	496
3	LTE UE - Global/All Ports : Current Attached UEs(EMM_REGISTERED)	496	496	496	496	496	496
4	LTE UE - Global/All Ports : Current Detached UEs(EMM_DEREGISTERED)	0	0	0	0	0	0
5	LTE UE - Global/All Ports : Current RRC Connected UEs	496	496	496	496	496	496
6	LTE UE - Global/All Ports : Current RRC IDLE UEs	0	0	0	0	0	0
7	LTE UE - Global/All Ports : Current APN Connections (Default Bearer)	496	496	496	496	496	496
8	LTE UE - Global/All Ports : Current Dedicated Bearers	0	0	0	0	0	0
9	LTE UE - Global/All Ports : ThroughPut UL	0	0	0	0	0	0
10	LTE UE - Global/All Ports : ThroughPut DL	0	0	0	0	0	0
11	LTE UE - Global/All Ports : Total Attach Attempts	496	496	496	496	496	496
12	LTE UE - Global/All Ports : Total Attach Succeeded	496	496	496	496	496	496
13	LTE UE - Global/All Ports : Total Attach Failed	0	0	0	0	0	0
14	LTE UE - Global/All Ports : Total Detach Attempts	0	0	0	0	0	0
15	LTE UE - Global/All Ports : Total Detach Succeeded	0	0	0	0	0	0
16	LTE UE - Global/All Ports : Total Detach Failed	0	0	0	0	0	0
17	LTE UE - Global/All Ports : UEs that attempted HO	0	0	0	0	0	0
18	LTE UE - Global/All Ports : Total HO Attempts	0	0	0	0	0	0
19	LTE UE - Global/All Ports : Total HO Succeeded	0	0	0	0	0	0
20	LTE UE - Global/All Ports : Total HO Failed	0	0	0	0	0	0

Figure 64. 496 UE Stats

LTEUE Per Range

	Stat Name	Range Identifier	UL Throughput	DL Throughput	Current Sessions	Sessions Initiated Count	Sessions Succeeded Count	Sessions Rejected Count
1	192.168.83.195/Card1/Port1 - 0	0	0	0	124	124	124	0
2	192.168.83.195/Card1/Port1 - 1	1	0	0	124	124	124	0
3	192.168.83.195/Card1/Port1 - 2	2	0	0	124	124	124	0
4	192.168.83.195/Card1/Port1 - 3	3	0	0	124	124	124	0

Figure 65. LTE UE Drill Down Per Range

User plane

Verify *L7 Client Objectives for each activity type* to make sure the test is meeting the pre-defined objective – 124 Video on Demand streams, 124 POP3 users, 124 FTP users with maximum 1 FTP connection per user and 124 HTTP users with maximum 3 concurrent HTTP connections per user.

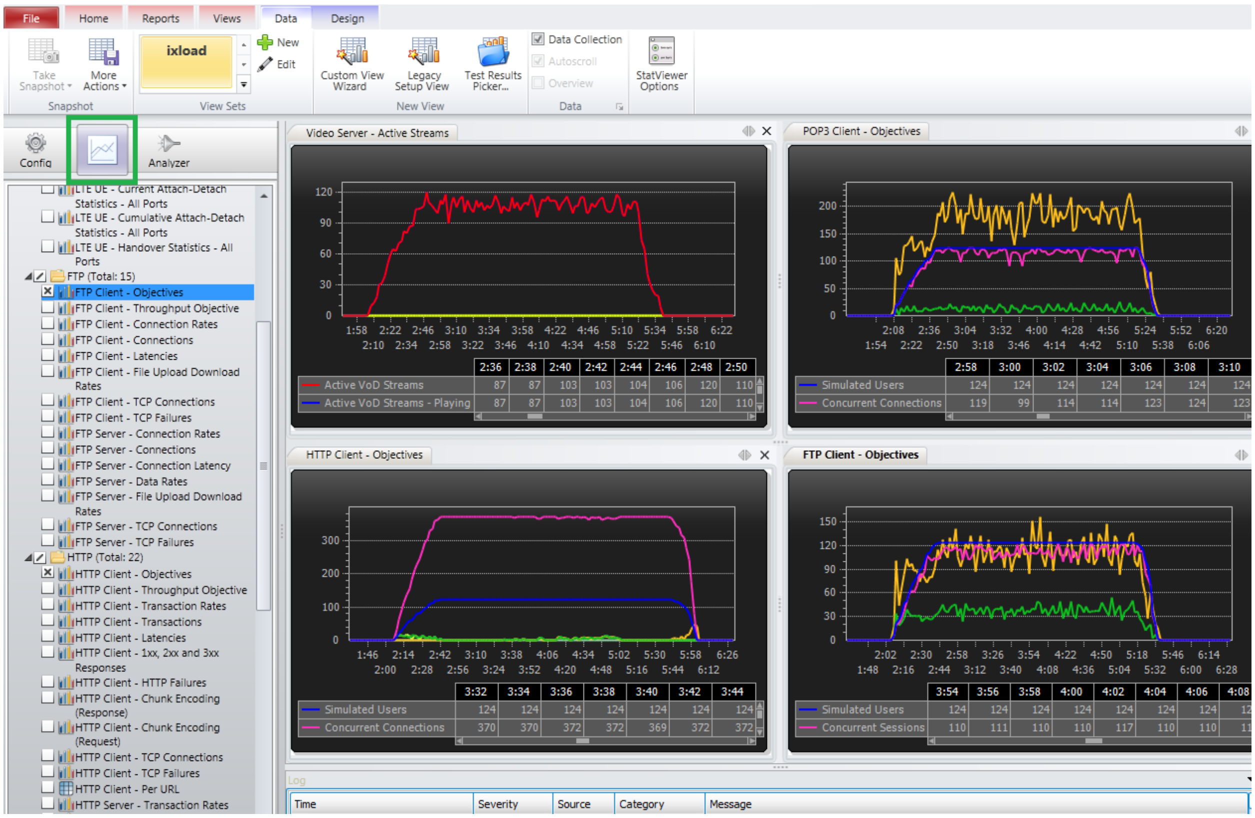


Figure 66. **L7 Activities objectives**

Quality of experience

The QoE is a subjective definition that can be interpreted based on specific L4-L7 traffic activities.

As examples IPTV Video activity offers the following stats to provide insight into QoE,

- Video packets Jitter distribution – high jitter imply poor experience for the user
- Inter Packet Arrival Time Distribution – higher inter packet arrival time imply poor experience for the user
- RTP Loss Distribution – Packet loss imply poor user experience

POP3 activity offers the following stats to provide insight into QoE,

- POP3 Mail Rates – closer to the maximum configured rates imply better experience for the user
- TCP Failure – TCP resets and retries imply poor user experience

FTP activity offers the following stats to provide insight into QoE,

- FTP File Upload Download Rates – closer to the maximum configured rates imply better user experience
- TCP Failure – TCP resets and retries imply poor user experience

Below are some screenshots from Scenario 3 run. But these measured values can be different for each setup.

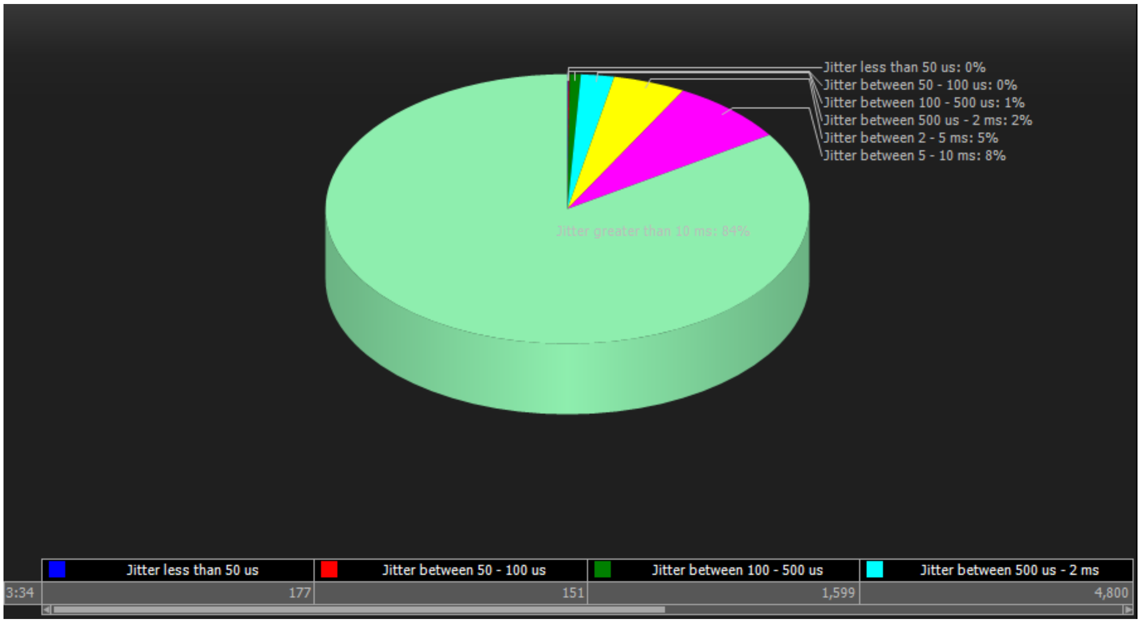


Figure 67. Video jitter distribution

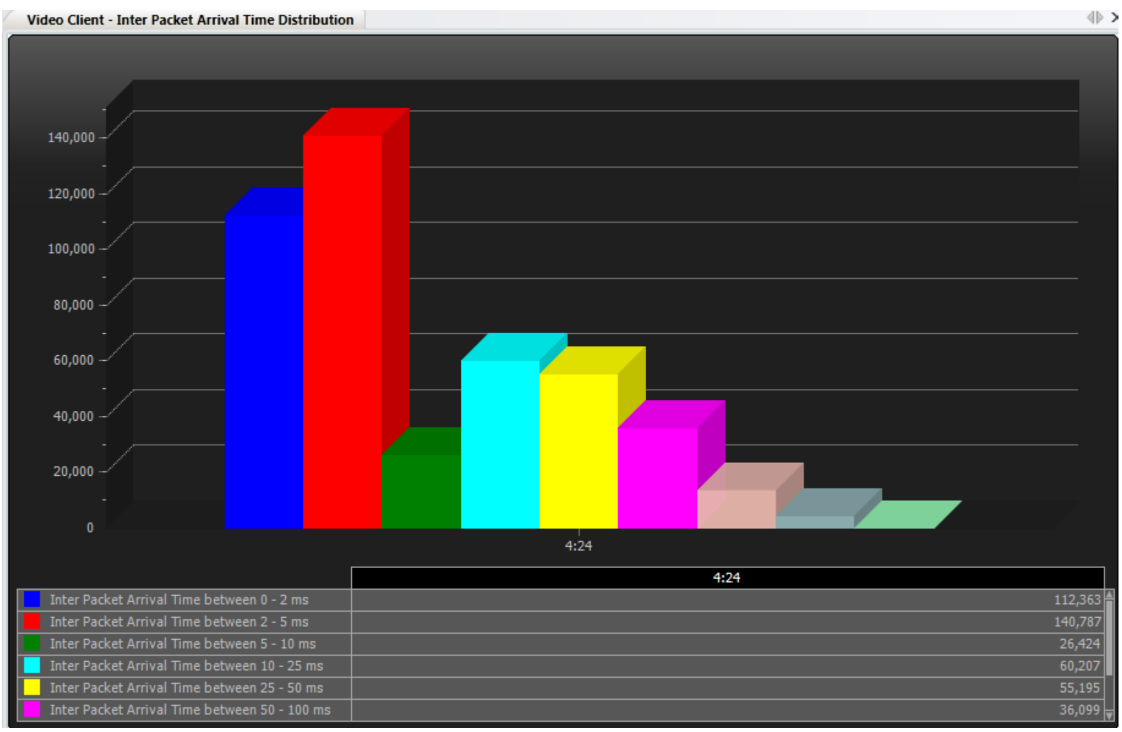


Figure 68. Video inter packet arrival distribution

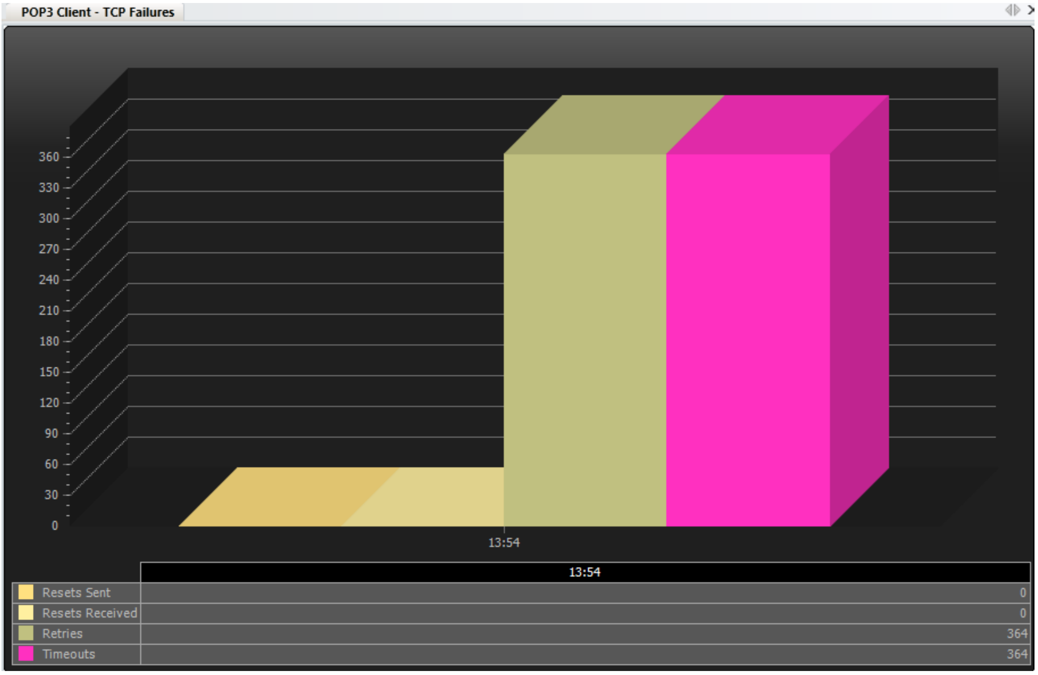


Figure 69. POP3 Client TCP Failures

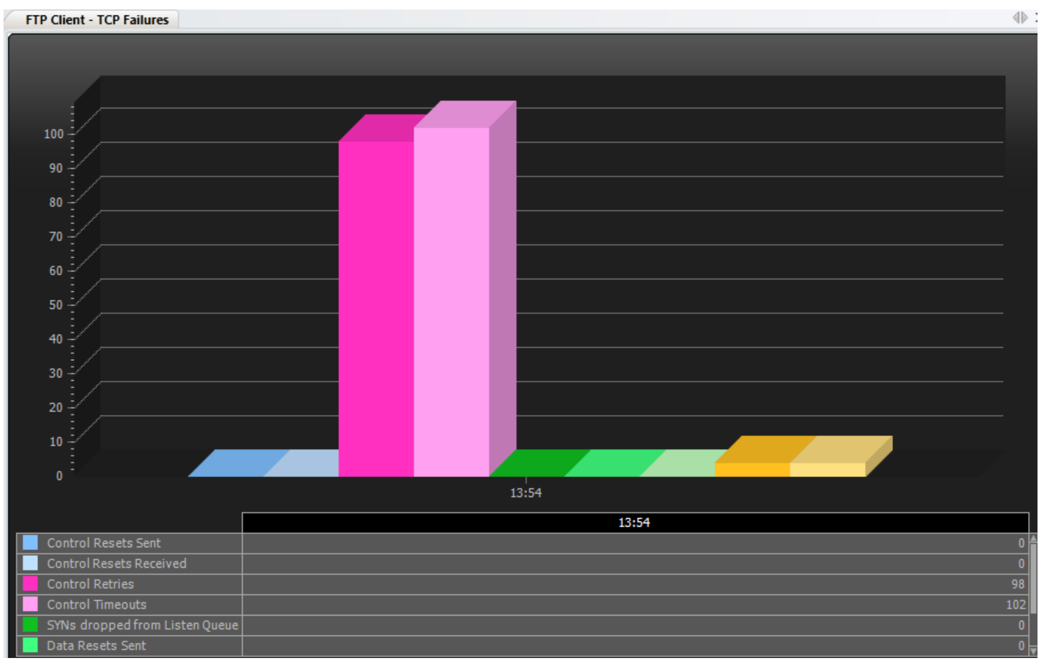


Figure 70. FTP Client TCP Failures

Test Case 4: VoLTE

Overview

With the migration of mobile networks to all IP networks defined by the LTE specification, there is a need to migrate the voice and sms services as well. Today, there are several options for carrying voice over LTE, using different technologies:

- **CSFB, Circuit Switched Fall Back**: The circuit switched fallback, CSFB option for providing voice over LTE has been standardized under 3GPP specification 23.272. Essentially LTE CSFB uses a variety of processes and network elements to enable the circuit to fall back to the 2G or 3G connection (GSM, UMTS, CDMA2000 1x) before a circuit switched call is initiated.
  The specification also allows for SMS to be carried as this is essential for very many set-up procedures for cellular telecommunications. To achieve this, the handset uses an interface known as SGs which allows messages to be sent over an LTE channel.
- **SV-LTE - simultaneous voice LTE**: SV-LTE allows running packet switched LTE services simultaneously with a circuit switched voice service. SV-LTE facility provides the facilities of CSFB at the same time as running a packet switched data service. This is an option that many operators will opt for. However it has the disadvantage that it requires two radios to run at the same time within the handset. This has a serious impact on battery life.
- **VoLGA, Voice over LTE via GAN**: The VoLGA standard was based on the existing 3GPP Generic Access Network (GAN) standard, and the goal was to enable LTE users to receive a consistent set of voice, SMS (and other circuit-switched) services as they transition between GSM, UMTS and LTE access networks.
- **Voice over LTE, VoLTE (initially called One Voice)**: The Voice over LTE, VoLTE aims for providing voice over an LTE system utilizes IMS enabling it to become part of a rich media solution.

One additional approach which is not initiated by operators is the usage of Over-the-top (OTT) content services, using applications like Skype and Google Talk to provide LTE voice service. However, handing the LTE voice service over completely to the OTT actors is expected to not receive too much support in the telecom industry while the voice call service is, and will still be, the main revenue source for the mobile operators.

VoLTE is the chosen standard for LTE Voice. VoLTE is defined in the GSM Association's (GSMA) Permanent Reference Document IR.92 which provides a profile of minimum mandatory 3GPP capabilities. The document is intended to ensure interoperable SIP-based IMS VoIP and SMS for UEs and the LTE EPC.

The typical topology for VoLTE is shown in the **Error! Reference source not found.**. The SIP r egistration and call control messages are sent from the User Endpoint (UE) over the default bearer in EPC to the Proxy Call Session Control Function (P-CSCF), the entry point in the IMS domain. In some networks an Session Border Controller (SBC) is used for this function. The Serving Call Session Control Function (S-CSCF) is the central node of the signaling plane. It is a SIP server that communicates to the Home Subscriber Server to download the users' profiles. S-CSCF controls over the Mr or Mg interfaces the Media Server and Media Gateway for voice routing.

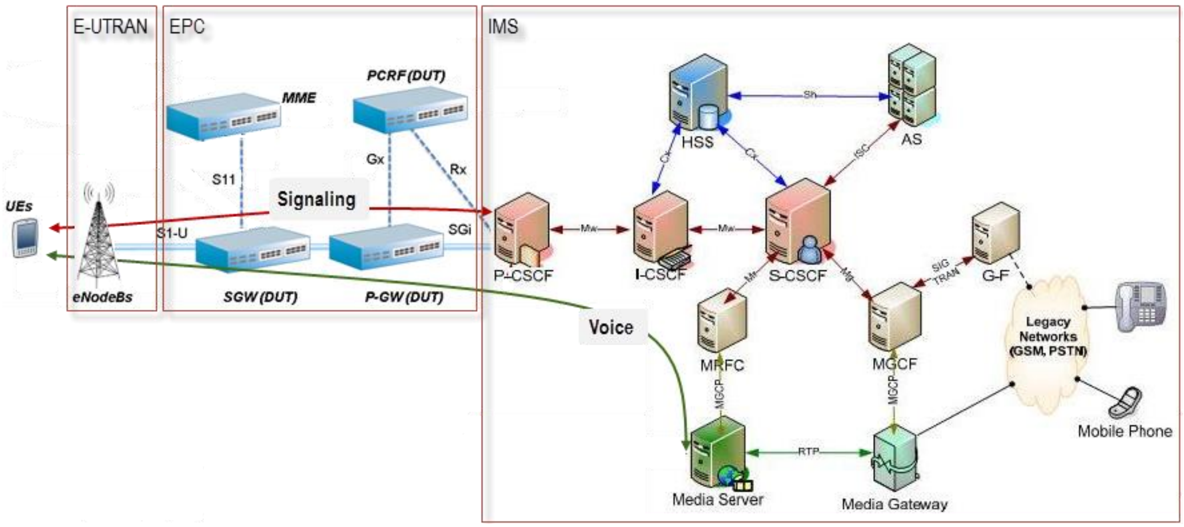


Figure 71. VoLTE Topology

In order to assure a good quality of voice, a dedicated bearer with high QoS is used for conversational speech in the EPC domain. The allocation of the dedicated bearer is requested by the P-CSCF to the Policy and Charging Rules Function (PCRF) over the Rx interface (this is a Diameter interface).

SMS-over-IP is also a functionality specified by VoLTE. The UE submits a short message via a SIP MESSAGE request that follows the same path to the S-CSCF; from here, depending on the user profile (obtained by S-CSCF from HSS) the SIP request is sent to the IP-SM-GW (IP Short Message Gateway); for simplicity this server is not represented in the topology shown in **Error! Reference source not found.**. The submission report is sent by the IP-SM-GW to the UE as a SIP MESSAGE Request. The SMS submit and submission report requests use the same SIP Method, but with different content-body.

Objective

Create and run a basic VoLTE scenario: 100 UEs attaching to the network at 10 UEs/sec performing 10 s long bi-directional voice calls during 3 minutes of sustain time.

Setup

Refer to **Error! Reference source not found.** - **Error! Reference source not found.** for more information on setup.

Multiple configuration parameters depend on the network under test, such as IP addresses for the application servers used, UE identifier parameters like IMSI and MSISDN, networking parameters, etc. These are typically obtained by knowing the network configuration.

Step-by-step Instructions

Follow the instructions from Scenario 1 to setup a 1 UE test configuration. Using that as a base, modify the following parts of the RXF to simulate a basic VoLTE scenario.

1) Open already created rxf file from 1 UE attach scenario.

2) On the “Originate” side replace the HTTP activity with a VoIP SIP Peer activity. Do the same for “Terminate” side.

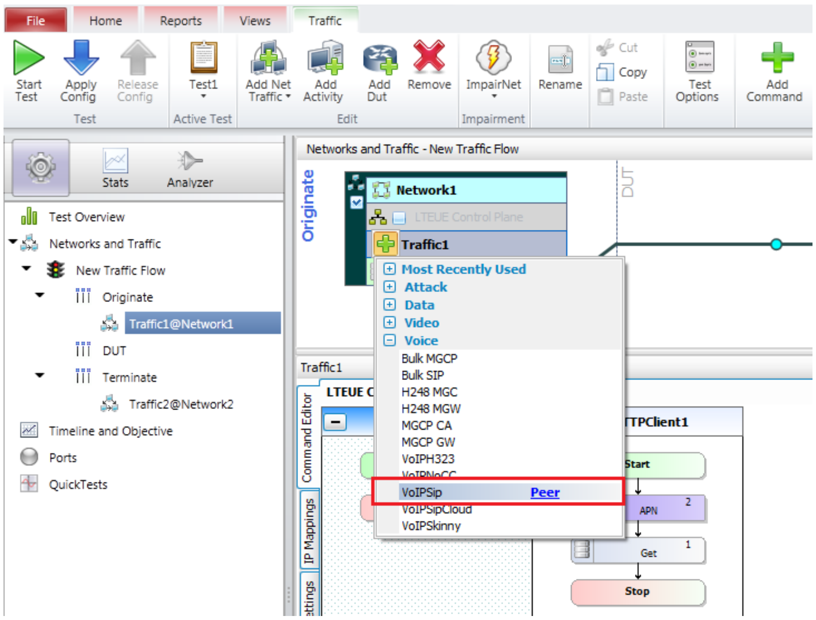


Figure 72. **Add VoIP Sip Peers**

3) On the “Terminate” side (SGi interface) set the IP Count value to 100. Each VoIP Peer will use a unique IP.

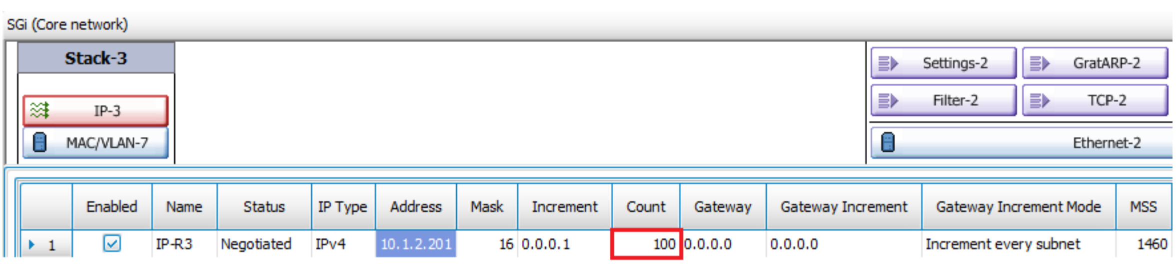


Figure 73. IP Count VoIP Sip Peer 2

4) On the “Originate” side select VoIP Sip Peer -> Settings and then “Workspace” Button on “Scenario” tab to display the **Workspace**. Add one **SIP MakeCall** procedure and one **SIP EndCall Initiate** procedure from **Procedure Library**. Add one **RTP Voice Session** function from VoIP **Media Library** section, also.

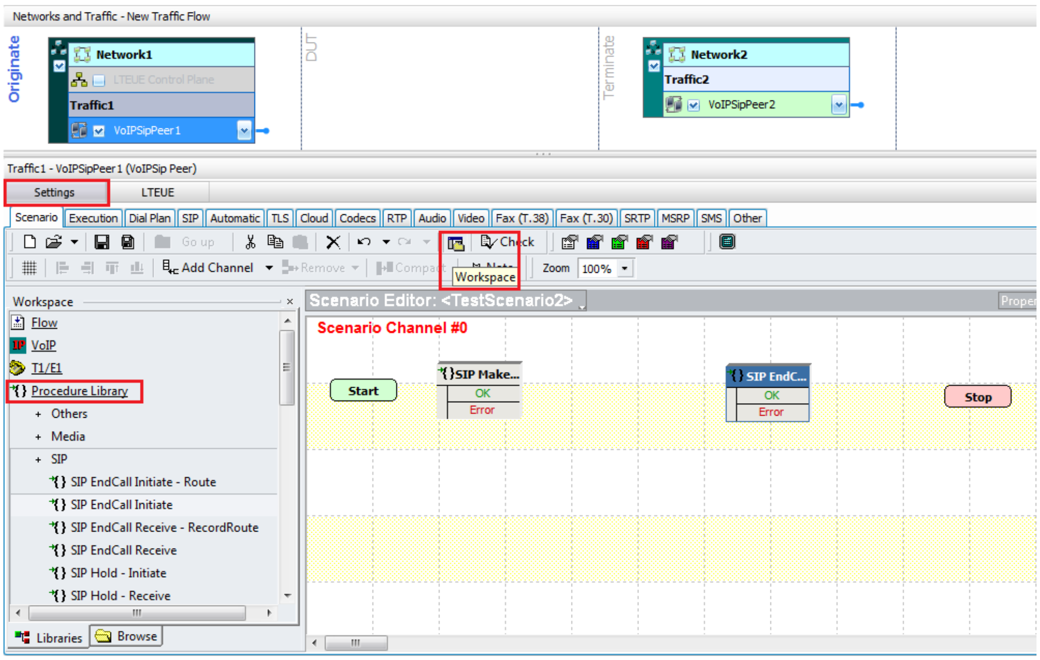


Figure 74. **Add VoIP Sip Procedures**

5) Insert a new channel at the end of scenario.

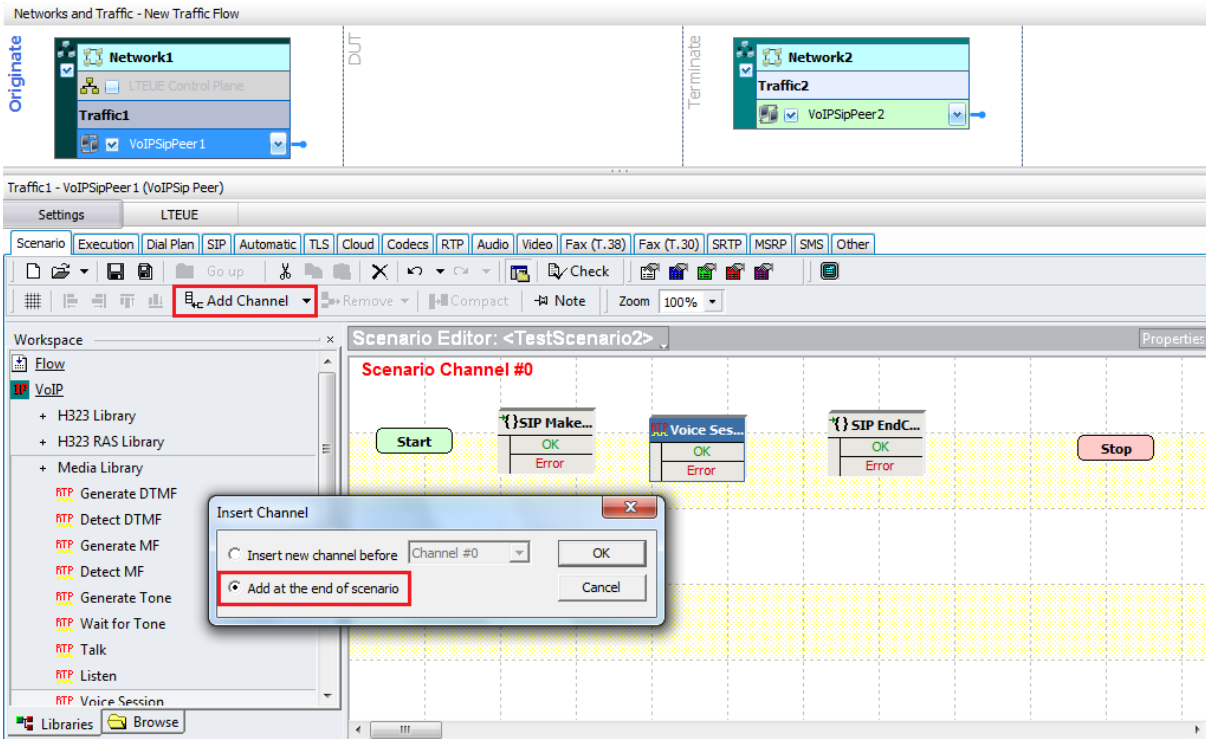


Figure 75. **Insert new channel**

6) Map the new channel to existing VoIP Sip Peer activity on the Terminate side

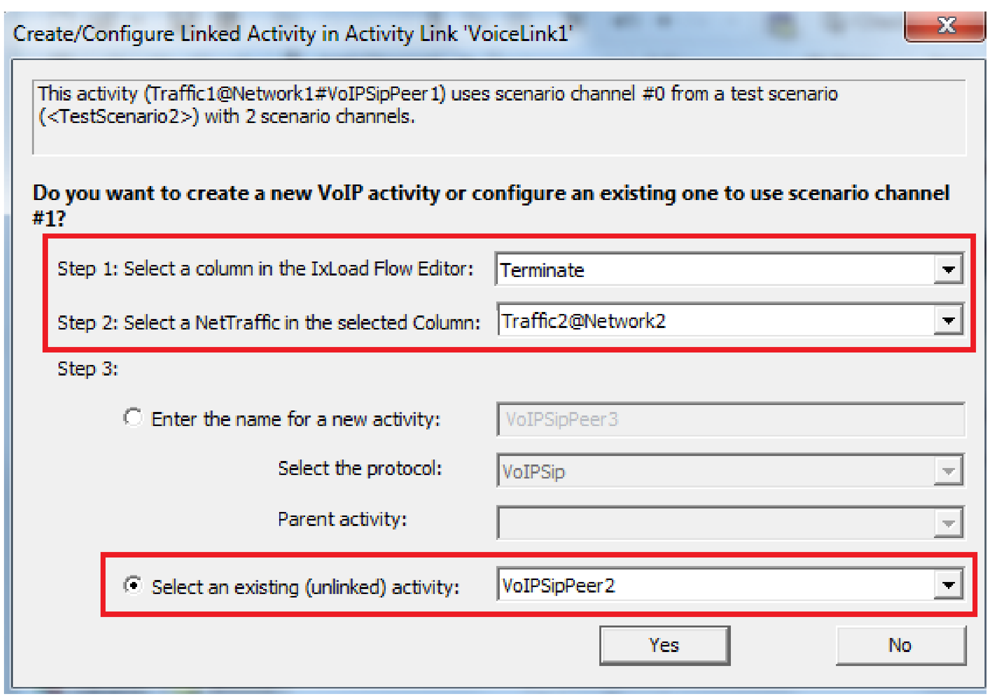


Figure 76. **Map VoIP channel**

7) Add a **SIP ReceiveCall** procedure, a **SIP EndCall Receive** procedure and an **RTP Voice Session** to the new channel.

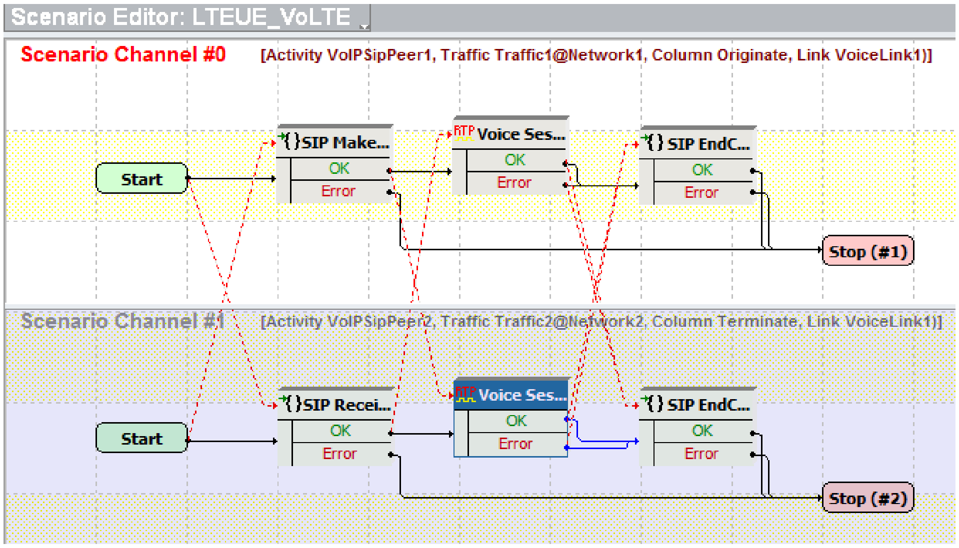


Figure 77. **Complete VoIP scenario**

8) Connect the VoIP procedures or functions by selecting an output and then drag and drop the wire to the next function/procedure:

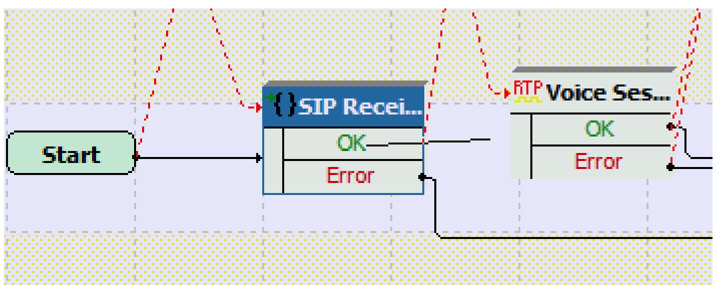


Figure 78. Link VoIP functions with drag and drop

VoIP Settings

Scenario tab

This is the 1st tab of the VoIP Settings where the SIP scenario must be configured or imported and linked to existing **VoIP SIP Peer** activities.
The **Workspace** that contains VoIP procedures and functions is located in this tab also.

Execution tab

Contains advanced settings for Channel mapping rules for SIP UA and media.
No changes are needed.

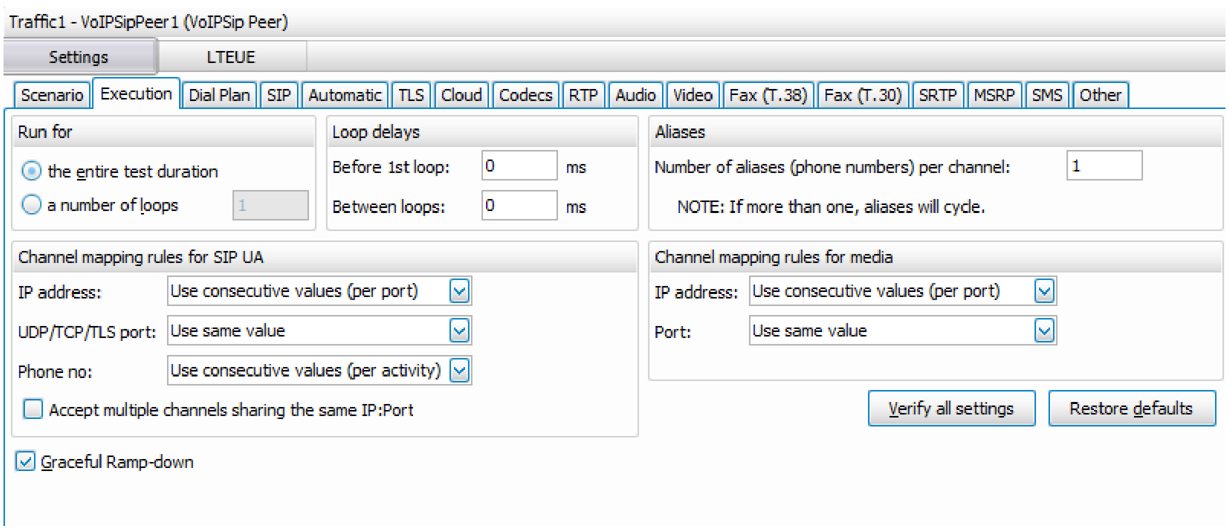


Figure 79. Execution tab

Dial Plan tab

Contains settings for IPs and phone numbers or URI used on the **Source** (Originate side) and on the **Destination** (Terminate side).
Select Traffic2_VoIPSipPeer2 as a destination.

No other changes are needed.

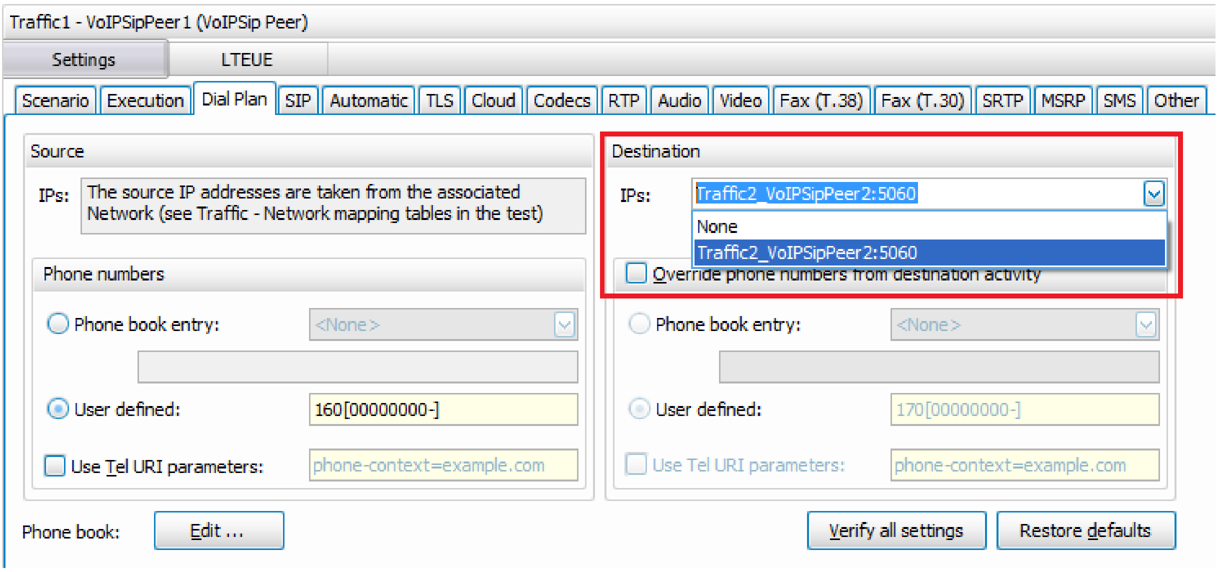


Figure 80. Dial Plan tab

SIP tab

Contains SIP Port to be used and advanced settings for Session Initiation Protocol. No changes are needed.

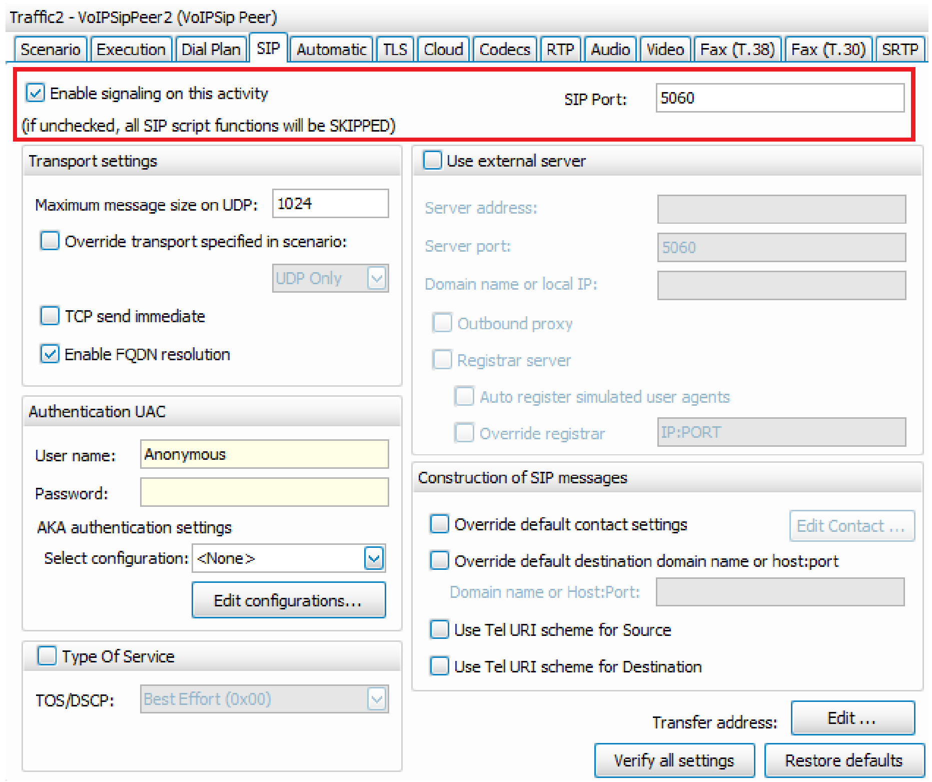


Figure 81. SIP tab

Automatic tab

Contains SIP timeout and retransmisions timers.
No changes are needed

Codecs tab

Contains the codecs to be used list and codec preference settings.
This example will use AMR Codec mode 0 and G711 A-Law.

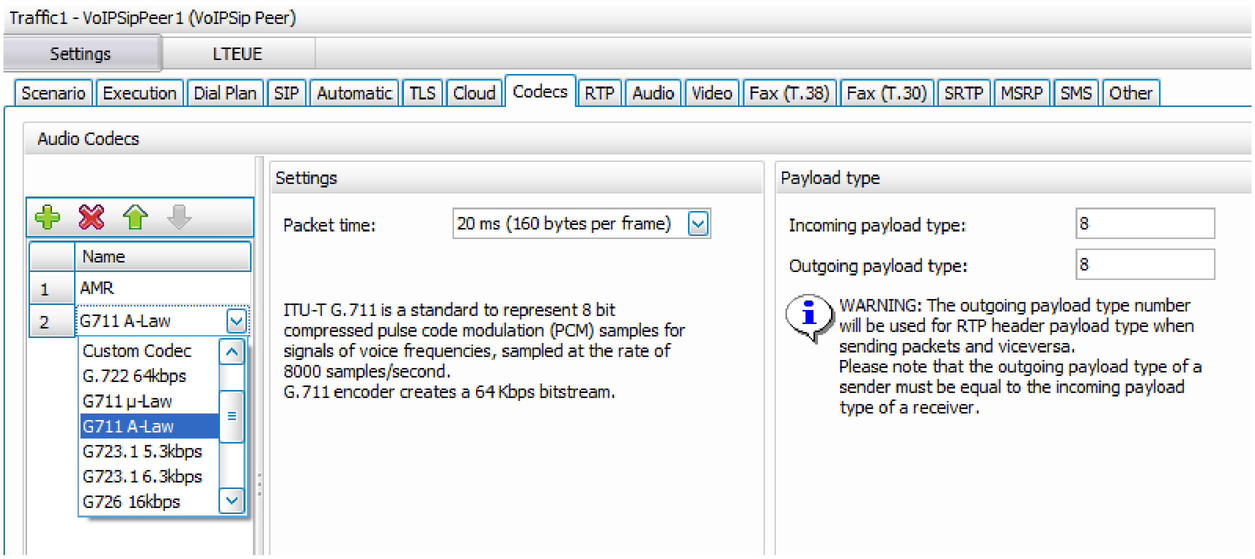


Figure 82. Codecs tab

RTP tab

Configure port 10000 to be used for RTP media.
Also, enable Calculate advanced statistics, Per stream statistics and MDI Statistics

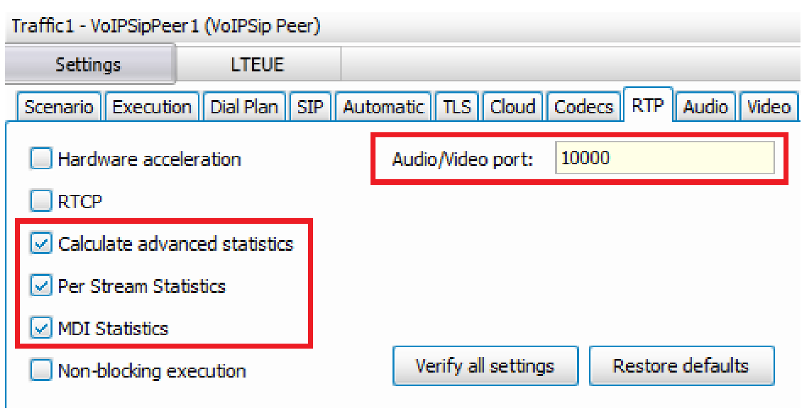


Figure 83. RTP tab

Audio tab

Check **Enable audio on this activity** option to enable RTP audio functions in this configuration
Enable **Perform MOS** and **Calculate One Way Delay** options also

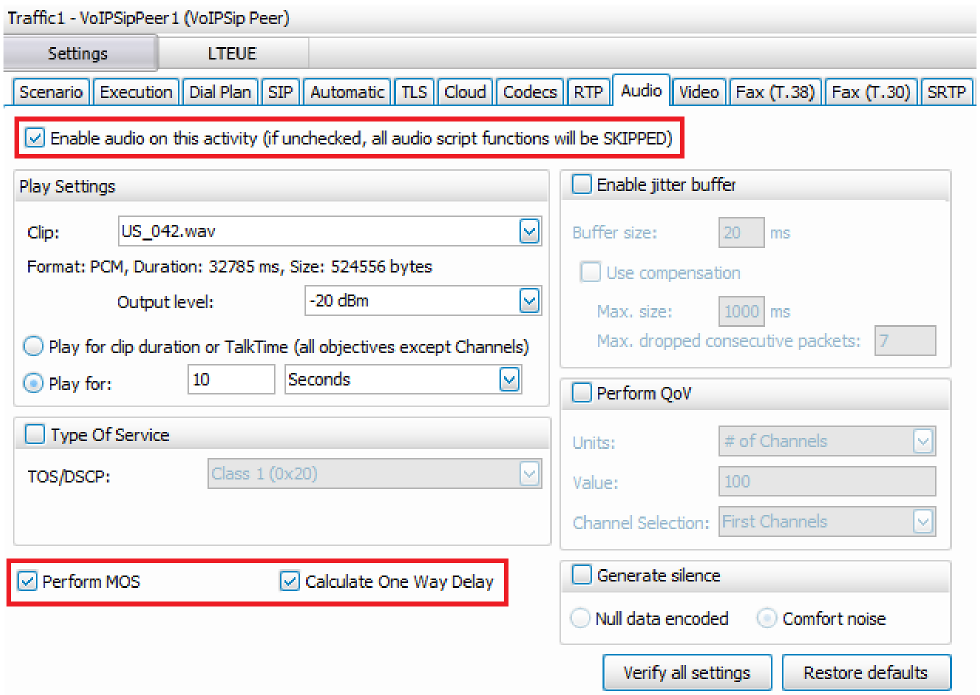


Figure 84. Audio tab

No other changes are needed for the rest of the tabs.

All **VoIP Settings** must be configured for **VoIP SIP Peer 2** also, except the **Destination** on the **Dial Plan** since **VoIP SIP Peer 1** is the call initiator.

User Equipment Layer

Identity:

Modify UE Count to 100.

Configure the appropriate values for **IMSI, IMEI** and **Software Version.** These values identify the subscription and equipment and must match the values configured in the system under test.

Sector layer

Sector Info tab

For this scenario all UE ranges will use the same sector.

No changes are needed.

RLC, MAC and PHY tabs

These tabs enable lower layer logging options. No changes are needed.

Radio/CPRI layer

Radio Head Info tab

No changes are needed. The same radio head can be used.

Sector tab

No changes are needed. The same frequency settings can be used.

Timeline and Objective

In this section we define the L4-L7 traffic activity objectives, which will indirectly drive our network layer objectives.

For this scenario we have to simulate 100 UEs on LTE Access side, each will be attaching to the network at 10 UEs/sec and will be performing 10 s long bi-directional voice calls during 3 minutes of sustain time.

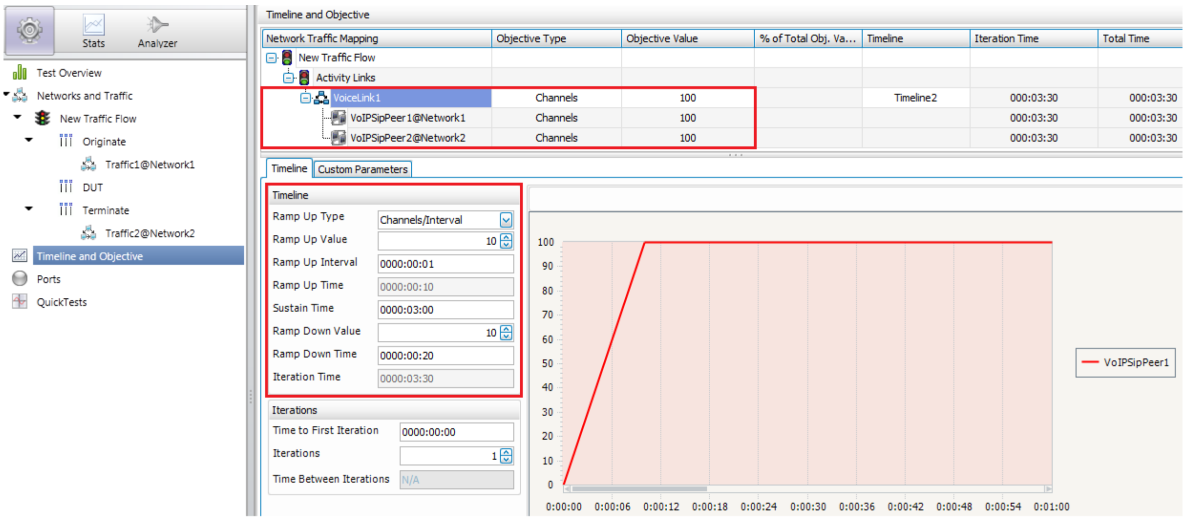


Figure 85. VoLTE scenario timeline and objectives

There are multiple objective types available for VoLTE scenarios. In this scenario the objective type that was configured is “Channels”, which represents the number of media calls to be emulated be each VoIP Peer in the scenario.

Refer to IxLoad manual for more on objective types available for voice scenarios.

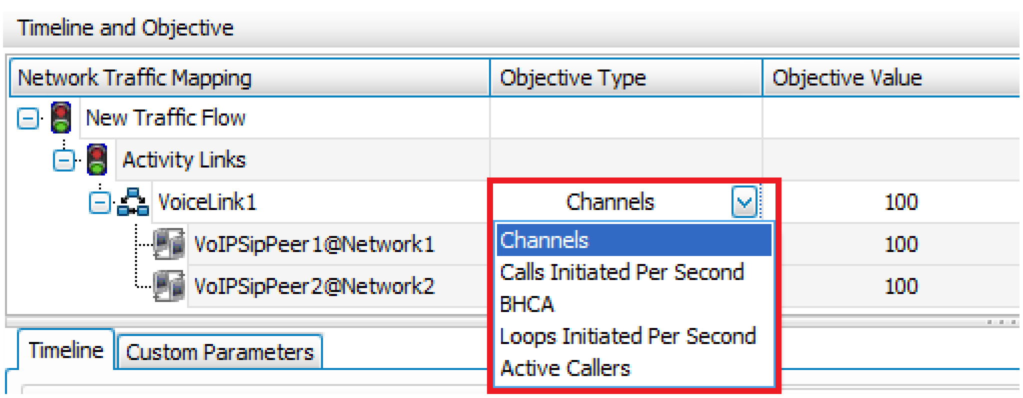


Figure 86. VoLTE objective types

Port Assignment

Refer to **Error! Reference source not found.** from Scenario 1.

Test Variables

Refer to attached RXF for variables used in this test. Many of the settings (like IMSI, cell ID, OP, K etc) will have to be updated to suit the network you are simulating against.

Results Analysis

Once the test is started IxLoad will automatically switch to Stats view, you can also use the Stats button in the upper-left side of IxLoad client GUI to enable this view.

One way to analyse stats is to start with Network layer – confirm all UEs have attached correctly, followed by traffic layer – confirm if we are hitting our test objective and finally analyse UEs Quality of Experience.

Network Layer Stats – LTE UE Global

Verify **LTE UE Global** stats to make sure all 100 UEs have attached suceessfully.

If there are failures check for

- RACH Success/Failure
- RRC Success/Failure
- Authentication Success/Failure

For specific UEs that fail attaches, you can also “drill down” stats and retrieve per UE range stats. These per-UE stats can then further be filtered and sorted to specific criteria. Refer to IxLoad manual for more on these features.

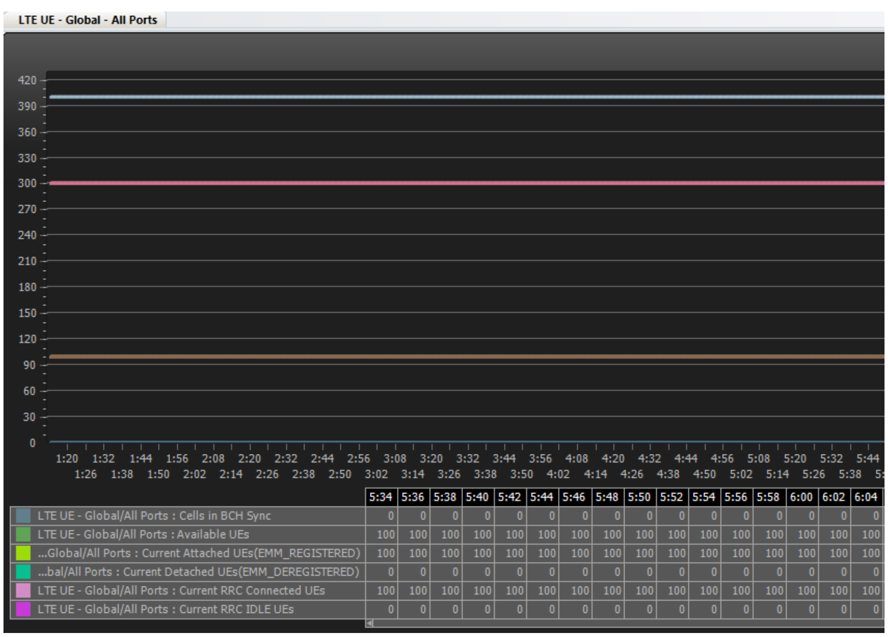


Figure 87. **VoLTE LTE UE Global stats**

User plane

Verify *L7 Client Objective* to make sure the test is meeting the pre-defined objective – 100 Voice Channels for LTE UE plugin. For this check **Channels** stat view:

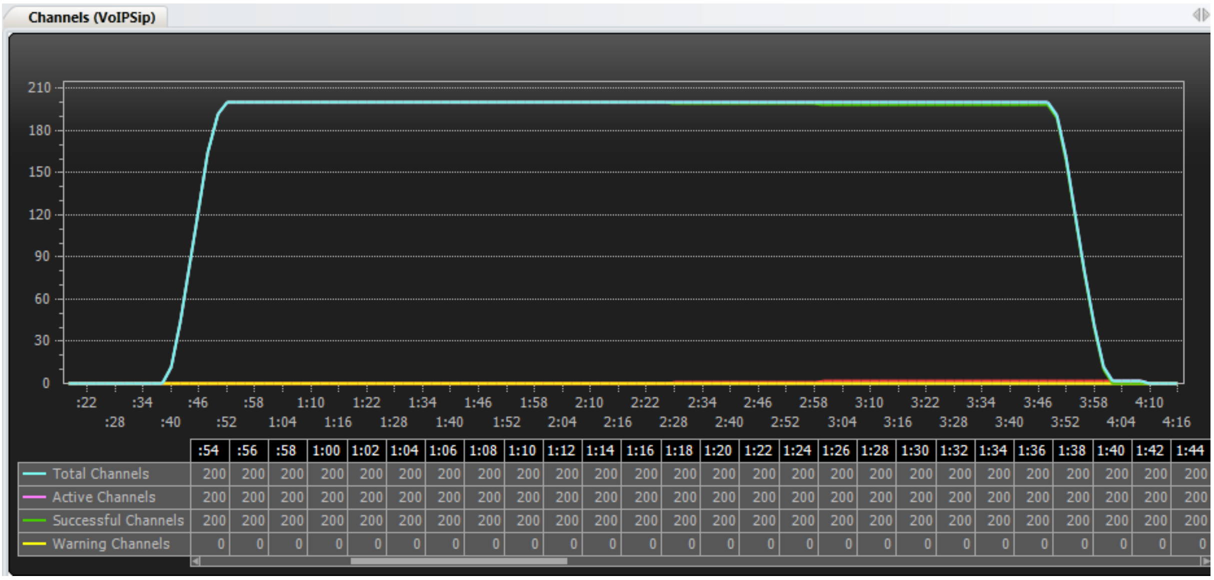


Figure 88. **VoLTE L7 objective - Channels**

Please note that VoIPSip **Channels** stat view displays the total number of media channels for all VoIP peers.

Being a bidirectional call (with media exchanged between both peers) can be seen that the total number of channels is 200, 100 for each side of the call.

Number of attempted, connected or failed calls can be verified within VoIPSip **Calls** stat view also:

Figure 89. **VoLTE Calls stats**

Each stream can be identified by details such as IP: port pair to check the number of packets Tx/Rx and real-time data rates, also. This can be done using **RTP Per Channel** stat view:

RTP Per Channel (VoIPSip)

	Stat Name	Activity Channel No.	Local IP and Port	Destination IP and Port	Bytes Sent	Packets Sent	Throughput Outbound [kbps]
1	192.168.83.195/Card1/Port1/VoIPSipPeer1/Channel0	0	5.0.0.1:10000	172.222.100.202:10000	8,626	227	8.000
2	192.168.83.195/Card1/Port1/VoIPSipPeer1/Channel1	1	5.0.0.2:10000	172.222.100.203:10000	8,398	221	8.000
3	192.168.83.195/Card1/Port1/VoIPSipPeer1/Channel2	2	5.0.0.3:10000	172.222.100.204:10000	8,474	223	8.000
4	192.168.83.195/Card1/Port1/VoIPSipPeer1/Channel3	3	5.0.0.4:10000	172.222.100.205:10000	8,398	221	8.000
5	192.168.83.195/Card1/Port1/VoIPSipPeer1/Channel4	4	5.0.0.5:10000	172.222.100.206:10000	8,132	214	8.000
6	192.168.83.195/Card1/Port1/VoIPSipPeer1/Channel5	5	5.0.0.6:10000	172.222.100.207:10000	8,132	214	8.000
7	192.168.83.195/Card1/Port1/VoIPSipPeer1/Channel6	6	5.0.0.7:10000	172.222.100.208:10000	7,980	210	8.000
8	192.168.83.195/Card1/Port1/VoIPSipPeer1/Channel7	7	5.0.0.8:10000	172.222.100.209:10000	7,828	206	8.000
9	192.168.83.195/Card1/Port1/VoIPSipPeer1/Channel8	8	5.0.0.9:10000	172.222.100.210:10000	7,942	209	8.000
10	192.168.83.195/Card1/Port1/VoIPSipPeer1/Channel9	9	5.0.0.10:10000	172.222.100.211:10000	7,904	208	8.000
11	192.168.83.195/Card1/Port1/VoIPSipPeer1/Channel10	10	5.0.0.11:10000	172.222.100.212:10000	6,992	184	24.000
12	192.168.83.195/Card1/Port1/VoIPSipPeer1/Channel11	11	5.0.0.12:10000	172.222.100.213:10000	6,764	178	24.000
13	192.168.83.195/Card1/Port1/VoIPSipPeer1/Channel12	12	5.0.0.13:10000	172.222.100.214:10000	6,422	169	24.000
14	192.168.83.195/Card1/Port1/VoIPSipPeer1/Channel13	13	5.0.0.14:10000	172.222.100.215:10000	6,536	172	24.000
15	192.168.83.195/Card1/Port1/VoIPSipPeer1/Channel14	14	5.0.0.15:10000	172.222.100.216:10000	6,650	175	24.000
16	192.168.83.195/Card1/Port1/VoIPSipPeer1/Channel15	15	5.0.0.16:10000	172.222.100.217:10000	6,384	168	24.000
17	192.168.83.195/Card1/Port1/VoIPSipPeer1/Channel16	16	5.0.0.17:10000	172.222.100.218:10000	6,270	165	24.000
18	192.168.83.195/Card1/Port1/VoIPSipPeer1/Channel17	17	5.0.0.18:10000	172.222.100.219:10000	6,194	163	24.000
19	192.168.83.195/Card1/Port1/VoIPSipPeer1/Channel18	18	5.0.0.19:10000	172.222.100.220:10000	6,080	160	24.000
20	192.168.83.195/Card1/Port1/VoIPSipPeer1/Channel19	19	5.0.0.20:10000	172.222.100.221:10000	6,042	159	16.000

1/6 (total rows: 300) All

Figure 90. **VoLTE RTP Per Channel stats**

Quality of experience

The QoE is a subjective definition that can be interpreted based on specific L4-L7 traffic activities.

Ensuring the QoE is a key objective for this scenario.

A wide selection of real-time media statistics and quality mesurements are available under RTP views.

For instance, RTP plugin offers the following stats to provide insight into QoE:

- Jitter & Delays – higher latencies imply poor experience for the user
- Maximum Consecutive lost RTP packets – high values imply poor experience for the user
- Mean Opinion Score (MOS) – calls with a value of MOS between 4 and 4.5 imply very good user experience while calls with MOS between 2 and 3 indicate a poor user experience
- R-Factor - calls with R-Factor value between 80 and 94 imply a good user experience while R-Factor values below 70 are an indicator of very poor quality of the call.

The user can find real-time media measurements such as these in RTP QoS, RTP Advanced QoS, RTP R-Factor & RTP MOS stat views.

Refer to IxLoad manual for details on these types of statistics.

RTP QoS (VoIPSip)

	Stat Name	1:40	1:42	1:44	1:46	1:48	1:50
1	Packets Sent	452,595	472,563	492,571	512,544	532,650	552,570
2	Packets Received	452,551	472,505	492,519	512,312	532,595	552,489
3	Bytes Sent	7,198,610	17,957,394	18,717,698	19,476,672	20,240,700	20,997,660
4	Bytes Received	7,196,938	17,955,190	18,715,722	19,467,856	20,238,610	20,994,582
5	Throughput Outbound (Kbps)	3,040	3,041	3,040	3,039	3,040	3,040
6	Throughput Inbound (Kbps)	3,047	3,039	3,041	3,012	3,066	3,036
7	Tx Packets Dropped	0	0	0	0	0	0
8	Lost Packets	1	1	1	1	1	1
9	Maximum Consecutive Lost Packets	1	1	1	1	1	1
10	Packet Errors Received	0	0	0	0	0	0
11	Duplicate Packets Received	0	0	0	0	0	0
12	Late Packets Received	0	0	0	0	0	0
13	Misordered Packets Received	0	0	0	0	0	0
14	One Way Delay (Avg) [us]	5,798	5,560	6,241	3,629	5,325	3,999
15	One Way Delay (Max) [us]	239,017	239,017	239,017	239,017	239,017	239,017

Figure 91. **VoLTE RTP QoS**

RTP Advanced QoS (VoIPSip)

	Stat Name	1:50	1:52	1:54	1:56	1:58	2:00	2:02	2:04	2:06	2:08	2:10	2:12
1	Delay Variation Jitter (Avg) [us]	3,261	2,724	2,801	7,086	11,136	11,153	12,971	11,988	12,858	2,952	3,957	3,242
2	Delay Variation Jitter (Max) [us]	217,291	217,291	217,291	217,291	217,291	217,291	217,291	217,291	217,291	217,291	217,291	217,291
3	Interarrival Jitter (Avg) [us]	4,429	4,405	3,590	14,362	12,409	10,257	9,703	9,480	12,601	3,857	4,954	4,410
4	Interarrival Jitter (Max) [us]	31,282	31,282	31,282	31,282	31,282	31,282	31,282	31,282	31,282	31,282	31,282	31,282
5	Bytes Lost Percentage [%]	0	0	0	0	0	0	0	0	0	0	0	0
6	Packet Size Mismatched	0	0	0	0	0	0	0	0	0	0	0	0
7	Packet Codec Mismatched	0	0	0	0	0	0	0	0	0	0	0	0
8	MDI MLR (Avg) [packets/s]	0	0	0	0	0	0	0	0	0	0	0	0
9	MDI MLR (Max) [packets/s]	1	1	1	1	1	1	1	1	1	1	1	1
10	MDI DF (Avg) [us]	66,218	54,055	59,074	79,046	101,123	91,337	117,659	112,882	108,954	79,257	80,297	71,375
11	MDI DF (Max) [us]	258,616	258,616	258,616	258,616	258,616	258,616	258,616	258,616	258,616	258,616	258,616	258,616

Figure 92. **VoLTE RTP Advanced QoS**

RTP R-Factor & MOS Degradation (VoIPSip)

	Stat Name	2:20	2:22	2:24	2:26	2:28	2:30	2:32	2:34	2:36	2:38	2:40	2:42	2:44
1	R-Factor Instant (Avg)						75.300	75.200	75.060	75.210	75.520	75.100		
2	R-Factor Instant Best	6.000	96.000	96.000	96.000	96.000	96.000	96.000	96.000	96.000	96.000	96.000	96.000	96.000
3	R-Factor Instant Worst	5.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000
4	MOS Instant (Avg)	3.820	3.830	3.820	3.830	3.820	3.830	3.820	3.830	3.830	3.830	3.830	3.820	3.830
5	MOS Instant Best	4.100	4.100	4.100	4.100	4.100	4.100	4.100	4.100	4.100	4.100	4.100	4.100	4.100
6	MOS Instant Worst	3.730	3.730	3.730	3.730	3.730	3.730	3.730	3.730	3.730	3.730	3.730	3.730	3.730
7	Loss Degradation						0.000	0.000	0.000	0.000	0.000	0.000		
8	Jitter Degradation						0.000	0.000	0.000	0.000	0.000	0.000		
9	Codec Degradation						4.000	4.000	4.000	4.000	4.000	4.000		
10	Delay Degradation						0.000	0.000	0.000	0.000	0.000	0.000		

Figure 93. **VoLTE RTP R-Factor & MOS**

Test Case 5: VoLTE Voice Call with Data in Background

Objective

Create and run a VoLTE scenario with data traffic in the background: 2 of the UEs attaching to the network and performing 5 minutes long, bi-directional voice calls.

Setup

Refer to Test Harness for more information on setup.

2 sectors are used in this scenario as an example, but it can be run also using only 1 cell sector.

Step-by-step Instructions

1) Follow the instructions from Scenario 1 to setup an LTE UE test configuration.
2) Configure 2 sectors on the setup and in **LTE UE** -> **Sector** -> **Sector Info**, verify that they are detected.

   *Note: This scenario can be executed using only 1 sector also

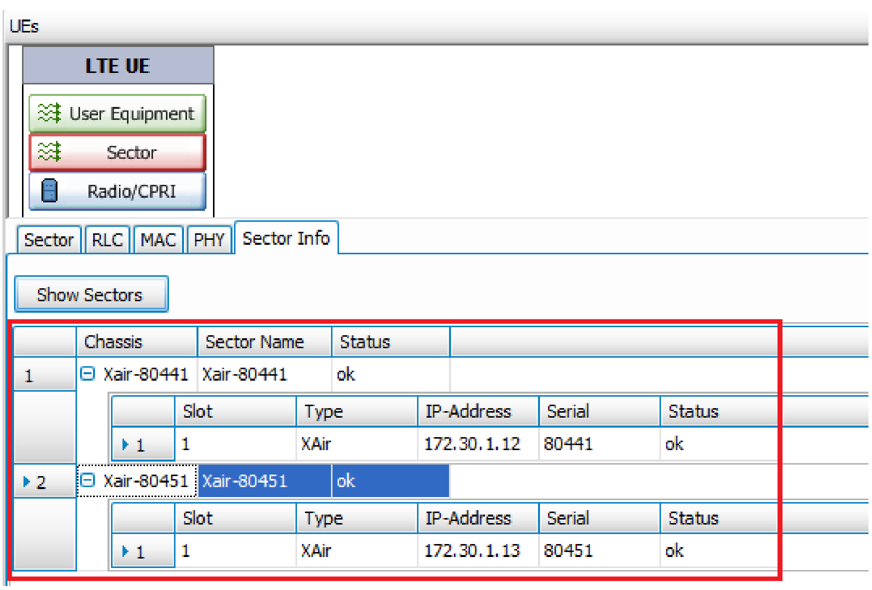


Figure 94. **2 sectors configuration**

3) Set the correct cell IDs and duplex mode used on available setup:

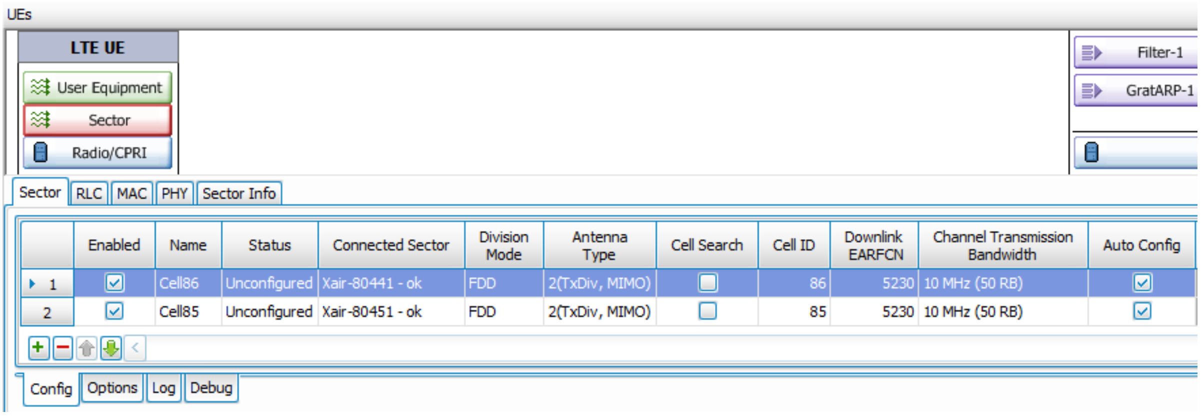


Figure 95. **2 sectors VoLTE**

4) On the LTE_UE stack, add 2 activities of **VoIPSipPeer** type and 4 of **FTPClient** type.

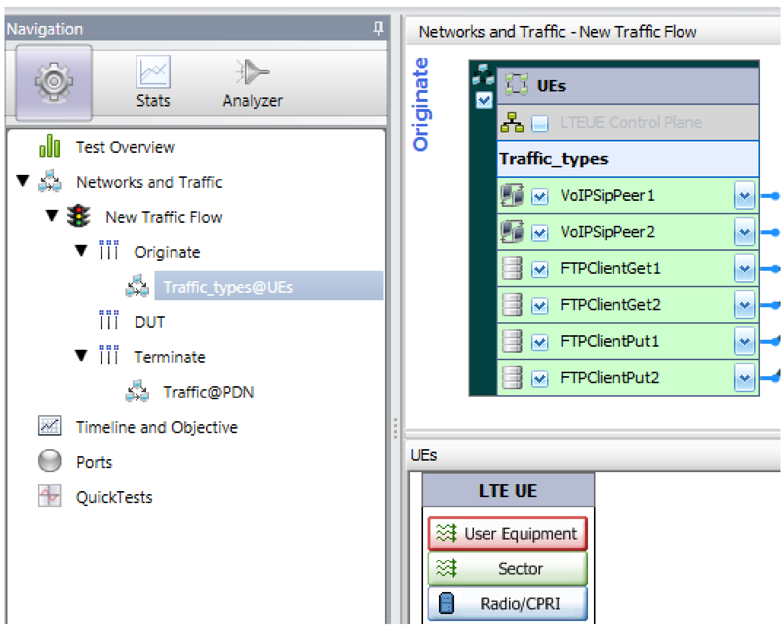


Figure 96. **VoLTE scenario activities**

5) In the **User Equipment -> UE tab,** configure 6 ranges of UEs, each with 1 client configured (Count=1).

Map 1 VoIPSipPeer, 1 FTP GET and 1 FTP PUT activitiy to each sector / cell.

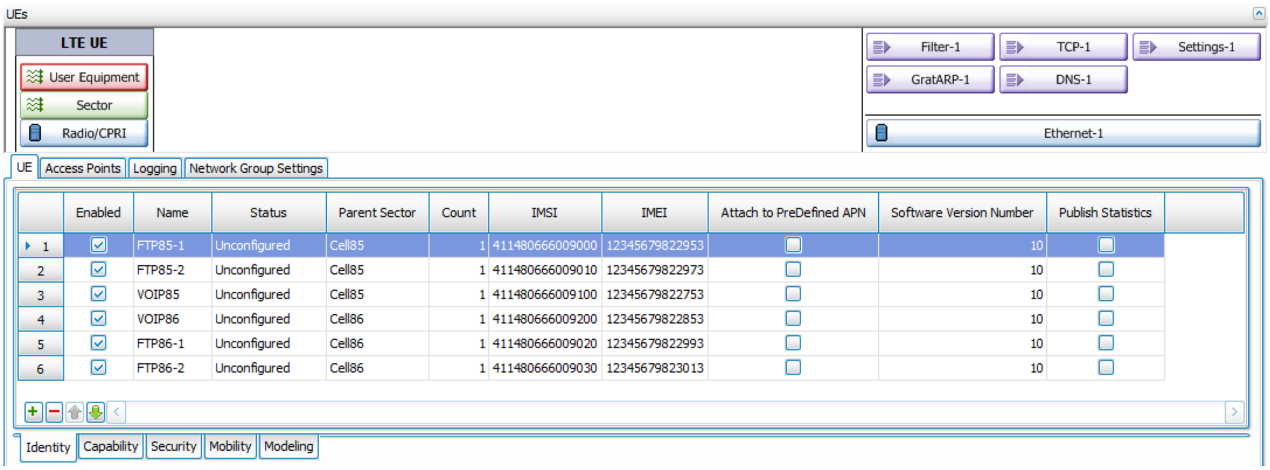


Figure 97. **VoLTE scenario UE ranges**

6) Map each UE range to only one activity type:

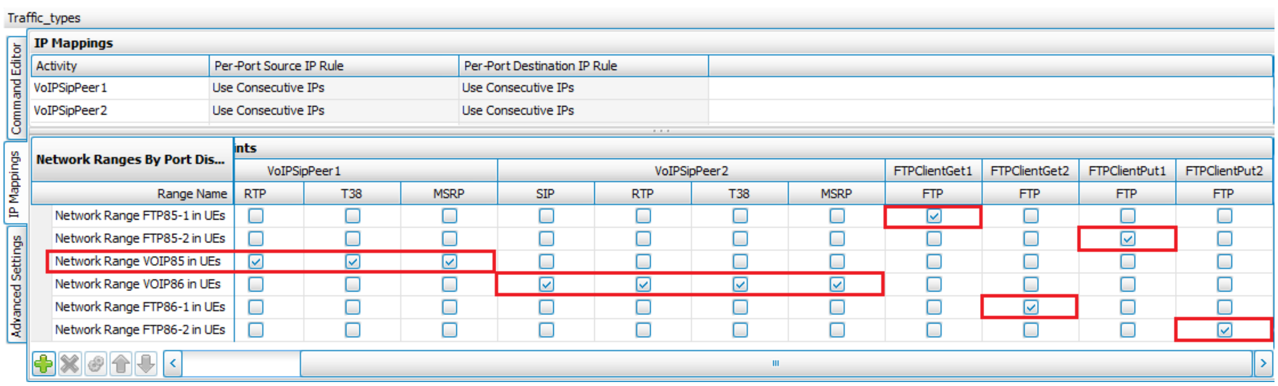


Figure 98. **VoLTE activity mapping**

7) On the PDN (Terminate) side add 1 VoIPSipCloud activity, 2 VoIPSipPeer activities and 1 FTPServer activity.

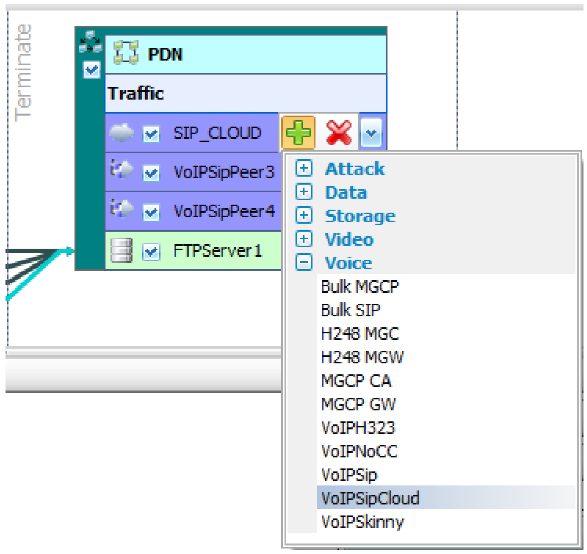
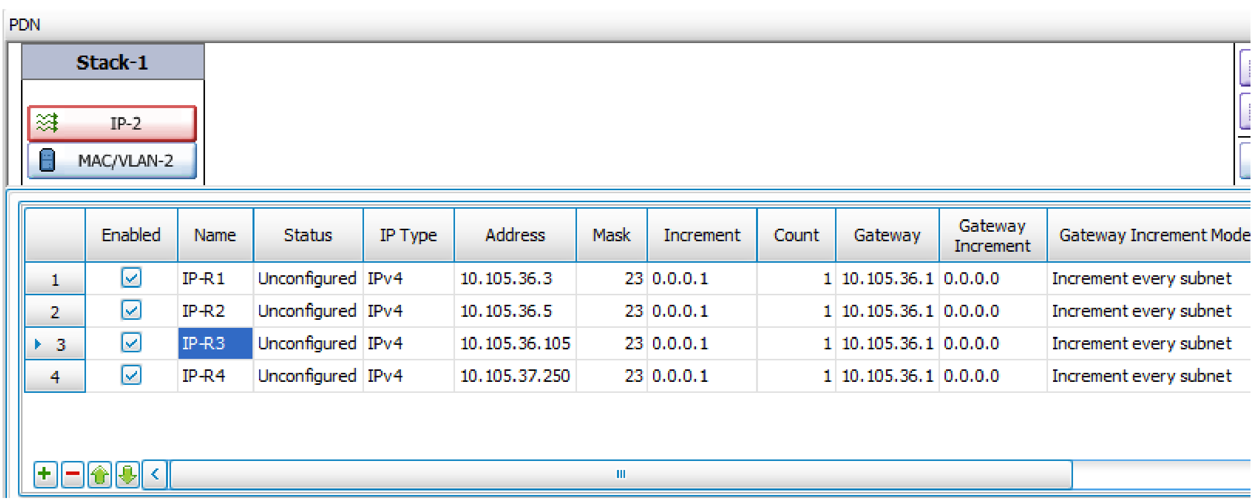


Figure 99. **PDN activities**

8) On the PDN stack, configure 4 IP ranges with 1 IP address each:



	Enabled	Name	Status	IP Type	Address	Mask	Increment	Count	Gateway	Gateway Increment	Gateway Increment Mode
1	☑	IP-R1	Unconfigured	IPv4	10.105.36.3	23	0.0.0.1	1	10.105.36.1	0.0.0.0	Increment every subnet
2	☑	IP-R2	Unconfigured	IPv4	10.105.36.5	23	0.0.0.1	1	10.105.36.1	0.0.0.0	Increment every subnet
3	☑	IP-R3	Unconfigured	IPv4	10.105.36.105	23	0.0.0.1	1	10.105.36.1	0.0.0.0	Increment every subnet
4	☑	IP-R4	Unconfigured	IPv4	10.105.37.250	23	0.0.0.1	1	10.105.36.1	0.0.0.0	Increment every subnet

Figure 100. **PDN IPs**

9) Map each IP range to only one activity.
   SIP_CLOUD must use **IP Round Robin** distribution type.

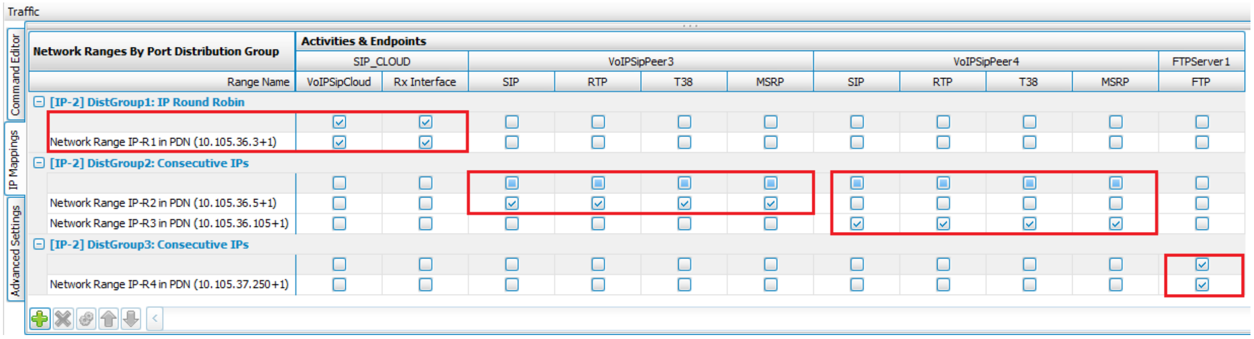


Figure 101. **IP activity mapping**

10) As **VoIPSipCloud** activity must emulate P-CSCF, you need to configure it with the following settings:
   - Select the **Enable proxy behaviour** checkbox
   - In the **Settings** tab, add 1 server and set the **IP address** to Network Range R1 (10.105.36.3), previously configured at IP level.
   - Set **Port** to 4060 and **Domain Name** to realm name for VoLTE / IMS

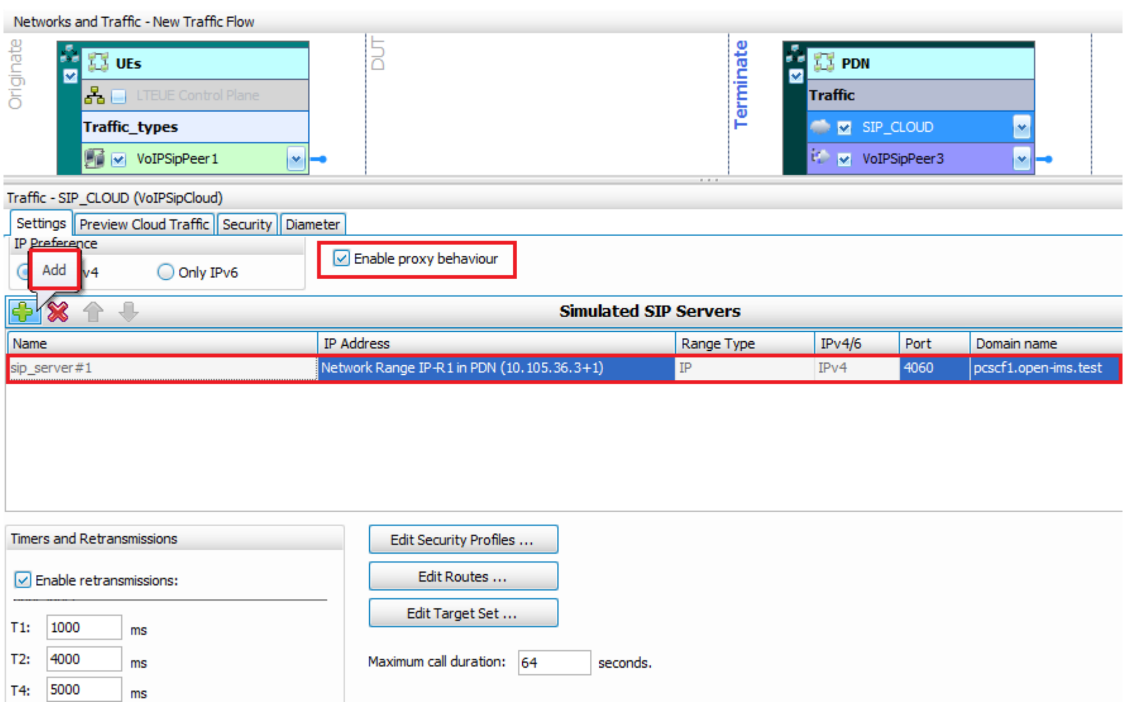


Figure 102. **SIP cloud** configuration

- Set the correct realm name in the **Security** tab also:

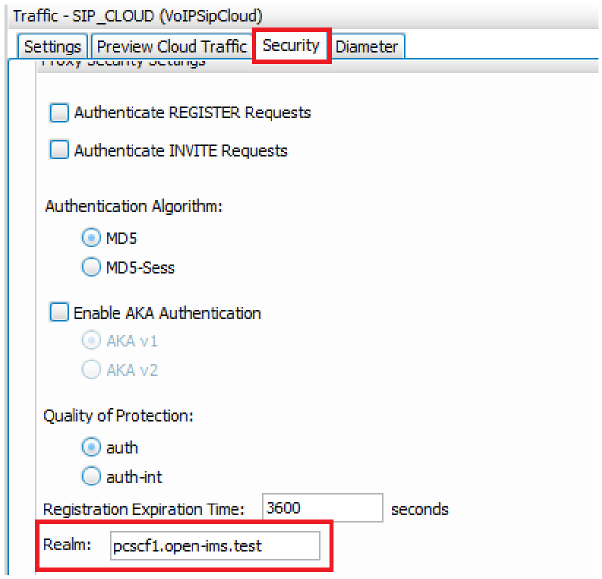


Figure 103. **SIP** cloud **security**

For this scenario, authentication was not set.

AKAv1 and AKAv2 methods can be configured.

- In the **Diameter tab,** select the **Enable Rx interface** checkbox and configure PCRF settings and Application Function settings of the PCSCF server to be emulated:
  - –IP or hostname for the PCRF used in the setup,
  - -PCRF's Rx interface port number
  - -PCRF's realm

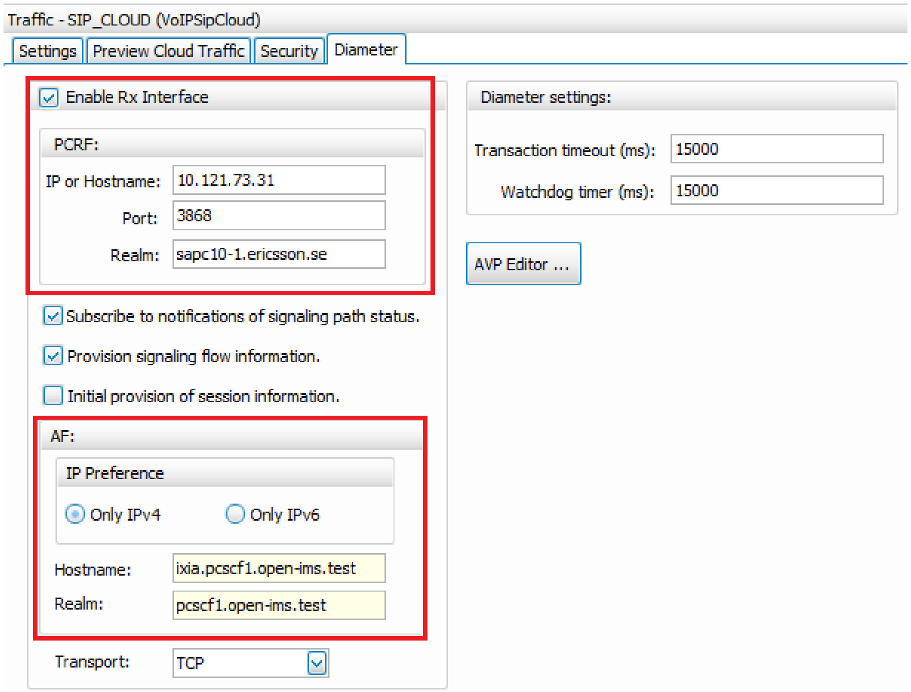


Figure 104. **SIP cloud Diameter**

11) In the **VoIPSipPeer** activities on the PDN side, select the **Enable SIP Cloud simulation using settings from,** and then select SIP_CLOUD.

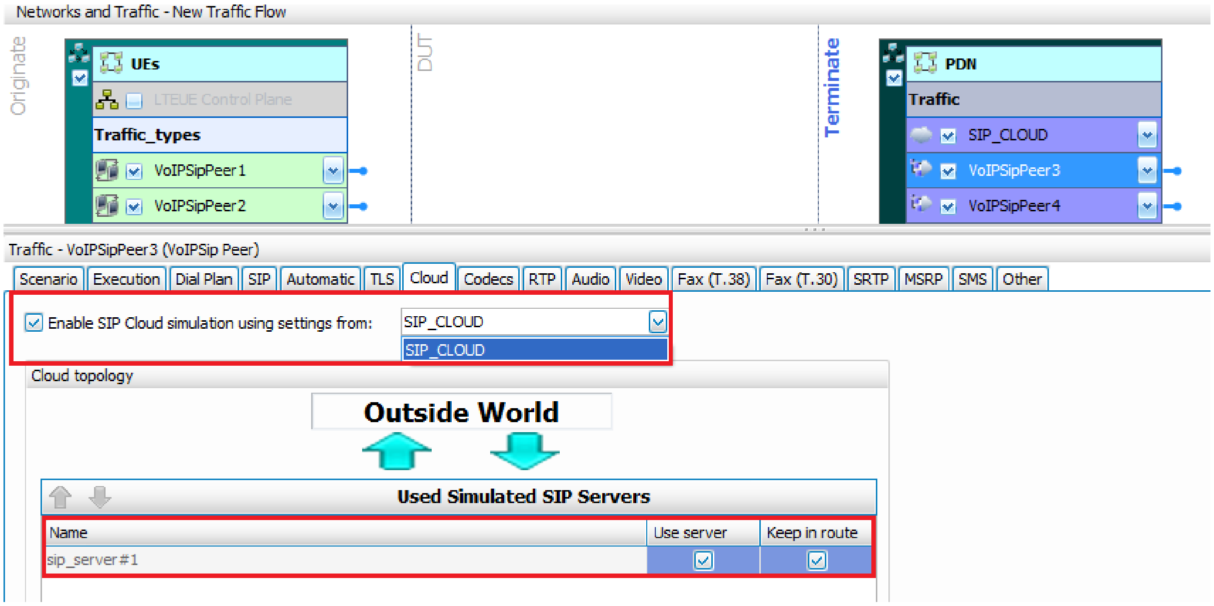


Figure 105. VoIP **SIP Peer Cloud**

12) Select **VoIPSipPeer1** activity. In **Settings** > **Scenario** tab, select **SIP IMS Make Call** procedure in the **Procedure Library** section.

Add this procedure to scenario editor:

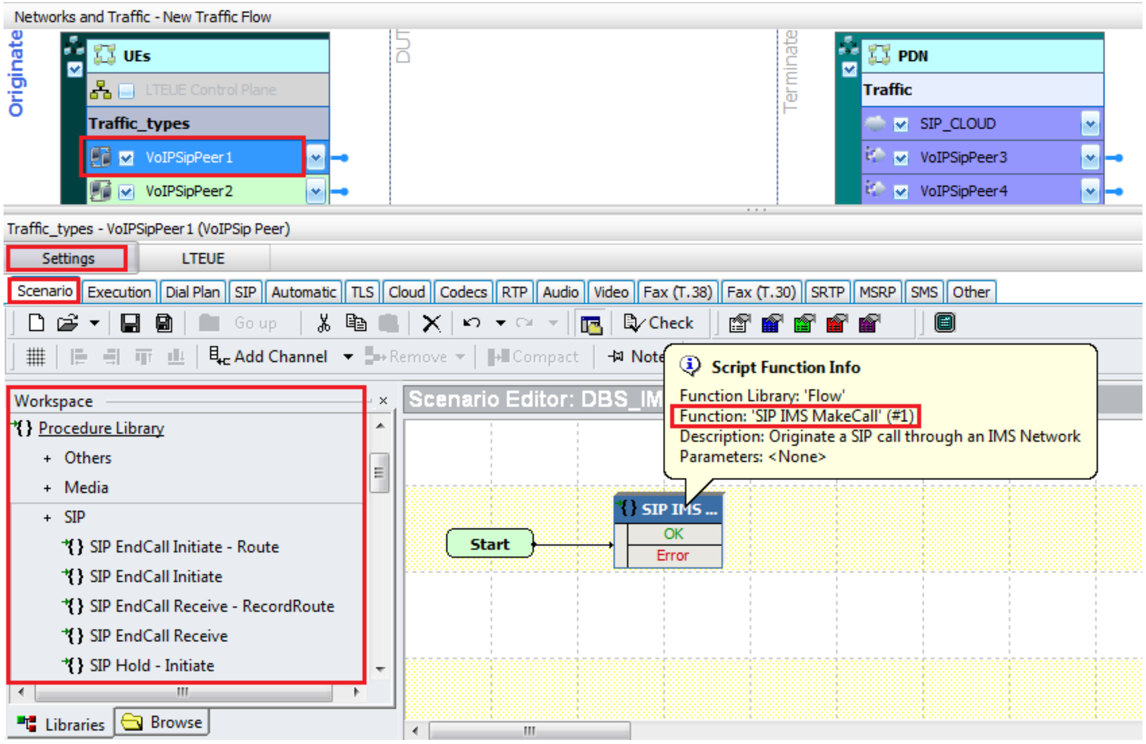


Figure 106. **SIP** IMS **MakeCall**

13) Complete **Scenario Channel#0** by adding one **RTP Voice Session** function and one **SIP IMS EndCall Initiate** procedure from Workspace and link them according to the following example. Save the.tst file.

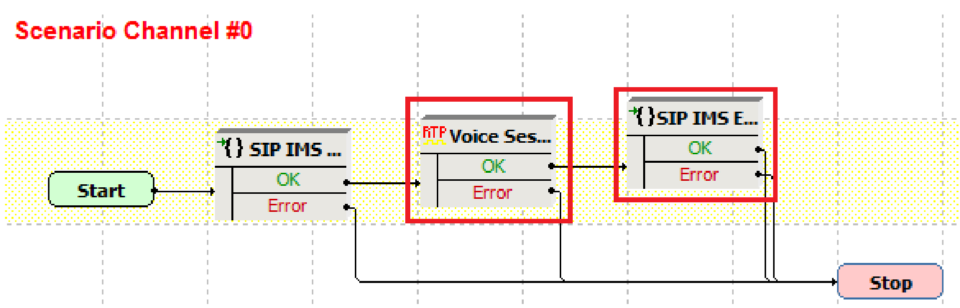


Figure 107. **SIP** IMS **MakeCall**

On the PDN side, add a **SIP IMS ReceiveCall** procedure, a **Voice Session** function and a **SIP IMS EndCall Receive** procedure. Save the .tst file with a different name from the LTE UE side .tst

14) On all VoIP SIP peers, configure the parameters in the **Execution** tab:

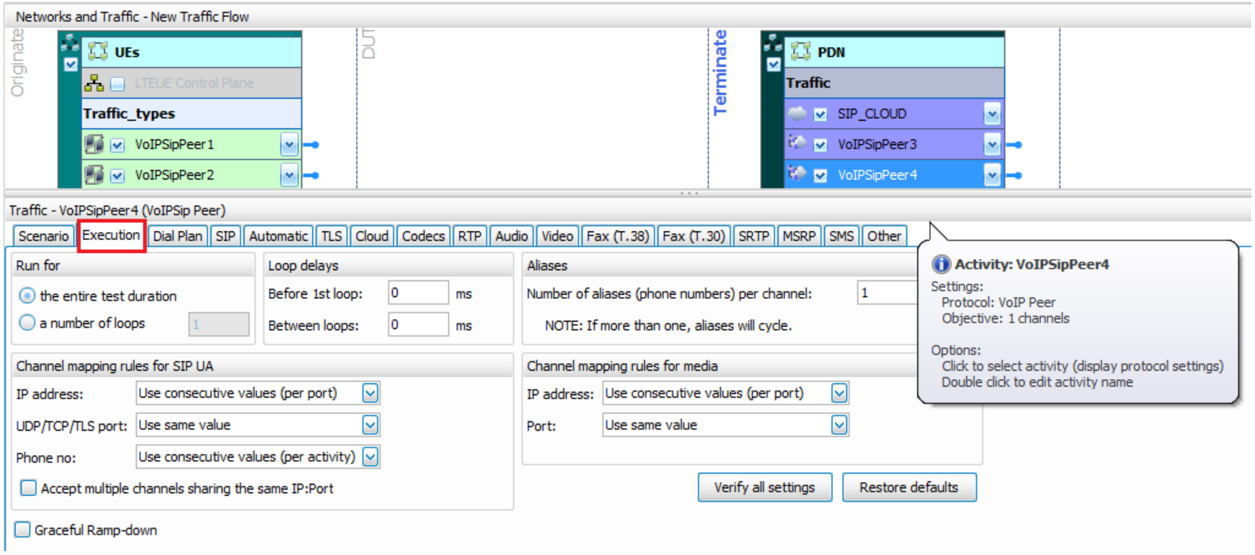


Figure 108. **VoIP SIP** peer **Execution**

15) For each VoIPSIP peer, configure the parameters in the **Dial Plan** tab, as it follows to reflect that VoIPSip Peer1 calls **VoIPSIPPeer3** and **VoIPSipPeer2** calls VoIPSipPeer4.

On the LTE UE side (callers side) for **Destination**, set the IP configured for the SIP Cloud. On the PDN side do not configure a Destination address.

Configure P-CSCF , because this is the first point of contact within the IMS core for VoLTE users.

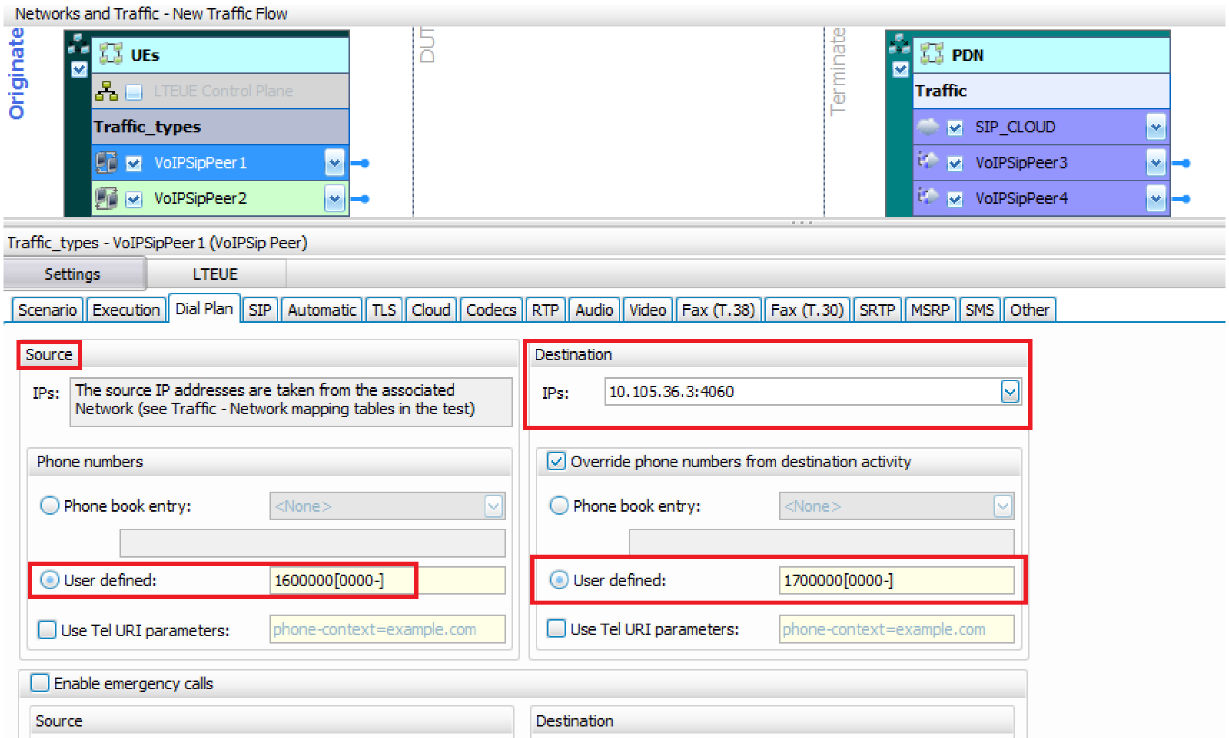


Figure 109. **VoIP SIP** peer **Dial Plan**

16) For each **VoIPSIP Peer** configure the codec to be used.

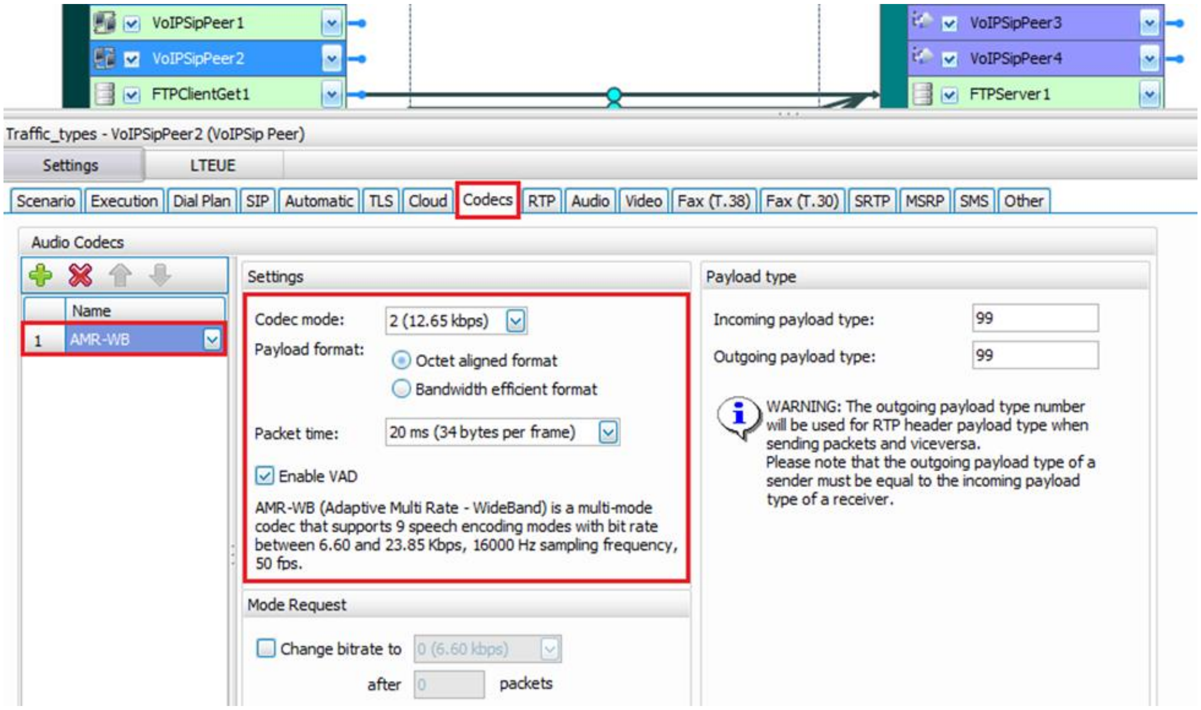


Figure 110. **VoIP SIP** peer **Codec**

17) For each **VoIPSIP Peer**, configure the audio/video media ports to be used:

For VoIPSIP Peer1 set Audio/Video port: [40000-41999,4]

For VoIPSIP Peer2 set Audio/Video port: [42000-43999,4]

For VoIPSIP Peer3 set Audio/Video port: [10000-11999,4]

For VoIPSIP Peer4 set Audio/Video port: [12000-13999,4]

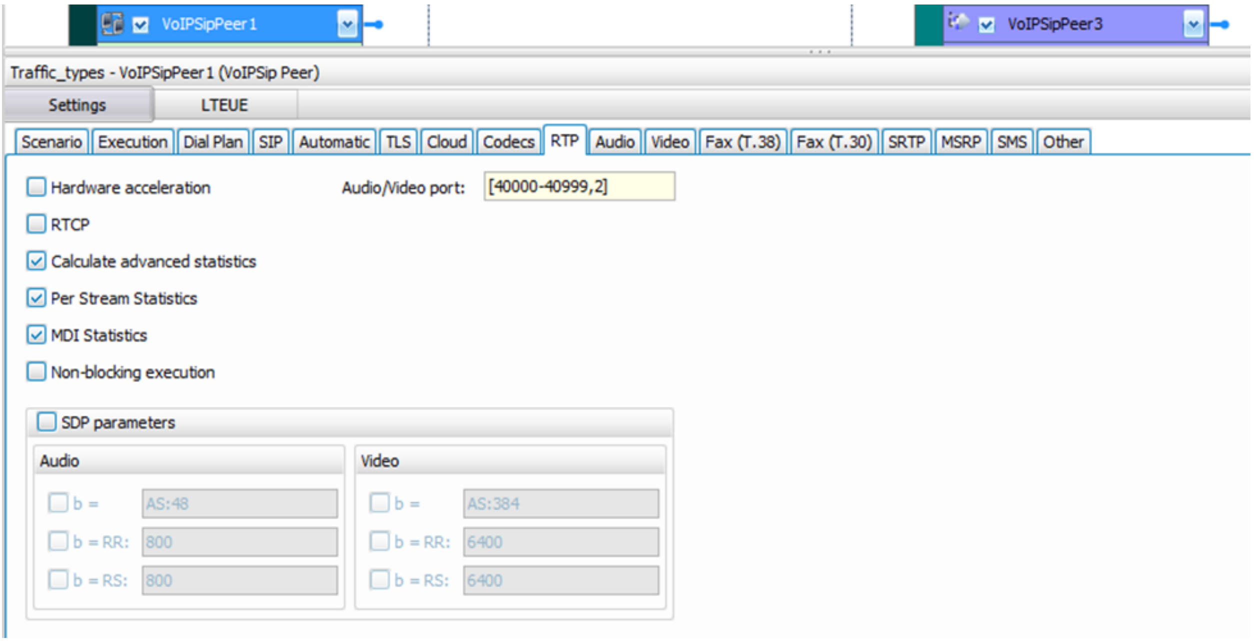


Figure 111. **Media ports**

18) In the **Audio** tab of each **VoIPSIP Peer**, enable audio for that activity and select the desired play time for the video clip chosen.

MOS measurement capability can be selected also.

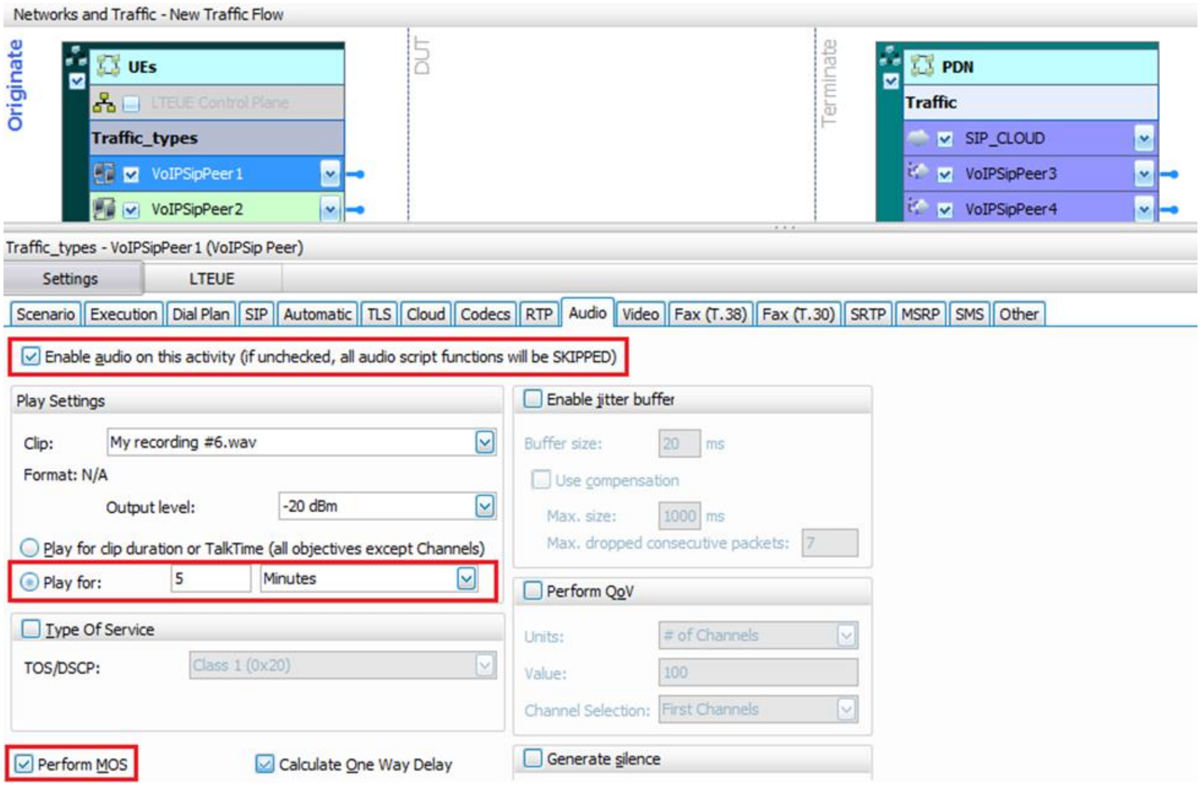


Figure 112. **Audio settings**

Timeline and Objective

In this section, the L4-L7 traffic activity objectives are defined, which indirectly drives the network layer objectives.

For this scenario, it is essential to simulate six UEs on the LTE Access side (one on each VoIPSipPeer1 activity and one for every FTP activity). Two UEs attach to the network and perform a five minutes long bi-directional voice call during the entire sustain time.

In the background, each of the FTP UEs perform uplink or downlink data traffic.

For VoLTE UEs, the selected objective type is Channels and for FTP UEs is Simulated Users.

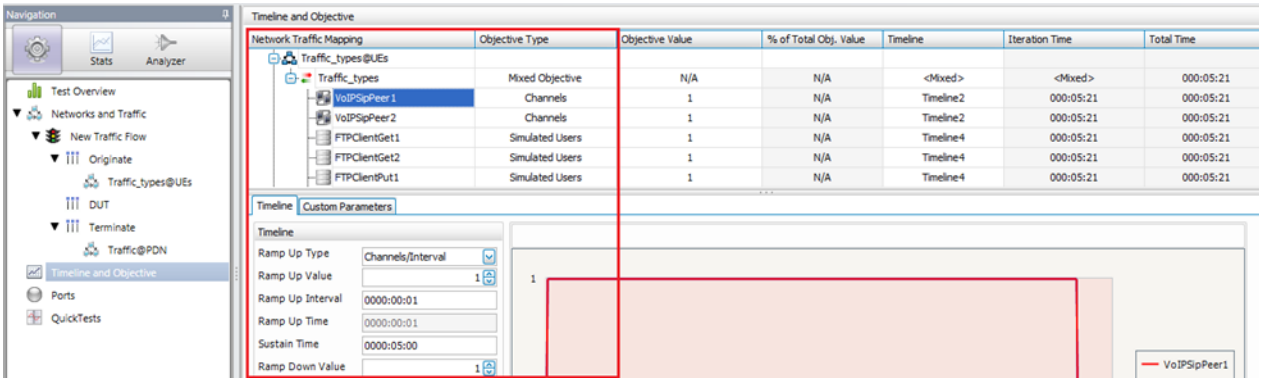


Figure 113. Timeline and objectives

Port Assignment

Refer to Port Assignment from Scenario 1.

Test Variables

Refer to the attached RXF for variables used in this test. Many of the settings (like IMSI, cell ID, OP, K, and so on) must be updated to suit the network you are simulating against.

Results Analysis

Once the test starts, IxLoad automatically switches to Stats view. You can also use the **Stats** button in the upper-left side of IxLoad client GUI to enable this view.

One way to analyze stats is to start with Network layer. Confirm all UEs are attached correctly, followed by traffic layer. Confirm, the test objective is met and finally analyze UEs Quality of Experience.

Network Layer Stats – LTE UE Global

Verify LTE UE Global stats to make sure all 6 UEs have attached suceessfully.

If there are failures check for:

- RACH Success/Failure
- RRC Success/Failure
- Authentication Success/Failure

User plane

You can verify the number of attempted, connected, or failed calls within VoIPSip Calls stat view:

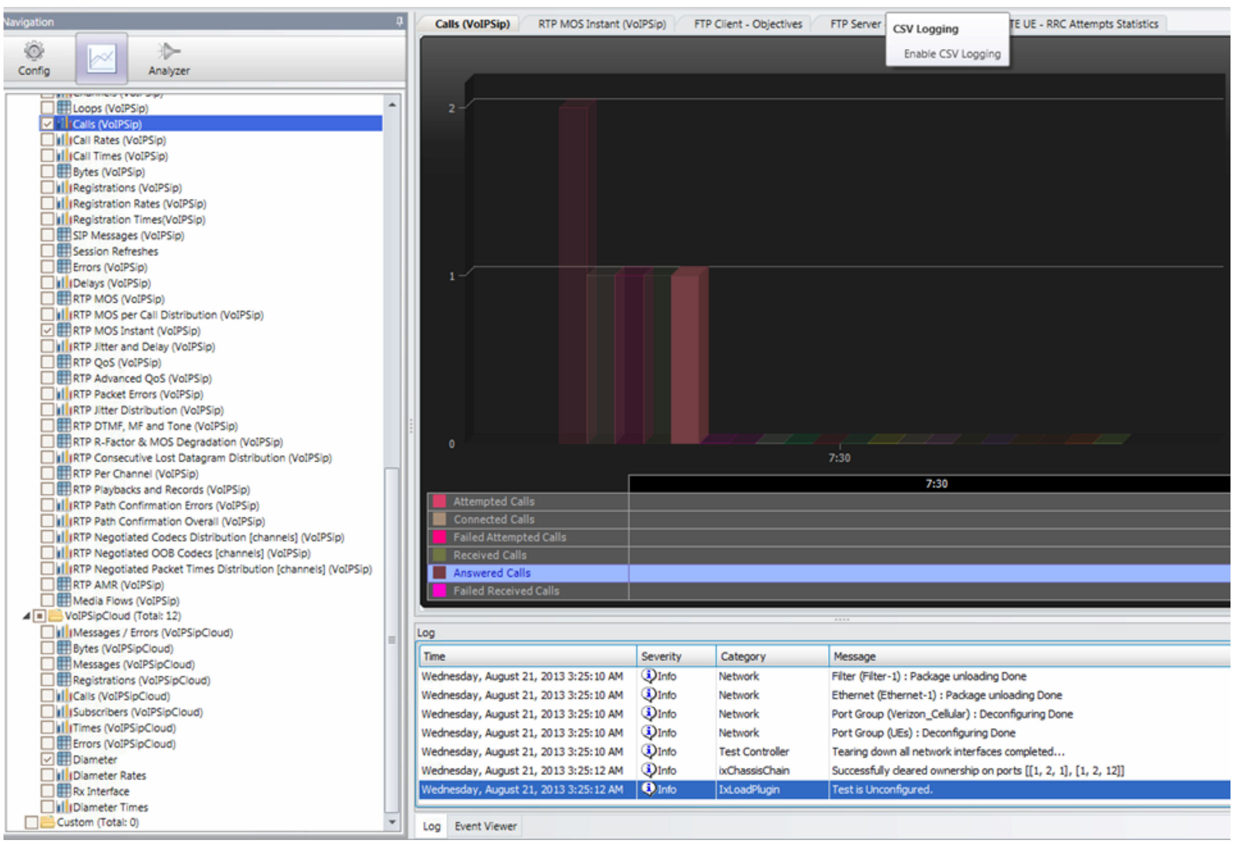


Figure 114. Call Stats

If there are failures, check for RTP, SIP, or Transport errors in **VoIP SIP Error** stat view:

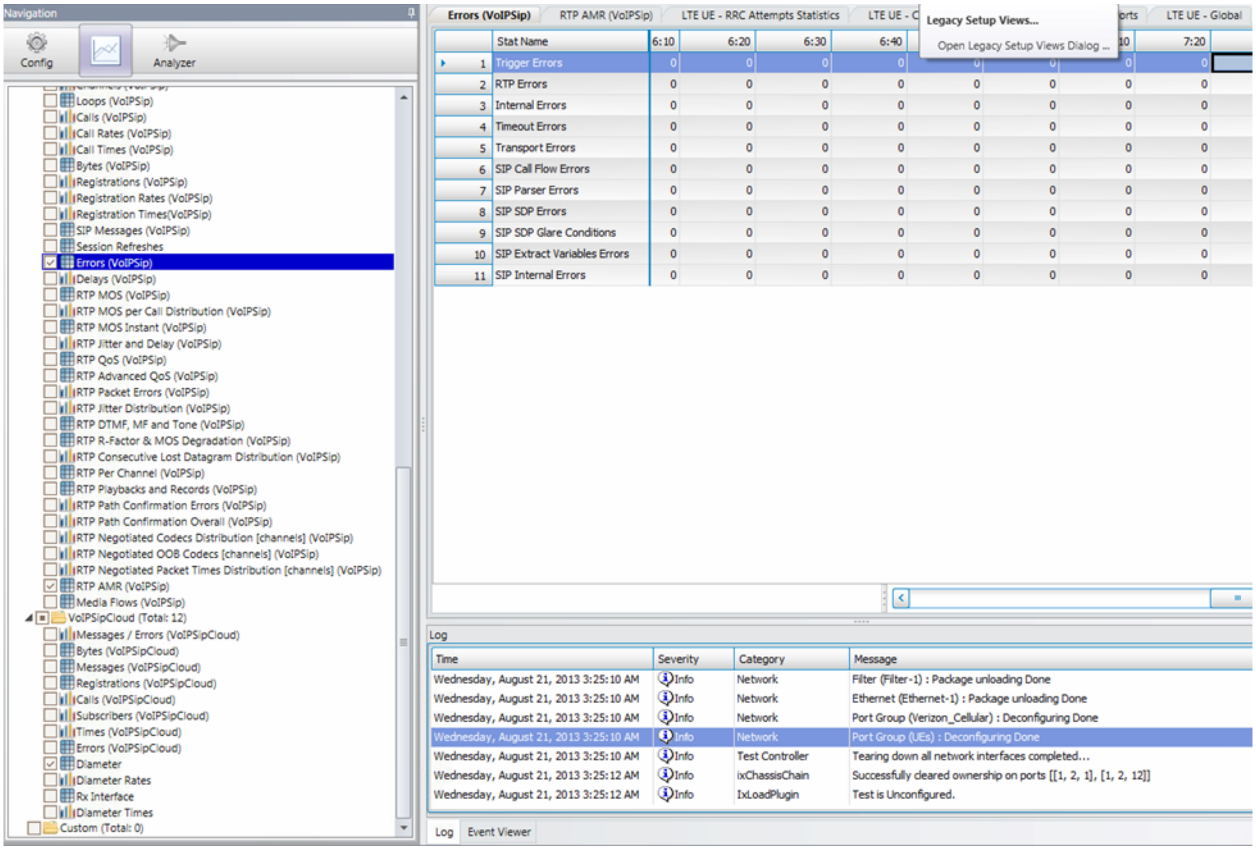


Figure 115. Errors **Stats**

Rx interface

To debug the problems in this interface, stats are available in **Diameter** and **Rx Interface** stat views.

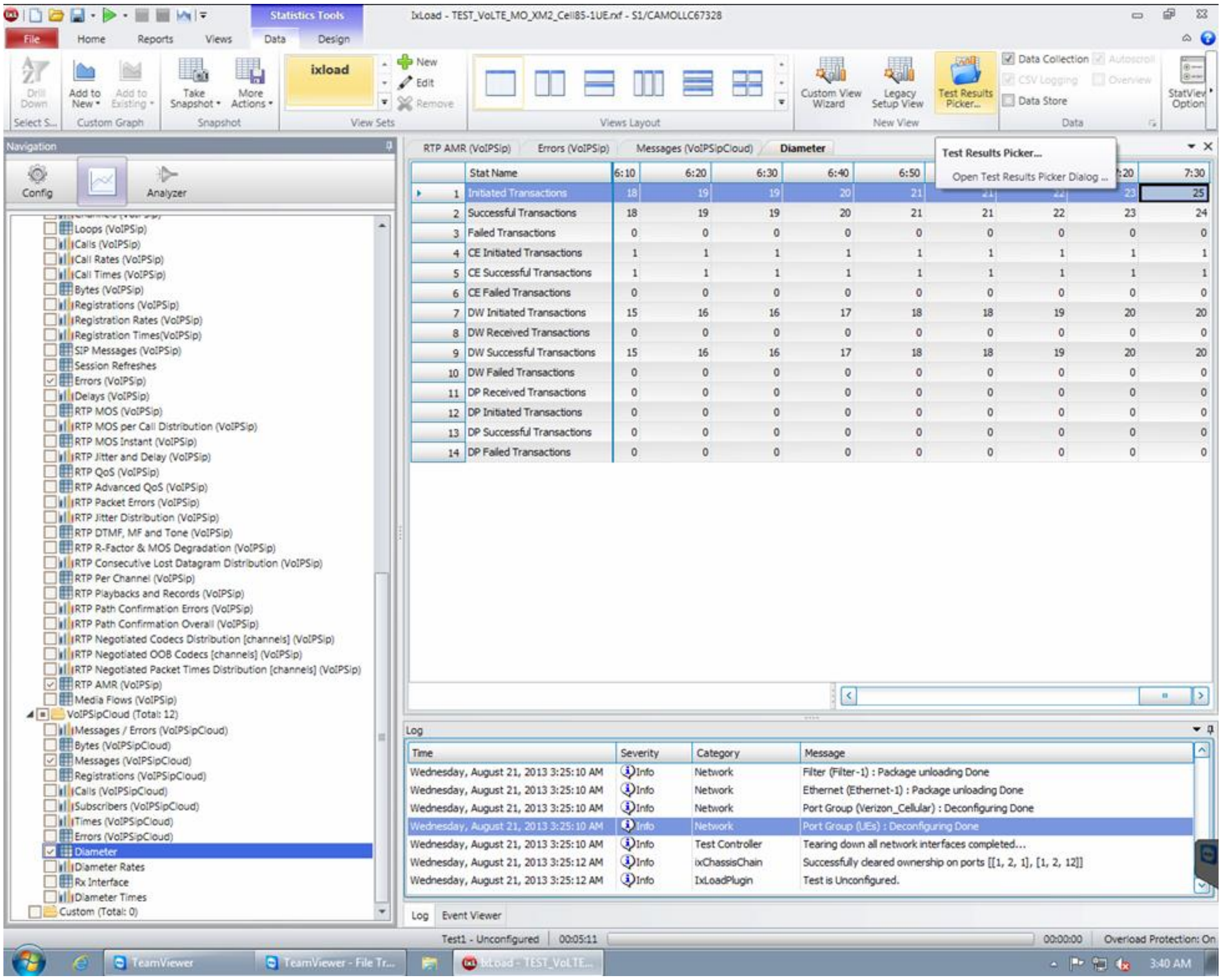


Figure 116. **Diameter** Transactions **statistics**

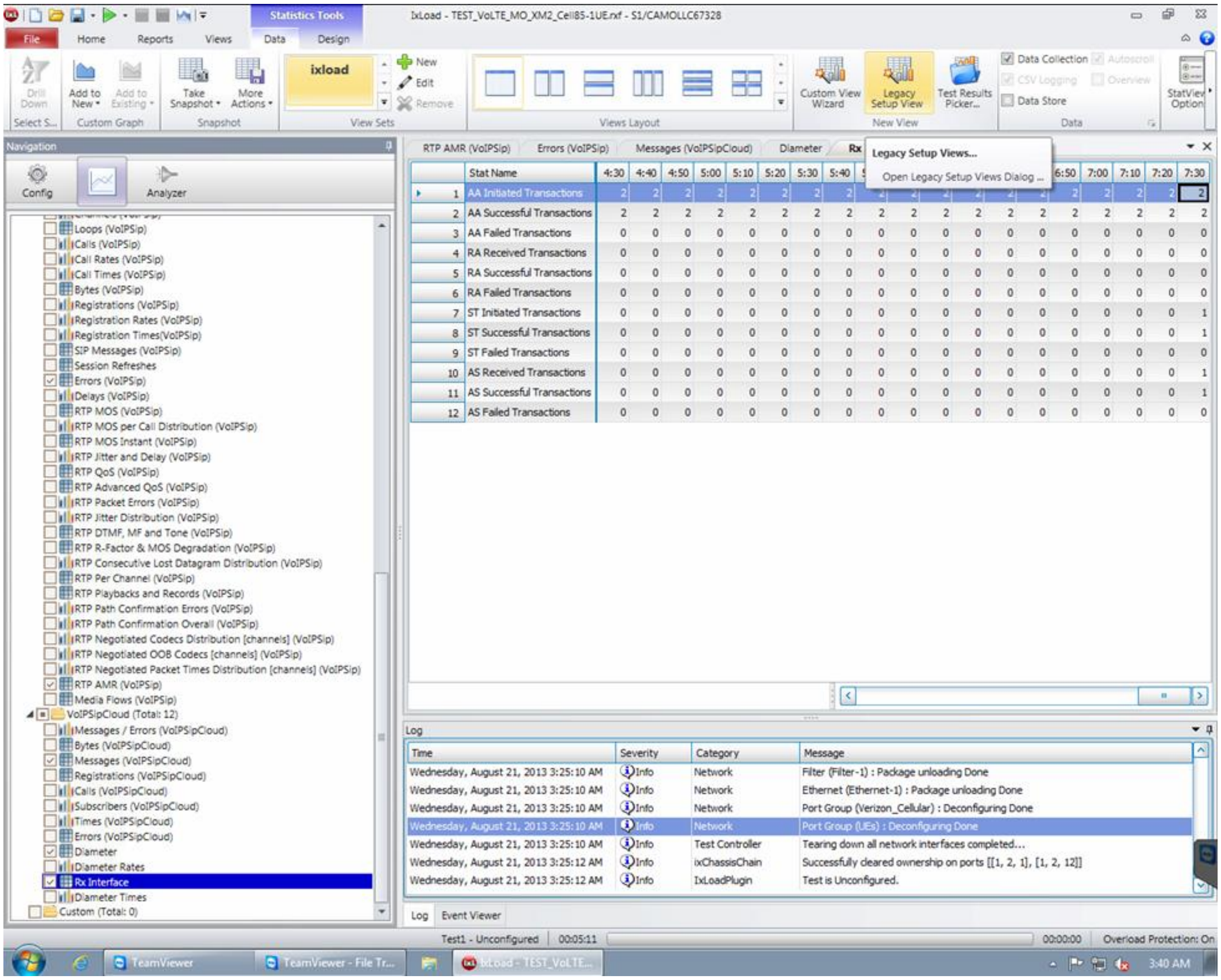


Figure 117. **Rx interface** statistics

Quality of experience

The QoE is a subjective definition that can be interpreted based on specific L4-L7 traffic activities.

Ensuring the QoE is a key objective for this scenario.

A wide selection of real-time media statistics and quality mesurements are available in the RTP views.

RTP QoS (VoIPSip)

	Stat Name	1:40	1:42	1:44	1:46	1:48	1:50
1	Packets Sent	452,595	472,563	492,571	512,544	532,650	552,570
2	Packets Received	452,551	472,505	492,519	512,312	532,595	552,489
3	Bytes Sent	7,198,610	17,957,394	18,717,698	19,476,672	20,240,700	20,997,660
4	Bytes Received	7,196,938	17,955,190	18,715,722	19,467,856	20,238,610	20,994,582
5	Throughput Outbound (Kbps)	3,040	3,041	3,040	3,039	3,040	3,040
6	Throughput Inbound (Kbps)	3,047	3,039	3,041	3,012	3,066	3,036
7	Tx Packets Dropped	0	0	0	0	0	0
8	Lost Packets	1	1	1	1	1	1
9	Maximum Consecutive Lost Packets	1	1	1	1	1	1
10	Packet Errors Received	0	0	0	0	0	0
11	Duplicate Packets Received	0	0	0	0	0	0
12	Late Packets Received	0	0	0	0	0	0
13	Misordered Packets Received	0	0	0	0	0	0
14	One Way Delay (Avg) [us]	5,798	5,560	6,241	3,629	5,325	3,999
15	One Way Delay (Max) [us]	239,017	239,017	239,017	239,017	239,017	239,017

Figure 118. **VoLTE** RTP **QoS**

RTP Advanced QoS (VoIPSip)

	Stat Name	1:50	1:52	1:54	1:56	1:58	2:00	2:02	2:04	2:06	2:08	2:10	2:12
1	Delay Variation Jitter (Avg) [us]	3,261	2,724	2,801	7,086	11,136	11,153	12,971	11,988	12,858	2,952	3,957	3,242
2	Delay Variation Jitter (Max) [us]	217,291	217,291	217,291	217,291	217,291	217,291	217,291	217,291	217,291	217,291	217,291	217,291
3	Interarrival Jitter (Avg) [us]	4,429	4,405	3,590	14,362	12,409	10,257	9,703	9,480	12,601	3,857	4,954	4,410
4	Interarrival Jitter (Max) [us]	31,282	31,282	31,282	31,282	31,282	31,282	31,282	31,282	31,282	31,282	31,282	31,282
5	Bytes Lost Percentage [%]	0	0	0	0	0	0	0	0	0	0	0	0
6	Packet Size Mismatched	0	0	0	0	0	0	0	0	0	0	0	0
7	Packet Codec Mismatched	0	0	0	0	0	0	0	0	0	0	0	0
8	MDI MLR (Avg) [packets/s]	0	0	0	0	0	0	0	0	0	0	0	0
9	MDI MLR (Max) [packets/s]	1	1	1	1	1	1	1	1	1	1	1	1
10	MDI DF (Avg) [us]	66,218	54,055	59,074	79,046	101,123	91,337	117,659	112,882	108,954	79,257	80,297	71,375
11	MDI DF (Max) [us]	258,616	258,616	258,616	258,616	258,616	258,616	258,616	258,616	258,616	258,616	258,616	258,616

Figure 119. **VoLTE RTP** Advanced **QoS**

RTP R-Factor & MOS Degradation (VoIPSip)

	Stat Name	2:20	2:22	2:24	2:26	2:28	2:30	2:32	2:34	2:36	2:38	2:40	2:42	2:44
1	R-Factor Instant (Avg)						75.300	75.200	75.060	75.210	75.520	75.100		
2	R-Factor Instant Best	6.000	96.000	96.000	96.000	96.000	96.000	96.000	96.000	96.000	96.000	96.000	96.000	96.000
3	R-Factor Instant Worst	5.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000
4	MOS Instant (Avg)	3.820	3.830	3.820	3.830	3.820	3.830	3.820	3.830	3.830	3.830	3.830	3.820	3.830
5	MOS Instant Best	4.100	4.100	4.100	4.100	4.100	4.100	4.100	4.100	4.100	4.100	4.100	4.100	4.100
6	MOS Instant Worst	3.730	3.730	3.730	3.730	3.730	3.730	3.730	3.730	3.730	3.730	3.730	3.730	3.730
7	Loss Degradation						0.000	0.000	0.000	0.000	0.000	0.000		
8	Jitter Degradation						0.000	0.000	0.000	0.000	0.000	0.000		
9	Codec Degradation						4.000	4.000	4.000	4.000	4.000	4.000		
10	Delay Degradation						0.000	0.000	0.000	0.000	0.000	0.000		

Figure 120. **VoLTE** RTP **R-Factor & MOS**

Test Case 6: Voice & Video VoLTE Call

Objective

Create and run a VoLTE scenario with data traffic in the background: Two of the UEs attaching to the network and performing five minutes long bi-directional voice and video calls.

Setup

Refer to Test Harness for more information on setup.

Two sectors are used in this scenario as an example, but it can be run also using only one cell sector.

Step-by-step Instructions

1. Load previous example. rxf (VoLTE voice configuration with data in the background).
2. On both LTE UE side and IP (PDN) side, replace Voice Session RTP function from the VoIP Scenario Editor with Multimedia Session RTP function (located in Workspace in the Media Library).

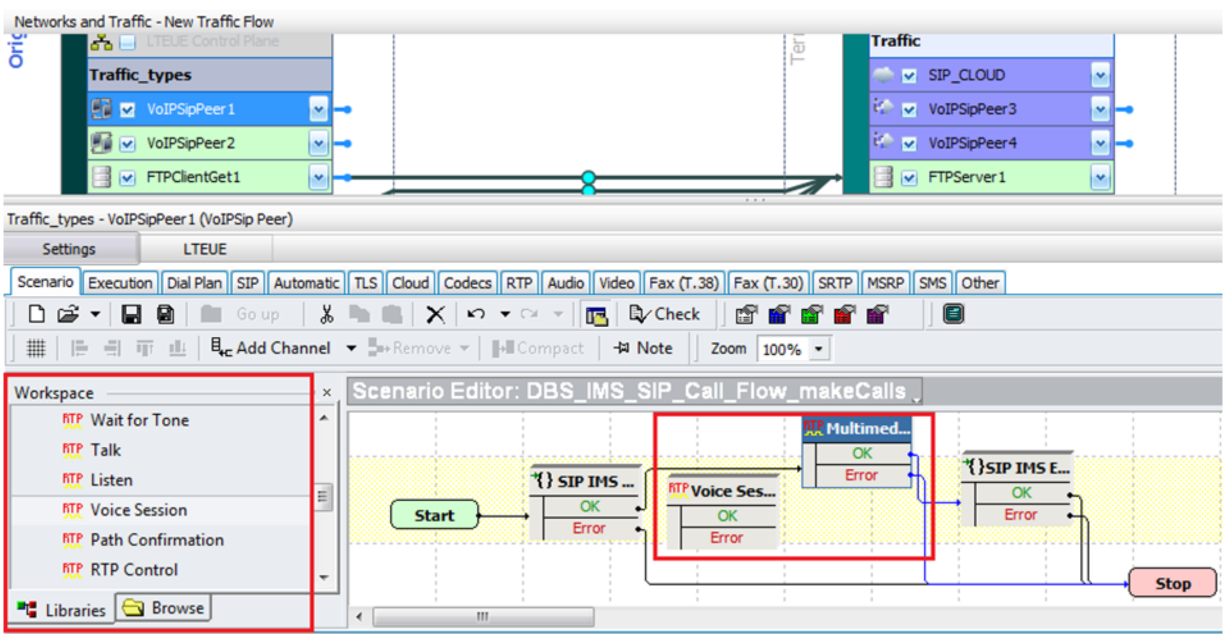


Figure 121. RTP **Multimedia**

3. In the **Video** tab, select **Enable video on this activity** and select a H.264 coded video clip. Set clip play duration.

   MOS or **One Way Delay** calculation can be selected here also.

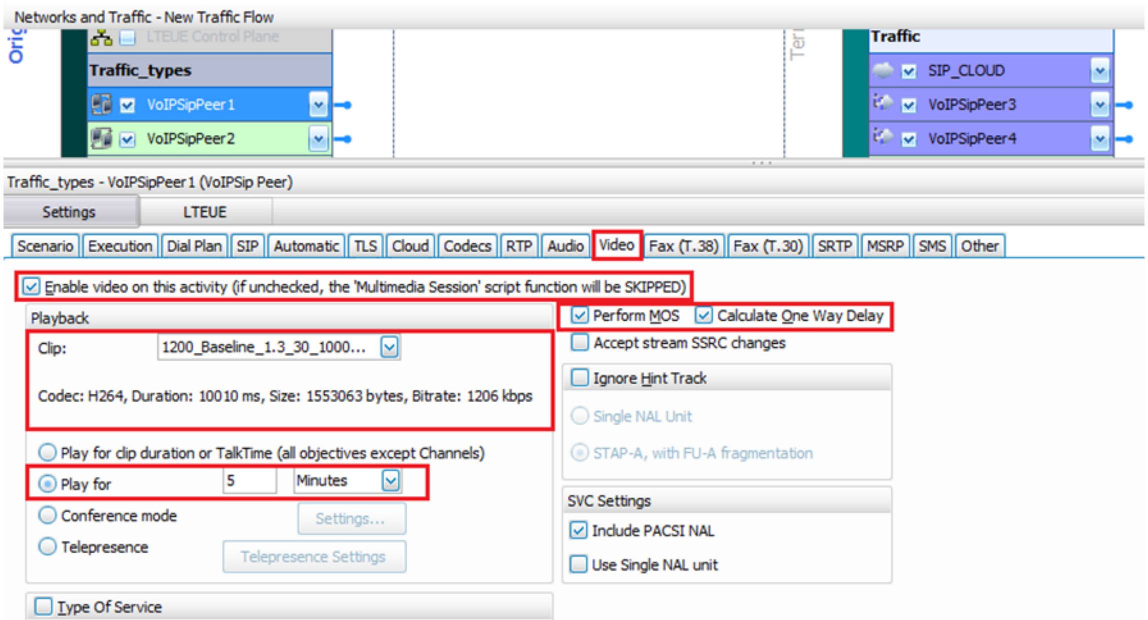


Figure 122. **Video settings**

4. Save the modified scenario file (.tst) with a different name to reflect the new functionality (For example, MakeCalls_Voice_Video for LTE UE side or RecvCalls_Voice_Video for Terminate side).

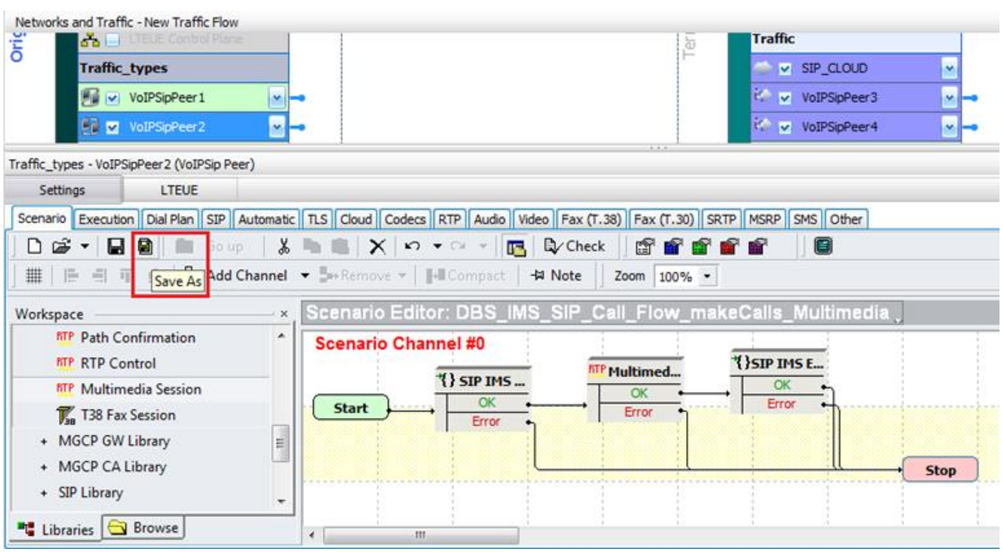


Figure 123. Multimedia **scenario**

Timeline and Objective

In this section, the L4-L7 traffic activity objectives are defined that indirectly drive the network layer objectives.

For this scenario, it is essential to simulate 6 UEs on LTE Access side (one on each VoIPSipPeer1 activity and one for every FTP activity).

Two UEs attach to the network and perform a 5 minutes long bi-directional voice and video call during the entire sustain time.

In the background, each of the FTP UEs perform uplink or downlink data traffic.

For VoLTE UEs, the selected objective type is Channels and for FTP UEs is Simulated Users

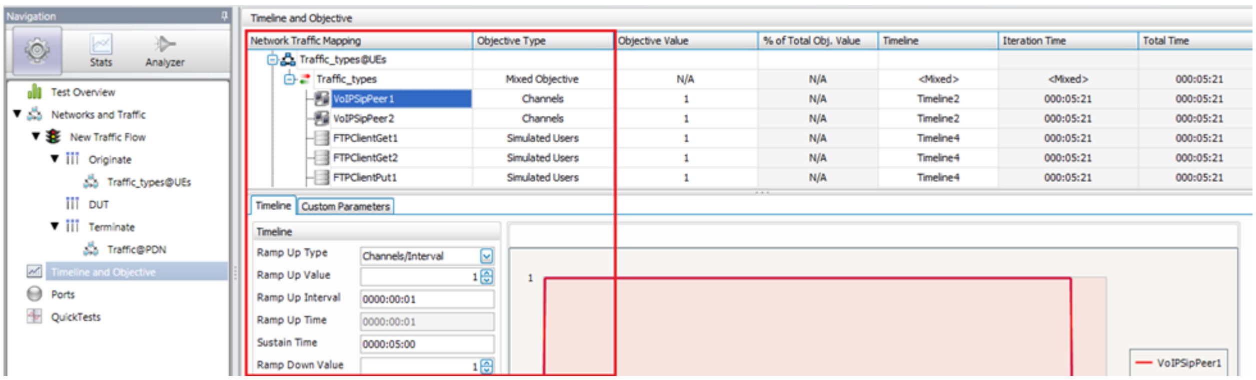


Figure 124. Timeline and objective

Port Assignment

Refer to Port Assignment from Scenario 1.

Test Variables

Refer to attached RXF for variables used in this test. Many of the settings (like IMSI, cell ID, OP, K, and so on) must be updated to suit the network you are simulating against.

Results Analysis

Once the test is started, IxLoad automatically switches to Stats view. You can also use the **Stats** button in the upper-left side of IxLoad client GUI to enable this view.

One way to analyse stats is to start with Network layer. Confirm that all UEs are attached correctly, followed by traffic layer. Confirm, if the test objective is met and finally analyse UEs Quality of Experience.

Network Layer Stats – LTE UE Global

Verify the LTE UE Global stats to make sure all 6 UEs have attached suceessfully.

If there are failures check for:

- RACH Success/Failure
- RRC Success/Failure
- Authentication Success/Failure

User plane

You can verify the number of attempted, connected, or failed calls within VoIPSip Calls stat view.

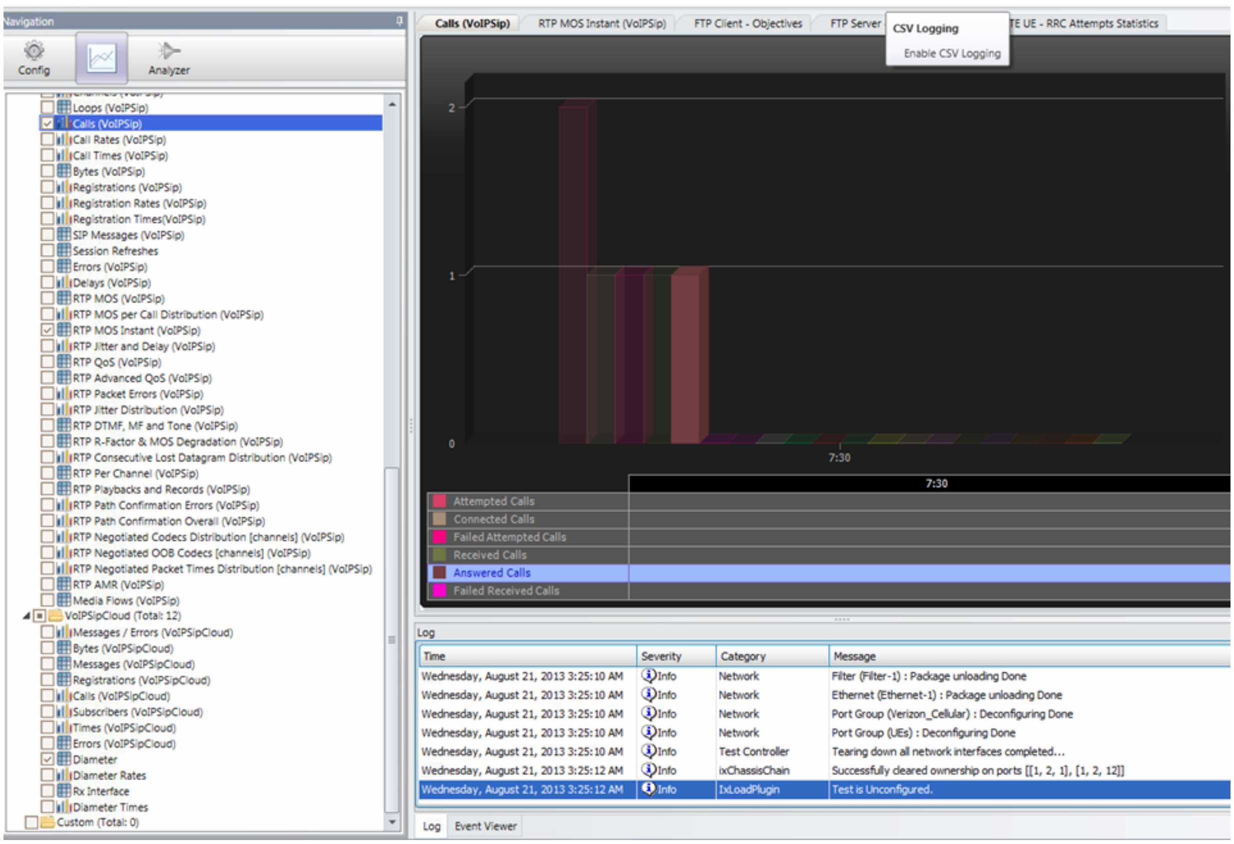


Figure 125. **Call Stats**

If there are failures check for RTP, SIP or Transport errors under VoIP SIP Error stat view:

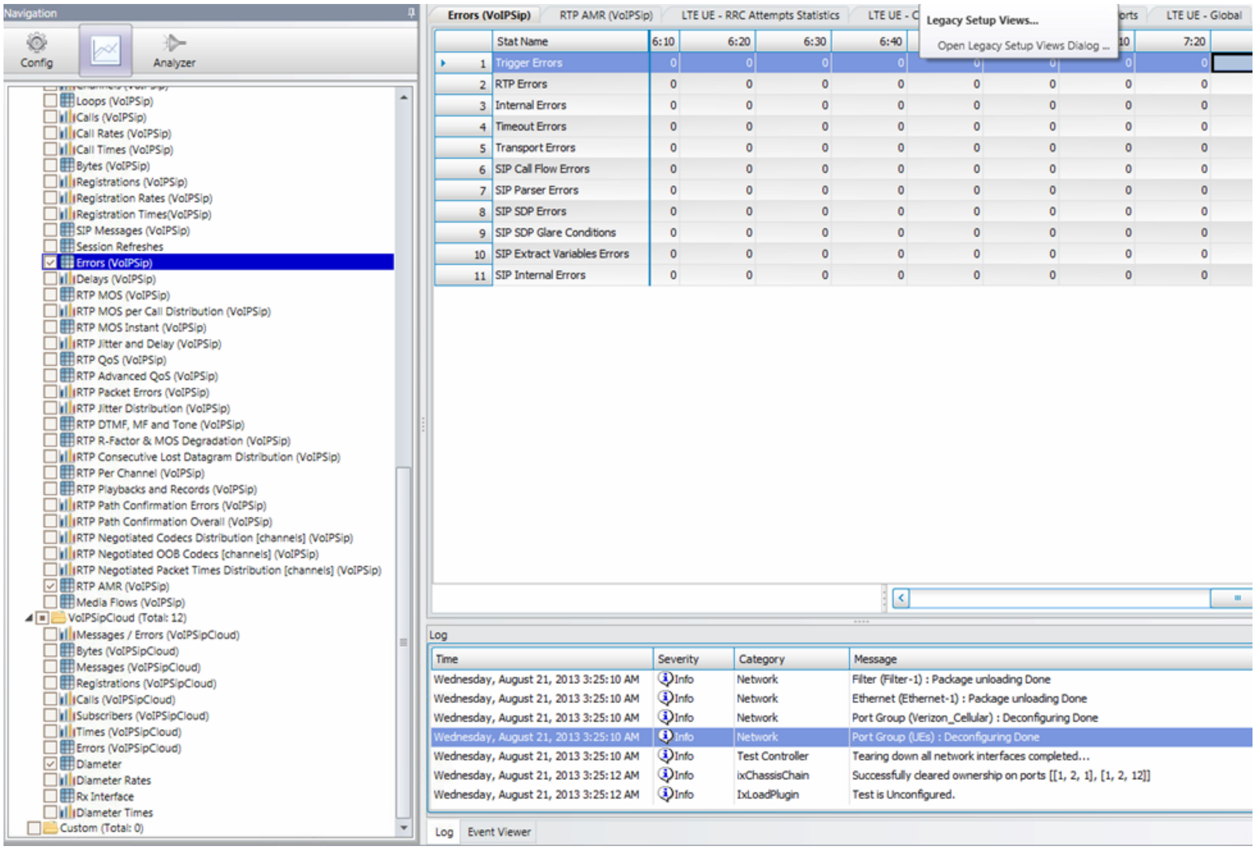


Figure 126. Errors **Stats**

Rx interface

To debug problems in this interface, stats are available in the Diameter and Rx Interface stat views.

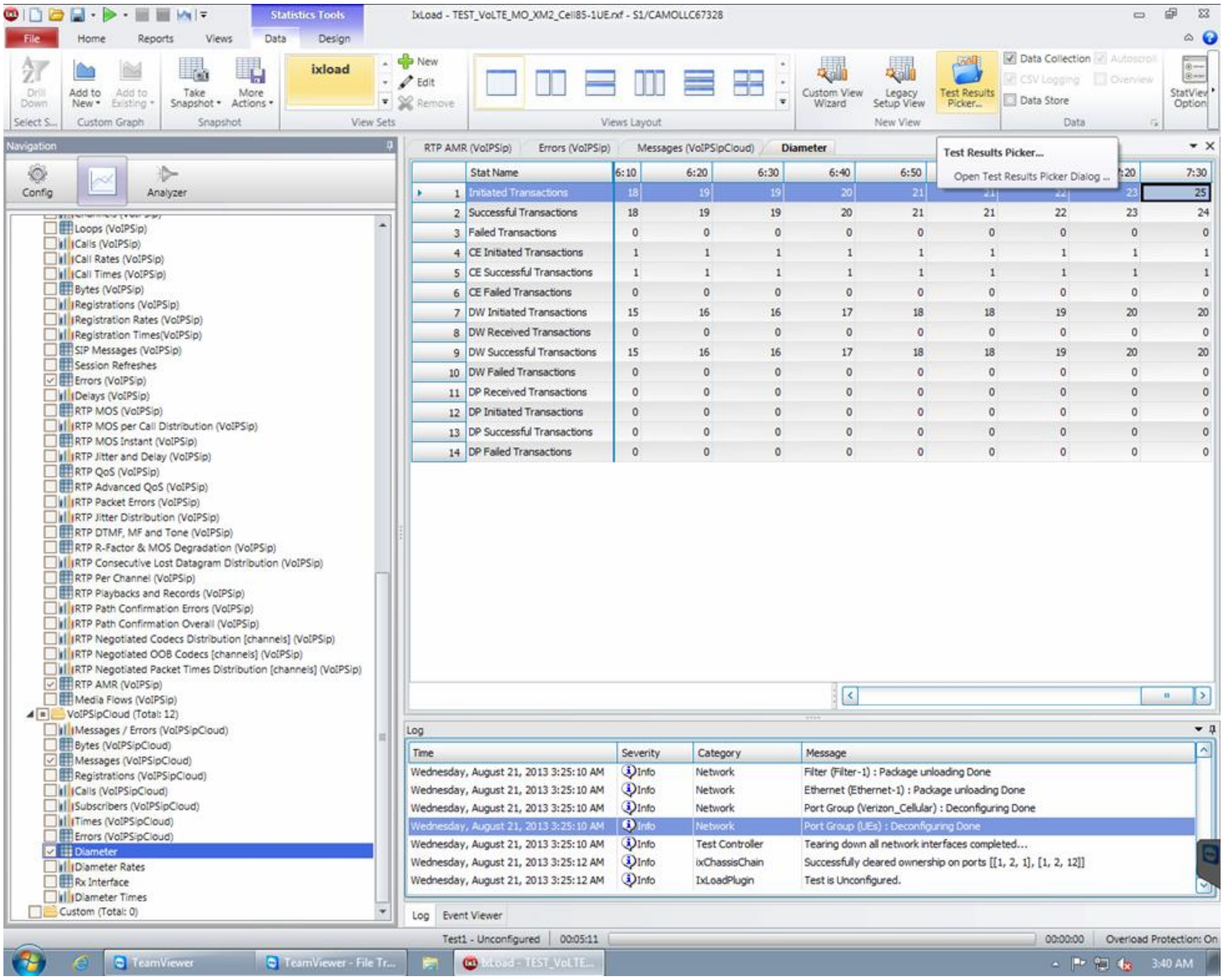


Figure 127. **Diameter** Transactions **statistics**

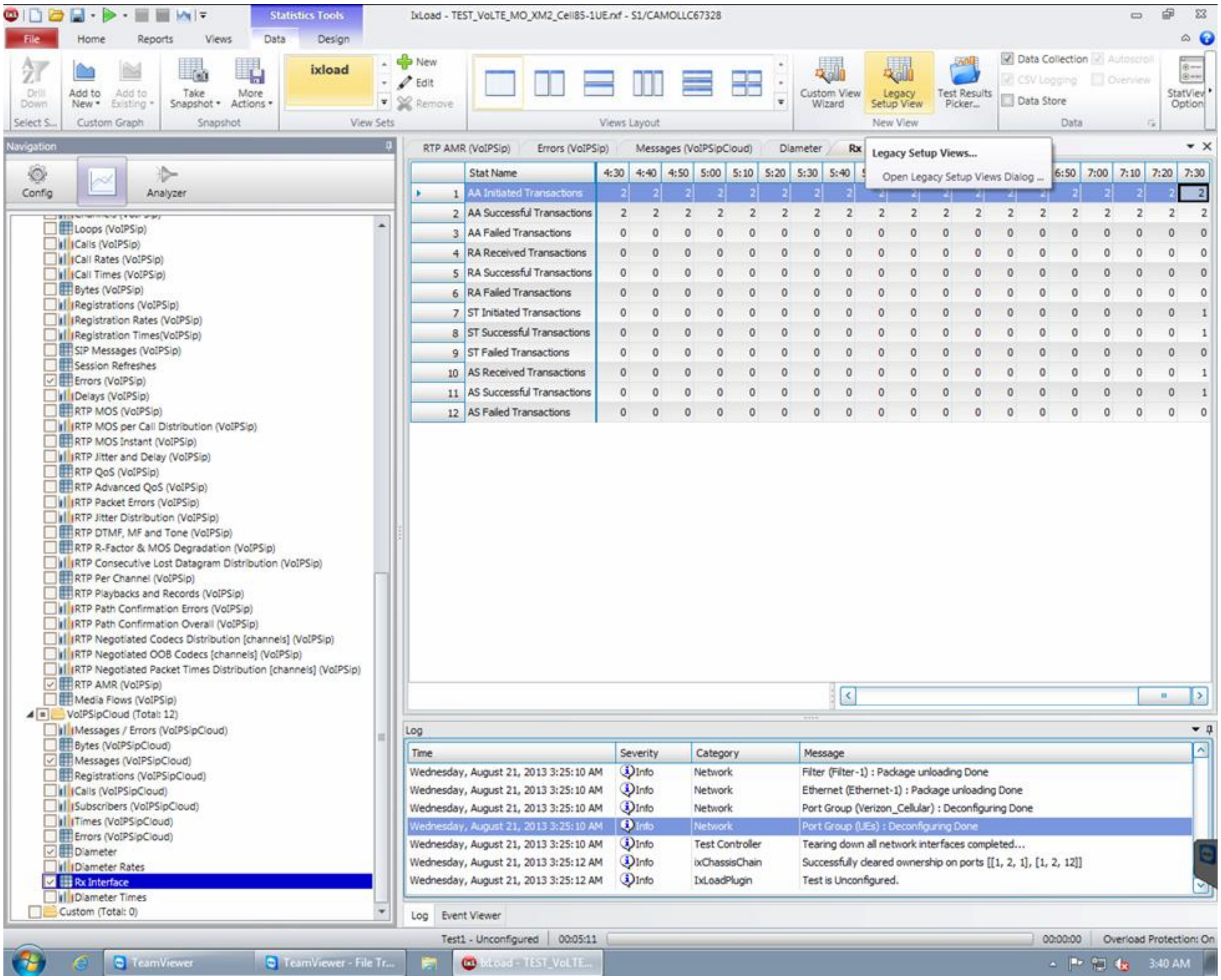


Figure 128. **Rx** interface **statistics**

Quality of experience

The QoE is a subjective definition that can be interpreted, based on specific L4-L7 traffic activities.

Ensuring the QoE is a key objective for this scenario.

A wide selection of real-time media statistics and quality mesurements are available in the RTP views.

RTP QoS (VoIPSip)

	Stat Name	1:40	1:42	1:44	1:46	1:48	1:50
1	Packets Sent	452,595	472,563	492,571	512,544	532,650	552,570
2	Packets Received	452,551	472,505	492,519	512,312	532,595	552,489
3	Bytes Sent	7,198,610	17,957,394	18,717,698	19,476,672	20,240,700	20,997,660
4	Bytes Received	7,196,938	17,955,190	18,715,722	19,467,856	20,238,610	20,994,582
5	Throughput Outbound (Kbps)	3,040	3,041	3,040	3,039	3,040	3,040
6	Throughput Inbound (Kbps)	3,047	3,039	3,041	3,012	3,066	3,036
7	Tx Packets Dropped	0	0	0	0	0	0
8	Lost Packets	1	1	1	1	1	1
9	Maximum Consecutive Lost Packets	1	1	1	1	1	1
10	Packet Errors Received	0	0	0	0	0	0
11	Duplicate Packets Received	0	0	0	0	0	0
12	Late Packets Received	0	0	0	0	0	0
13	Misordered Packets Received	0	0	0	0	0	0
14	One Way Delay (Avg) [us]	5,798	5,560	6,241	3,629	5,325	3,999
15	One Way Delay (Max) [us]	239,017	239,017	239,017	239,017	239,017	239,017

Figure 129. **VoLTE RTP QoS**

RTP Advanced QoS (VoIPSip)

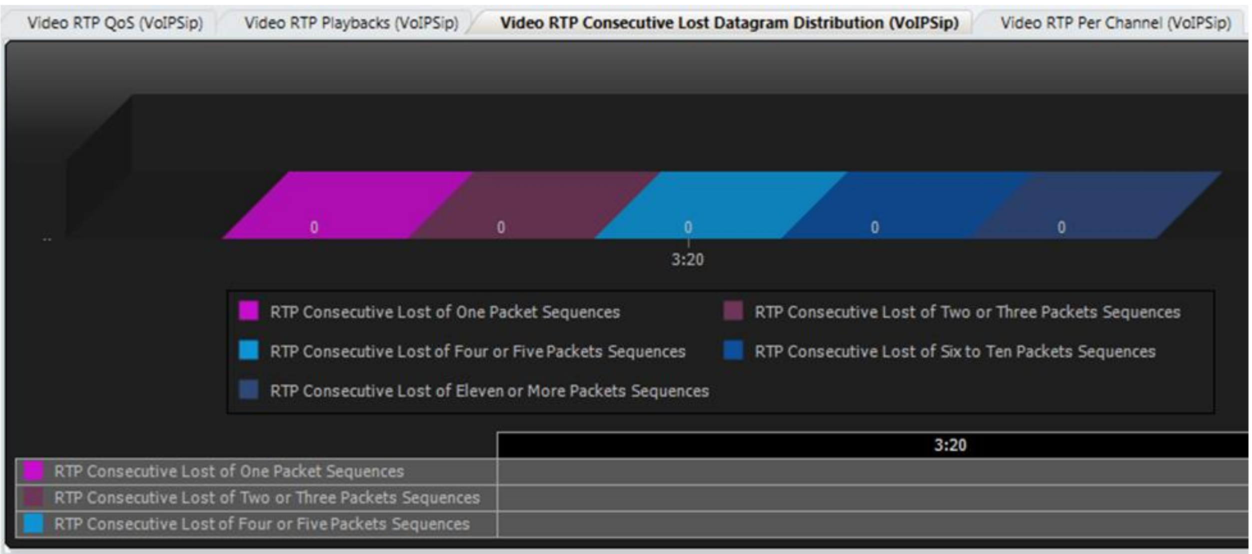
	Stat Name	1:50	1:52	1:54	1:56	1:58	2:00	2:02	2:04	2:06	2:08	2:10	2:12
1	Delay Variation Jitter (Avg) [us]	3,261	2,724	2,801	7,086	11,136	11,153	12,971	11,988	12,858	2,952	3,957	3,242
2	Delay Variation Jitter (Max) [us]	217,291	217,291	217,291	217,291	217,291	217,291	217,291	217,291	217,291	217,291	217,291	217,291
3	Interarrival Jitter (Avg) [us]	4,429	4,405	3,590	14,362	12,409	10,257	9,703	9,480	12,601	3,857	4,954	4,410
4	Interarrival Jitter (Max) [us]	31,282	31,282	31,282	31,282	31,282	31,282	31,282	31,282	31,282	31,282	31,282	31,282
5	Bytes Lost Percentage [%]	0	0	0	0	0	0	0	0	0	0	0	0
6	Packet Size Mismatched	0	0	0	0	0	0	0	0	0	0	0	0
7	Packet Codec Mismatched	0	0	0	0	0	0	0	0	0	0	0	0
8	MDI MLR (Avg) [packets/s]	0	0	0	0	0	0	0	0	0	0	0	0
9	MDI MLR (Max) [packets/s]	1	1	1	1	1	1	1	1	1	1	1	1
10	MDI DF (Avg) [us]	66,218	54,055	59,074	79,046	101,123	91,337	117,659	112,882	108,954	79,257	80,297	71,375
11	MDI DF (Max) [us]	258,616	258,616	258,616	258,616	258,616	258,616	258,616	258,616	258,616	258,616	258,616	258,616

Figure 130. **VoLTE RTP** Advanced **QoS**

RTP R-Factor & MOS Degradation (VoIPSip)

	Stat Name	2:20	2:22	2:24	2:26	2:28	2:30	2:32	2:34	2:36	2:38	2:40	2:42	2:44
1	R-Factor Instant (Avg)						75.300	75.200	75.060	75.210	75.520	75.100		
2	R-Factor Instant Best	6.000	96.000	96.000	96.000	96.000	96.000	96.000	96.000	96.000	96.000	96.000	96.000	96.000
3	R-Factor Instant Worst	5.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000
4	MOS Instant (Avg)	3.820	3.830	3.820	3.830	3.820	3.830	3.820	3.830	3.830	3.830	3.830	3.820	3.830
5	MOS Instant Best	4.100	4.100	4.100	4.100	4.100	4.100	4.100	4.100	4.100	4.100	4.100	4.100	4.100
6	MOS Instant Worst	3.730	3.730	3.730	3.730	3.730	3.730	3.730	3.730	3.730	3.730	3.730	3.730	3.730
7	Loss Degradation						0.000	0.000	0.000	0.000	0.000	0.000		
8	Jitter Degradation						0.000	0.000	0.000	0.000	0.000	0.000		
9	Codec Degradation						4.000	4.000	4.000	4.000	4.000	4.000		
10	Delay Degradation						0.000	0.000	0.000	0.000	0.000	0.000		

Figure 131. **VoLTE RTP R-Factor & MOS**



Log

Time	Severity	Category	Message
Wednesday, August 21, 2013 2:03:57 PM	Info	Test Controller	Starting the STAT Requests...
Wednesday, August 21, 2013 2:03:57 PM	Info	Network	GratARP (GratARP-2) : Activated
Wednesday, August 21, 2013 2:03:58 PM	Info	Test Controller	The Stat requests are done for publisher Stackmanager
Wednesday, August 21, 2013 2:04:08 PM	Info	Test Controller	The Stat requests are done for publisher IxLoad
Wednesday, August 21, 2013 2:04:11 PM	Info	Test Controller	Test is Running.

Figure 132. Video **RTP statistics**

Test Case 7: Channel Modeling Scenario

Overview

In the real world, a wireless UE performance is often impacted based on the RF Propagation conditions that it experiences at a given location or due to its mobility. With this feature, it is possible to simulate UEs under the different RF conditions, namely near-cell, mid-cell, far-cell, as well as UEs under different channel propagation conditions (EVA, EPA, HST, and so on) and test the effect of the eNodeB scheduler on each UE type.

This test simulates UEs and tries to observe the effect on their DL throughput as they transition to different RF conditions.

Objective

Create test with the following configuration:

- Three UE ranges with five UEs in each range, with the intention of assigning each UE range to a specific RF condition.
- All UEs attach under normal RF condition and start DL traffic (full throughput)
- Two minutes into the Test UEs move into near-cell, mid-cell, and far-cell RF conditions respectively

Measure the effect of changing RF conditions to total system throughput and per-UE system thoroughput.

Setup

Refer to Test Harness for more information on setup.

Step-by-step Instructions

So far, NetTraffic is used as the base object for all test configurations. For this exercise, use SubscriberMode NetTraffic object. A SubscriberMode configuration is optional for channel modeling, but it allows for more elaborate channel modeling configurations. For instance, the following channel model scenarios are only possible under Subscriber Mode:

- Simulating UE RF condition transitions before/after specific traffic activities
- Simulating UE RF condition transitions few random seconds after a Handover
- Simulating UE RF condition transitions after UE exits RRC IDLE state

NetTraffic based channel model test cases are limited to a static timer based configurations.

1. Start IxLoad and add Subscriber Mode NetTraffic object and configure LTEUE plugin in the similar way as described in Test Case 1: Single UE Attach with User Plane Data Traffic.

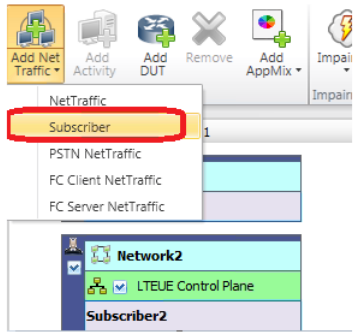


Figure 133. Add Subscriber Mode

2. Add three UE Ranges and configure five UEs in each range for this test case. Each UE range is a collection of UEs that exhibit similar behavior. Configure the rest of the LTEUE plugin as described in previous test cases (including Test Case 1)

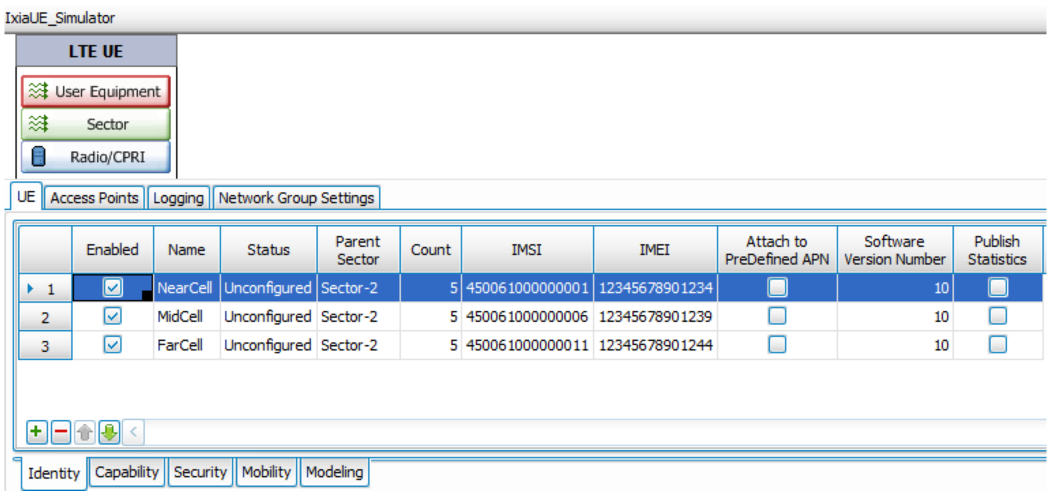


Figure 134. Add 3 UE Ranges

3. Click User Equipment > Modeling and select **Enable Modeling for each UE range**. Channel modeling configuration is optional.

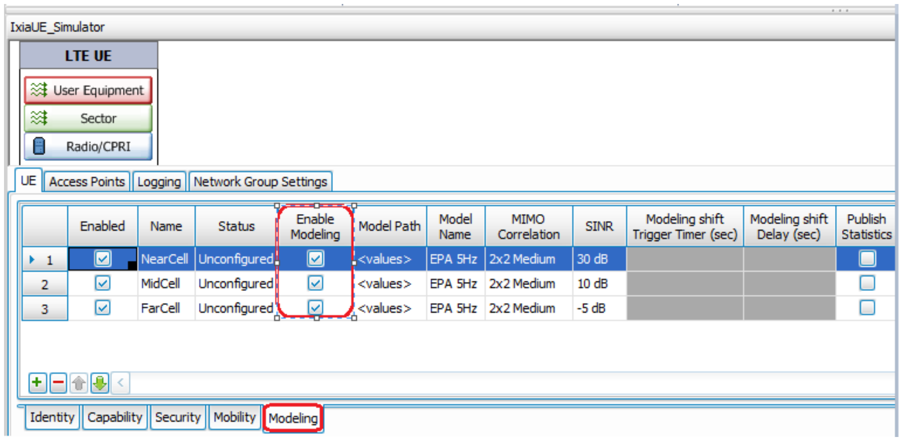


Figure 135. Enable Channel **Modeling**

4. Near Cell UEs are typically in very good RF conditions. They exhibit high SINR (Signal to Interference Noice Ratio) and generally get scheduled, that is,. more throughput. Far Cell UEs on the other hand are in poor RF conditions and exhibit low SINR with higher BLER (Block Error Rate) and low CQI (Channel Quality Indicator). With IxLoad, you can customize these parameters, however the default settings must work out of the box as well. Set appropriate SINR for each UE range.

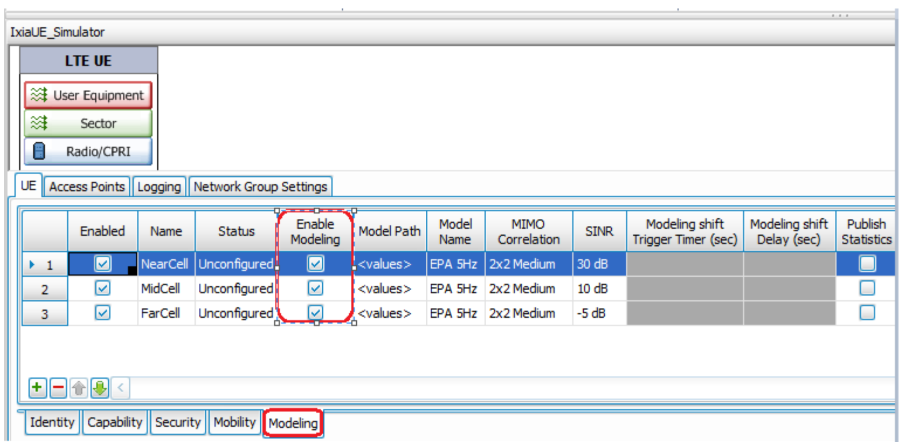


Figure 136. SINR for each UE Range

5. You can leave model path field blank, because, static models (UEs are either Near-cell, mid-cell, far-cell conditions throughout the test after they transition once) are simulated. Same for MIMO Correlation and Model Name, leave them configured at Medium correlation and EPA 5Hz for the entire test. If you wish to configure an ever changing RF condition for each UE range, click on Model Path to configure the respective RF condition transitions.

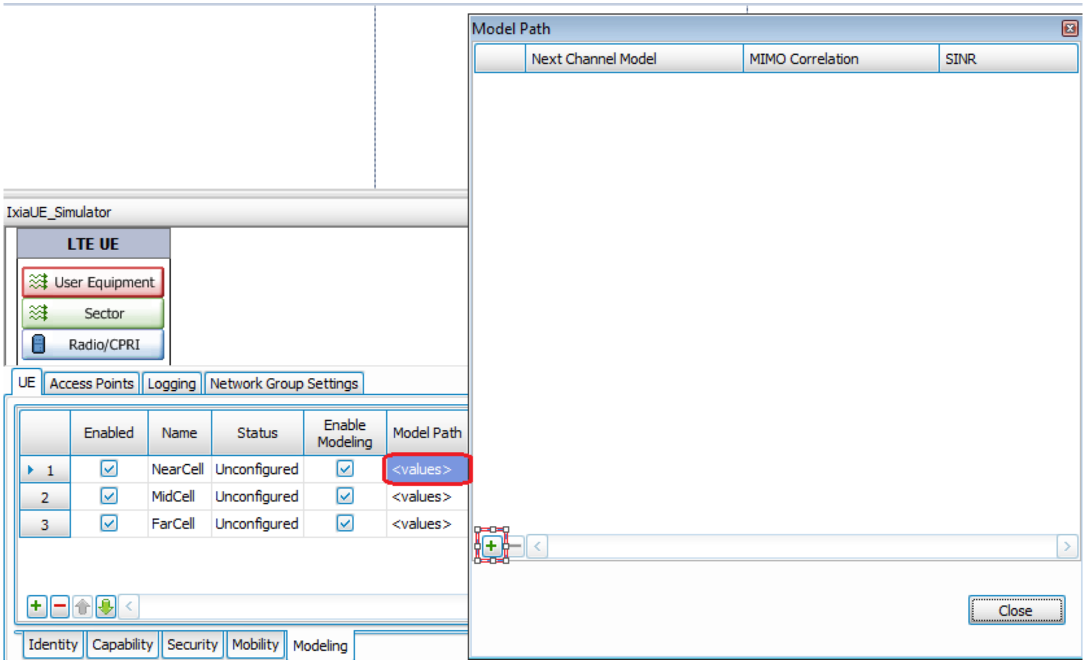


Figure 137. Model **Path**

6. In this step, configure when channel model transitions occur. In subscriber mode, all network events are driven by Network Commands. Modeling is the network command for a modeling transition. Per the figure below, click the ***Subscriber*** layer to configure these transitions. As per the test case, UEs transition into their respective RF conditions after two minutes of attaching.

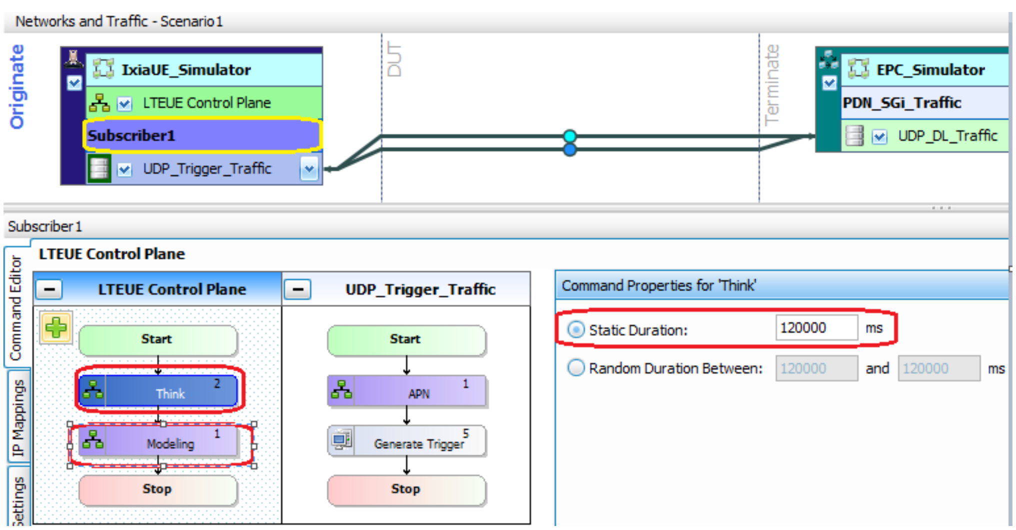


Figure 138. Modeling Network **Command**

7. Configure the traffic as explained in the previous test cases.

8. Keep the timeline and objective configuration similar to previous test cases.

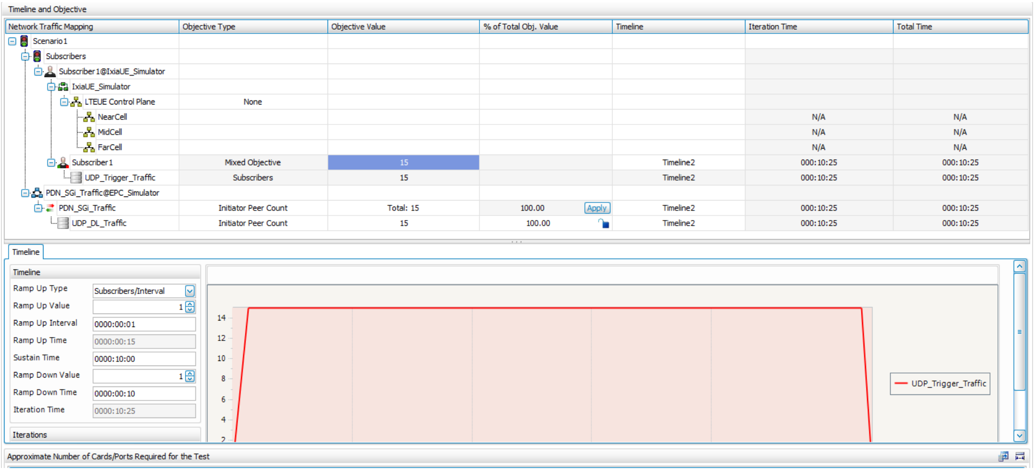


Figure 139. Timeline and Objective

9. Assign 1 port to the test and start the execution.
10. After test starts, make sure all UEs have attached.
11. Note maximum DL throughput – both system and perUE. The summary below shows all UEs have attached, with each UE getting about 4.7Mbps of DL throughput and total system throughput of about 70Mbps.

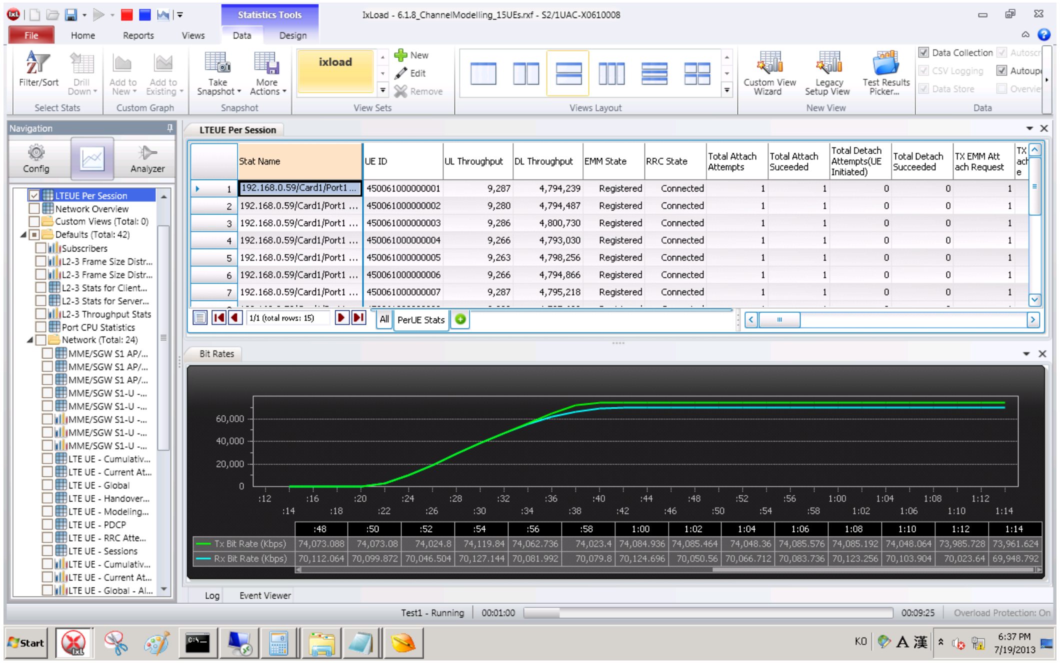


Figure 140. Summary

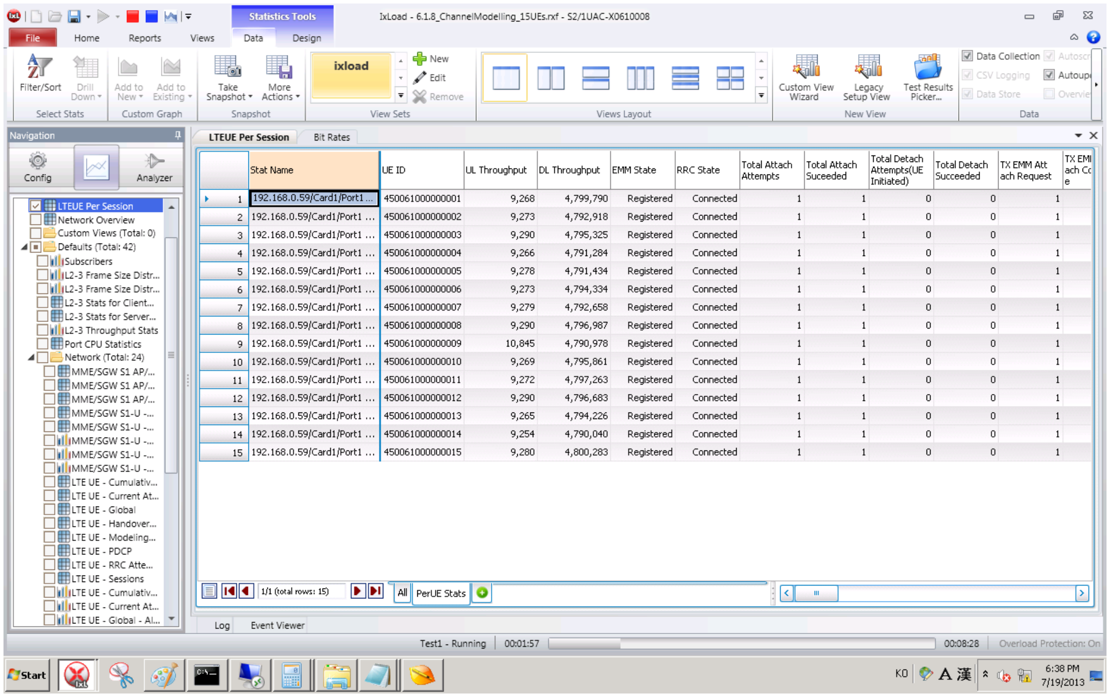


Figure 141. Per UE DL Throughput

12. Based on the configuration, two minutes into the test UEs must transition to their respective RF conditions. Soon after this behavior, the scheduler adapts and allocates resources differently to each UE category. This must be noticeable in the total system throughput and per UE throughput.

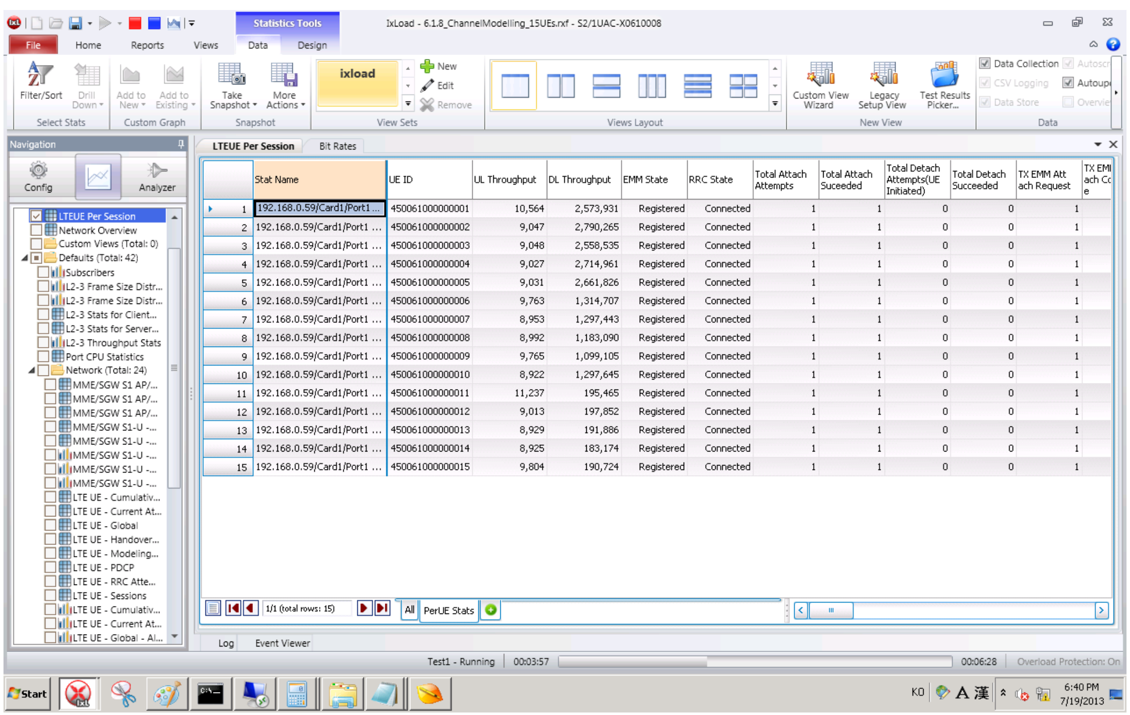


Figure 142. Per UE System Throughput after Modeling

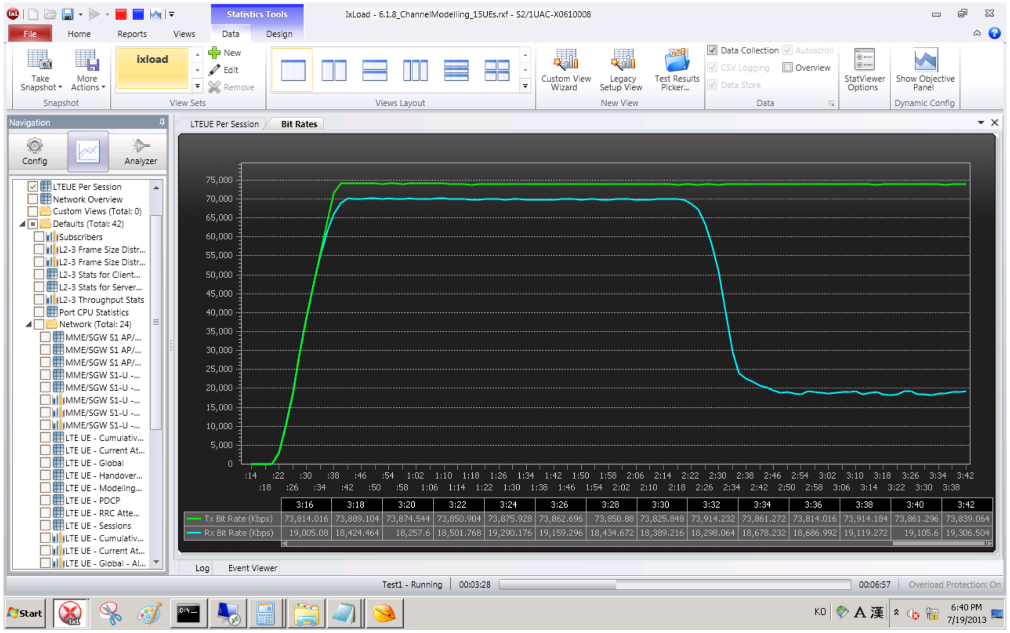


Figure 143. Total System Throughput **after Modeling**

As you can see from results, the per UE throughput for each UE ranges changes from:

- Near-Cell = 4.7 Mbps to 2.5 Mbps
- Mid-Cell = 4.7 Mbps to 1.3 Mbps
- Far-Cell = 4.7 Mbps to 190kbps

This clearly indicates that in this configuration, you can influence the eNodeB schdeduler and test its performance under different conditionsUEs are either Near-cell, mid-cell, far-cell conditions throughout the test after they transition once

Contact Ixia

IXIA WORLDWIDE
26601 W. AGOURA ROAD
CALABASAS, CA 91302

(TOLL FREE NORTH AMERICA)
1.877.367.4942
(OUTSIDE NORTH AMERICA)
+1.818.871.1800
(FAX) 818.871.1805
www.ixiacom.com

IXIA EUROPE
CLARION HOUSE, NORREYS DRIVE
MAIDENHEAD SL6 4FL
UNITED KINGDOM

SALES +44.1628.408750
(FAX) +44.1628.639916

IXIA ASIA PACIFIC
101 THOMSON ROAD,
#29-04/05 UNITED SQUARE
SINGAPORE 307591

SALES +65.6332.0125
(FAX) +65.6332.0127