

# **LTE Multi-RAT**

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# ***Interworking with 4G & 2G/3G***

### Course Duration:

- 2 days

### Course Description:

- This course focuses on the inter-system operation between the new EPS and the legacy GSM/UMTS networks and explains how major CS services like Voice and SMS are supported in LTE or pushed back on legacy network .
- We highlight how legacy voice call is supported in EPS through either CSFB (circuit-switched fallback) or VoIP-IMS (voice over IP using IP Multimedia Subsystem) and how SMS via SGs-interface (legacy circuit-switched based) or SMS over SIP-IMS are possible.
- One aspect of this course is to explain how NAS (non-access stratum) has to behave in Multi-RAT environment during iRAT reselections and handovers .
- Further this course points out the functionality of Idle Signaling Reduction (ISR) and UE's priority-based cell reselection among GERAN, UTRAN and E-UTRAN using Subscriber Profile ID, the SPID for RAT/frequency priority parameters
- ISR is mandatory for UE to support and allows a Paging Co-ordination between LTE and legacy PS-Domain of GERAN/UTRAN as the UE keeps both LAC/RAC+PTMSI as well LTE TAC and GUTI (Global Unique Temporary ID replacing in LTE LAC/RAC + PTMSI)
- Inter-system changes between the RAT's can be basically performed in two ways, either seamless using handovers with minimum service interruption time, or alternatively relying on more or less advanced iRAT reselections, starting from RRC Connection Release with Redirection Info, Cell Change Order and Network Assisted Cell Change.
- Handovers between the RAT's (particular between LTE and UMTS) are the preferred choice for delay critical services like voice (SRVCC-Handover from LTE to GERAN or UTRAN) requiring the highest degree of interoperability between UE, EPS and GERAN/UTRA, however, more cost-effective for non real-time services are so called Redirections, Cell Change Order and to a certain extend Network Assisted Cell Change procedures.
- In practice this means the operator has to decide when and how to configure Measurement Gaps in E-UTRAN or Compressed Mode in UMTS for inter-RAT measurements. In EGPRS the focus is on features like NACC, alternatively PS-Handover and DTM (dual transfer mode) and how they are beneficial not only for the subscriber but also for the operator's business case.
- In order to get to know the LTE signaling and its parameters, the course starts with a solid description about E-UTRAN's air-interface, and particular how resources get allocated through the master control channel using various Downlink Control Information's (DCI's).

- Based on the experience of participants the repetition of LTE only related subjects can be kept short.
- Further the course analyzes the RRC Signaling in E-UTRAN for example how Handovers and Measurements Configurations are signaled or how a UE drops when being out-of-sync in LTE.
- Great emphasis is put on the layer 1 measurements of the other RAT when preparing for handover. Particularly the course focus on IRAT neighbor scanning and Pilot measurements when UE is in LTE or UMTS or GERAN connected mode.

## **Prerequisites:**

- The student should possess experience of wireless communications, particularly within the area of either GERAN or UTRAN is advantageous.

## **Course Target:**

- The student will obtain solid understanding of EPS and its interworking with existing GERAN/UTRAN and legacy Core Networks. Particular the issues with Voice (CS-fallback) and SRVCC (VoIPIMS to GERAN/UTRAN Handover) are one of the focal points.

## **Some of your Questions that will be answered:**

- What is the legacy GERAN/UTRAN Architecture requiring the UE to support NMO-1, 2 or 3?
- How can ISR help in reducing the Routing and Tracking Area Updates?
- How could the Paging Success Rate be improved with LAC/RAC Harmonization in GERAN/UTRAN?
- What are the differences between Network Operation Modes in GERAN/UTRAN and UE Operation modes in EPS?
- What are the advantages for subscriber and operator when the UE performs prioritized Cell Reselection compared to ordinary offset based Reselection?
- What is the difference between dedicated and common prioritizes for Inter Frequency and Inter-RAT's neighbors?
- How can a Voice call be supported in EPS and how to ensure Service Continuity between different RAT's
- Is SMS in roaming situations still supported in EPS via SGs-interface? And how does SMS over IMS work?
- How many PDP Contexts should a GERAN/UTRAN network support in order to compete with the number of possible EPS Bearers in LTE/SAE?

## **Who should attend this Course:**

- This trainings enables Operators and Vendors to solve the interworking problems between the newly defined E-UTRAN and the existing 2G and 3G Radio Access Networks.

## Table of Content:

### The LTE Air-interface

- **Requirements on LTE**

- ⇒ General Requirements

- SON (self optimizing network) Introduction , Automatic Neighbor Reporting (ANR) Introduction

- **Important Characteristics of LTE Physical Layer**

- eNodeB Self-Configuration, Automatic Neighbor Relation (ANR), Inter Cell Interference Coordination (ICIC), Fast Frequency Domain Scheduling (FFDS) combined with Adaptive Modulation & Coding (AMC), Low complexity Network (UE and E-UTRAN)

- **Network Structure – Interworking between legacy & new Core**

- Control Plane / E-UTRAN – EPC, User Plane E-UTRAN – EPC (S5/S8 GTP-based), SGSN Selection of PDN-GW versus GGSN

- **Why OFDM?**

- ⇒ The Multipath Phenomenon

- Single Carrier Modulation and Channel Equalization, Delay Spread, Multipath-induced Time Delays result in ISI

- ⇒ Technique behind OFDM - FFT

- Basics on FFT / IFFT , IFFT/FFT processing , How does the FFT process keep the individual modulated carriers from interfering with one another? , How is OFDM implemented ? , What are the downsides to OFDM? , And what is OFDMA? , How is OFDMA accomplished?

- ⇒ Simple OFDM Processing Chain

- ⇒ Purpose of Cyclic Prefix in OFDM

- Inter Carrier Interference (ICI), Frequency & Time Synchronization

- ⇒ LTE specific OFDM/FFT and sub-carrier Parameters

- ⇒ Time / Frequency View on OFDM: The "Grid"

- ⇒ Resource Blocks and TTI in LTE

- ⇒ SC-FDMA

- Why SC-FDMA?, The Processing Chain of SC-FDMA

- **The Frequency Bands for LTE , UMTS and GSM**

- ⇒ Flexible Bandwidths – MIB, Primary & Secondary Sync Location for LTE Cell Search

- ⇒ E-UTRAN Channel Bandwidth and E-UTRAN's

- ⇒ E-UTRAN Absolute Radio Frequency Channel Numbering  
UE Power Classes

- **LTE Channel Concept**

- ⇒ Overview on Channel Types and User Bearers

- ⇒ Mapping of Channels in E-UTRAN

- ⇒ Primary & Secondary Synchronization Signals and PBCH

- Content and Meaning of PSC and SSC, Content and Meaning of the PBCH

⇒ Master Control Channel - PDCCH  
Relationship between PDCCH and PDSCH, RRC's Transmission Mode and PDCCH's DCI, Principle  
Examples for Downlink and Uplink Resource Allocations: DCI-Format 1 / Resource Allocation Type 0

⇒ FDD Time Structure / Frequency Grid  
Downlink OFDM Carpet, Uplink Time-Frequency Grid (FDD)

⇒ Downlink Reference Signals (Pilot) - Common Reference Signals  
RSRP and RSRQ

## ● Important Physical Layer Procedures

⇒ E-UTRAN Cell Search – Blind CP Detection  
Synchronization Sequences and Cell Search in LTE, Secondary Synchronization Signal (SSS) Sequences, Cell Search Performance in LTE, UMTS Cell Search Procedure (Review), UMTS Scrambling Code Groups, Cell Search in GSM

⇒ Random Access Procedure in E-UTRAN  
Contention based and non-contention based random access procedure

⇒ LTE's Timing Advance Control in LTE Connected Mode

⇒ Neighbor Measurements  
LTE Measurements: RSRQ and RSRP, UMTS Measurements CPICH RSCP and Ec/No, UMTS TDD Measurements, CDMA2000 Measurements, GSM RXLEV Measurements from Neighbor Cells

## Topology of evolved Packet System (EPS) and legacy Networks

### ● LTE and System Architecture Evolution (SAE)

⇒ Evolved Packet Core (EPC) in Context

⇒ Full Architecture Overview – Interfaces between all RAT's

⇒ Zoom into the Evolved Packet System (EPS)

### ● Network Layout and Important Identifiers

⇒ Organization of the E-UTRAN  
Tracking Areas

⇒ Identifiers of the UE  
M-TMSI and S-TMSI, GUTI (Globally Unique Temporary UE Identity )

⇒ Storage of EMM Information on USIM

### ● Network Operation Mode's in (E)GPRS and UMTS

⇒ Network Architecture with GERAN, UTRAN and E-UTRAN  
Support for voice services in LTE (SRVCC vs. CSFB)

⇒ LAC+RAC Harmonization in GERAN+UTRAN

⇒ Review of NMO in GERAN (Gs-Interface availability)  
Network Operation Mode I (NOM I), Network Operation Mode II (NOM II), Mobile Station Classes in GERAN

⇒ Dual Transfer Mode (DTM) – Simple Class A UE

⇒ Routing Area Update after LTE/UMTS to 2G Handover  
No DTM Support – Class B Type UE (2G/EGPRS only)

- **Interworking between EPS, GSM/GPRS & UMTS**
    - ⇒ Interworking using legacy Gn-interface
    - ⇒ S3/S4-capable SGSN (Rel. 8 SGSN)
  - **EPS Architecture for Voice Support (CSFB or VoIPIMS with SRVCC)**
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## RRC Signaling in LTE

- **Differences between UMTS RRC and LTE**
  - ⇒ Reduced User Plane Latency in E-UTRAN
  - ⇒ Reduced Control Plane Latency (State Changes) in LTE
  - ⇒ State Characteristics of RRC (E-UTRAN)
    - Characteristics of RRC\_IDLE, Characteristics of RRC\_CONNECTED
  - ⇒ E-UTRAN Signaling Radio Bearers (SRB's)
    - Overview
  - ⇒ E-UTRA States and Inter RAT Mobility Procedures
    - RRC\_IDLE, RRC\_CONNECTED:, Mobility Control in RRC\_IDLE and RRC\_CONNECTED, Mobility in RRC\_IDLE mode, Mobility in RRC\_Connected mode , Connection Reestablishment Procedure, Handover to LTE, Mobility from LTE
- **RRC Messaging**
  - ⇒ End to End Protocol Stack Overview (AS + NAS)
  - ⇒ System Information Broadcasting & Acquisition
  - ⇒ Paging Procedure in E-UTRAN for PS and CS Domain
  - ⇒ Example Message Flows (AS + NAS)
    - RRC Establishment Procedure including Attach and PDN Connectivity Request , Default EPS Bearer Activation on RRC
  - ⇒ Inter RAT RRC Procedures
    - Handover to E-UTRA (incoming HO from other RAT), Mobility from E-UTRA (Outgoing - towards other RAT's), Reception of the MobilityFromEUTRACommand by the UE, Inter-RAT cell change order from GERAN to E-UTRAN
- **Handover in LTE**
  - ⇒ UTRAN and E-UTRAN differences in mobility UTRAN
  - ⇒ Measurements
  - ⇒ Report Configuration of Inter-RAT Neighbors (GERAN/UTRAN)
  - ⇒ Example of E-UTRAN Measurement Control
    - Example for Intra-Frequency Hard HO
  - ⇒ Measurement Events in E-UTRAN
  - ⇒ Event Triggered (Periodical) Reporting
    - Intra Frequency ANR (Automatic Neighbor Reporting), Intra Frequency ANR Definition
- **NAS Message Transfer (EMM, ESM) and SMS**

- **RRC Procedure Delay**

- ⇒ Introduction

- ⇒ Fixed Procedure Delay Values for eNB originated RRC

- Conditionally mandatory Release 9 features

- **Measurement Gaps and Compressed Mode**

- ⇒ Measurement Gaps in LTE

- ⇒ Compressed Mode in UMTS for E-UTRAN Measurements

- **Rel. 8 Access Stratum Feature Handling & Group Indicator -Early UE Handling**

- ⇒ First Part of Feature Group Table

- ⇒ Second Part of Feature Group Table

- Rel. 9 Features supposed to be tested

- ⇒ UMTS Rel. 8 – LTE FGI for Mobility to E-UTRAN

- UMTS - UE Multi-mode/Multi-RAT Capability

- ⇒ Mobility from LTE towards other RAT's & Inter-frequency HO

- **Layer 1 and Layer 2 Drops in LTE**

- ⇒ Layer 1 Drop – Radio Link Failure

- Intra LTE Handover Event A3 – Drop in case of Slow HO, Radio Link Failure – N310 consecutive out of Sync's, Radio Link Monitoring Testing – SNR levels for Qin and Qout

- ⇒ Cell Selection after Drop – Call Re-Establishment

- ⇒ RRC Re-establishment Success or Reject

- Re-Establishment Failure Cases

- **Intra LTE HHO**

- ⇒ X2-based Handover Scenario

- Initial Conditions, Detailed Description, Seamless Handover

- **Security in LTE**

- **CSG - Closed Subscriber Group**

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## EPS NAS & Core Network Procedures

- **The “Mainstream” Protocol Stacks**

- ⇒ Control Plane / E-UTRAN - EPC

- ⇒ User Plane E-UTRAN – EPC (S5/S8 GTP-based)

- **The NAS (Non-Access Stratum)**

- ⇒ EPS Mobility Management (EMM)

- Important EMM-Procedures, NAS security, Possible Combinations of NAS and AS States, Relationship between EMM and ECM

- ⇒ UE Mode of Operation

- **Important EMM-Scenarios**

- ⇒ Attachment through E-UTRAN / new MME  
EMM Combined Attach Request & Accept
- ⇒ Tracking Area Update (Inter-MME / with new S-GW)  
Initial Conditions, Detailed Description
- ⇒ Tracking Area Update (Inter-MME / with new S-GW) (continued)
- ⇒ Tracking Area Update (Inter-MME / with new S-GW) (continued)
- ⇒ ESM Message Format – NSAPI vs. EPS Bearer ID  
Security Header, Procedure Transaction Identity
- **Dedicated EPS Bearer Establishment**
  - ⇒ Network Initiated (IMS triggered during Call Establishment)  
Initial Conditions, Detailed Description of PDN-GW & PCRF interworking
  - ⇒ Example for VoIP-IMS in LTE – S1-MME/UserPlane  
Three EPS Bearers for a Voice Call?
  - ⇒ SIP Signaling for VoIPIMS
- **Bearer Concept & QoS-Architecture in SAE**
  - ⇒ SAE-Bearers, Classification and Policy Enforcement  
Example for Traffic Flow Template (TFT) – QCI 5, Example for Traffic Flow Template (TFT) – QCI 1
  - ⇒ The QoS-Profile of the SAE-Bearer  
AMBR - Aggregate Maximum Bit Rate, QCI-Values and their Meanings, Mapping between Rel. 8 QoS and earlier Releases, QoS Simplification in Rel. 8 compared to Rel. 99

## UE's Idle Mode Behavior and Performance Requirements

- **LTE Idle Mode Procedures – Neighbor Cell Monitoring & Cell Reselection**
  - ⇒ Priority-Based Cell Reselection of Multi-RAT UE's  
RAT Frequency Selection Priority RFSP or Subscribed Profile ID (SPID), Possible Usage of RFSP in the Radio Access Network (RAN), Common and/or Dedicated Priorities from various RAT's, SPID or RFSC, E-UTRAN priority-based Cell Reselection Details, UTRAN priority-based Cell Reselection Details, GERAN priority-based Cell Reselection Details
  - ⇒ Cell Selection in E-UTRAN  
Cell Selection Criterion in Rel. 9 (Cell reselection enhancements), PLMN selection in E-UTRAN, Cell Selection and Reselection in Rel. 8, Cell Selection Process in Rel. 8, Cell Selection Criterion in Rel. 8
  - ⇒ Cell Reselection Evaluation Process in E-UTRAN  
Reselection Priorities Handling, Triggering Measurements, Measurement Rules for Cell Reselection
  - ⇒ Mobility States in E-UTRAN – Tuning Treselection Timer  
Scaling Rules based on Mobility State
  - ⇒ E-UTRAN Inter-Freq and IRAT Cell Reselection Criteria
  - ⇒ Intra-Freq and equal Priority Inter-Freq Reselection Criteria  
Cell Ranking Criterion in E-UTRAN for equal Priority inter-Freq and intra-Freq
  - ⇒ Cell Reselection towards lower Priority E-UTRAN Freq or IRAT Freq than Serving Freq
- **GERAN to E-UTRAN Cell Reselection**

⇒ IRAT Measurements when camping in GSM or GPRS

⇒ IRAT Cell Reselection based on Priority – 2G to 3G / LTE

Cell Reselection Criteria's, Rel. 9 Algorithm for inter-RAT cell re-selection based on priority information, Cell Reselection from GERAN towards higher prioritized IRAT Frequency (Rel. 8), Cell Reselection from GERAN towards lower prioritized IRAT Frequency

- **IRAT Reselection from UMTS to LTE**

Measurement Rules for Cell Reselection , Inter-frequency & Inter-RAT with absolute Priorities, Cell Reselection Criteria, Absolute Priority based Inter-Frequency & Inter-RAT Cell Reselection

- **Constraints of the PLMN and Cell Selection Procedure**

⇒ NAS Aspects of the PLMN and Cell Selection Procedure

⇒ Prioritization of PLMN's

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## PS related Interworking between different RAT's

- **LTE to UMTS IRAT Handover for PS**

⇒ E-UTRAN to UTRAN IRAT Handover Preparation Phase

⇒ E-UTRAN to UTRAN IRAT Handover Execution Phase

- **IRAT Handover from UMTS to LTE**

⇒ Handover Preparation

⇒ Handover Execution – UMTS to LTE HO

UMTS to LTE Transparent Container – HO Command from eNodeB sent to SRNC, Handover to E-UTRA – Incoming HO from other RAT's to LTE

- **Redirection's from E-UTRAN to UTRAN and GERAN**

⇒ Redirection from E-UTRAN to UTRAN

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## CS Interworking Solutions between LTE and legacy 2G/3G

- **Idle Signaling Reduction**

⇒ Paging in GERAN/UTRAN/E-UTRAN w/o ISR and with ISR

⇒ ISR Activation Example

General description of the ISR concept

⇒ Downlink PS Data Transfer with ISR active

⇒ Setting of TIN (Temporary ID for next Update)

- **CS Fallback (use of legacy GERAN/UTRAN for voice)**

⇒ Overview of CS Fallback Solutions

⇒ Mobile Terminating Call when ISR is active and SGs is active between MSC/VLR and MME

⇒ Mobile Terminating call in idle mode (without ISR)



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⇒ Mobile Originating call – No PS HO support  
Mobile Terminated CS Call - Roaming Retry for CS fallback

⇒ SMS Handling in Comparison

⇒ Sending of SMS via SGs-Interface  
Mobile originating SMS in Active Mode

- **SRVCC – Rescue-HO for VoIP-IMS to CS-Domain**

⇒ SRVCC from LTE to GSM (w/o DTM support)

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## Solutions of Practical Exercises