# LTE Training Programs

## Course Outlines

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LTE Network Overview (2 Days)

LTE Network Architecture

- Evolution of cellular networks
- Evolution of 3GPP releases, from release 99 to release 8
- Logical architecture of EPS (E-UTRAN and EPC)
- Overview of the LTE QoS framework

EPC Architecture

- Introduction to Evolved Packet Core (EPC)
- Role of the MME, S-GW and PDN-GW
- Interfaces in EPS
- Introduction to Interface Protocols S1 and X2

E-UTRAN Architecture

- Functionality of the eNodeB
- Radio interface techniques used in uplink and downlink
- Cyclic Prefix
- Link Adaption in LTE
- Basic principles of MIMO
- Reference symbols in UL & DL

LTE Idle Mode and Mobility scenarios

- UE Authentication and Registration Process
- UE Identities in LTE Network
- LTE idle mode mobility
- Different types of handover in LTE
- Measurement reporting procedures in LTE
- Intra and inter Frequency Handover in LTE
- IRAT Handover scenarios

Voice in LTE

- CSFB in LTE
- SRVCC
- IMS Voice Call flow
LTE Air Interface (3 Days)

Day 1

Overview of LTE/SAE

- Expectations of 4G wireless technology
- LTE and SAE Design Goals
- 3GPP Evolution
- Radio Technology Trends
- Core Network Technology Trends
- Components of LTE network
  - Roles of Network entities
- Interfaces
- Comparison with 3G
- LTE advanced basics

LTE-Technology – OFDM, OFDMA, and MIMO Basics

- Need for OFDM
- Basic OFDM terminology
- Time and frequency views of a OFDM signal
- OFDM examples in commercial wireless
- OFDMA and SCFDMA technologies
- Multiple antenna technologies and their impact
- HARQ and its role

Day 2

LTE Downlink Basics

- LTE OFDMA parameters
- Downlink Channels
- Downlink frames and slots and terminology
- Broadcast signals and then properties
- System information and its transmission
- Transmission of control information and user data
- Role of reference signals in channel estimation
- Differences between FDD and TDD versions of LTE

LTE Uplink Basics
• UL frame description  
• Channels in UL  
• Random access in LTE  
• UE identifiers  

Day 3

Network Entry and service establishment

• Network entry process and role of core network components  
• Security aspects in LTE; confidentiality, integrity, and authentication  
• IP address allocation  
• QoS in LTE  
• Bearers  

Data Transmission in DL and UL

• Radio interface architecture and data flow; PDCP, RLS, MAC, and transport blocks  
• Scheduling and conveying allocation information  
• Link adaptation and feedback; modulation and error control coding  
• Bandwidth request  
• MIMO modes in LTE  
• Data rate calculations  
• Retransmissions – HARQ and ARQ  
• End-to-end picture  

Mobility and power save

• Handover in LTE  
• Signalling during handover  
• Idle mode and its benefits  
• RRC states of UE  
• Location Update Procedure (Idle Mode mobility Management  
• Signalling in Idle mode  
• Handover between LTE and 3G
LTE RAN Signaling (2 Days)

LTE Access Stratum and Non Access Stratum – An Overview

- Need for Access Stratum and Non Access Stratum Protocols
- Overview of Access Stratum Functions
- Overview of Non Access Stratum Functions
- Overview of Access and Non Access Stratum Protocols in LTE Network
- End to End to call flow (EPS) in LTE Network
- Control Plane Architecture – End to End View
- User Plane Architecture – End to End View

LTE Bearer – An Overview

- LTE Radio Bearer and EPS Bearer
- LTE Bearer Attributes
- End to End QoS
- Security of Bearer

Non Access stratum Procedures

- Tracking Area in LTE
- Authentication Procedure in LTE
- Mobility Management Procedure in LTE

Layer 3 Signaling

- RRC Layer Functionalities - System Information, Paging, Mobility
- RRC States and the difference between all states
• RRC Layer interaction with other layers
• X2AP signalling protocol Overview and Procedure
• S1AP signalling protocol Overview and Procedure
• GTP-C Protocol Overview

**L2 Protocols - PDCP, RLC, MAC and GTP-U Protocols**

• Functions of PDCP
• Functions of RLC and different RLC Modes
• RLC Data Structure
• MAC Layer Functionality and Architecture
• MAC layer mapping to logical, transport and Physical Channels
• MAC Packet Data Unit (PDU) format
• GTP-U Overview

**Mobility Procedures in LTE**

• LTE Handover in Radio Network
• S1 Handover Overview
• IRAT Handover Procedures and Options – Overview
  o LTE to other 3GPP technologies
  o LTE to CDMA/EVDO
  o LTE to WiFi
• CS Fall Back for Voice Call
LTE Evolved Packet Core – Explained (2 Days)

LTE EPC Overview

- Introduction
- EPC Architecture – Nodes and Functions
- EPC Interfaces and Protocols

EPC Signaling Fundamentals

- EPC Network and UE Identities
- Mobility and Connection Management
- EPC Bearers
- EPC Procedures
  - Attach / Detach
  - Service Request
  - Tracking area update
  - Dedicated Bearer Activation

Security in EPC

- Authentication and Key Agreement
- Authentication Procedure
- LTE Key Hierarchy
- IPSec

QoS Framework in LTE-EPC

- PCC Architecture
- Nodes
  - PCRF
  - PCEF
  - 3GPP AAA

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Dedicated Bearer Activation

- Interfaces
  - Gx
  - Rx
  - Sp
- SDF and SDF Aggregation
- DL and UL Traffic Flow Templates

LTE Mobility

- Intra LTE Mobility
  - X-2 based handovers
  - Intra and Inter MME handovers
  - Intra and Inter S-GW Handovers
  - Tracking Area Updates
- Interworking with other 3GPP networks

VoLTE

- Options for Voice services on LTE
  - CSFB on 3GPP Networks
  - CSFB on 3GPP2 Networks
  - VoLGA
  - SRVCC
- Interacting with other Networks for Voice
LTE EPC Signaling (2 Days)

Introduction
- Overview of 3GPP releases
- Current status of the LTE/EPC standardization work

EPS Network Architecture
- Legacy architecture and bearer concepts
- EPS nodes and interfaces
- Architecture with Gn-SGSNs (e.g. pre-R8 SGSN)
- Node selection functions
- CP and UP bearers and protocol stacks

NAS Protocols (EMM and ESM)
- Mobility management procedures
- Session management procedures
- NAS states and state transitions
- MME/SGW pool areas
- Authentication and Key Agreement
- Security keys and key derivation functions
- NAS message security
- Network Domain Security (NDS)
- NAS message formats

GPRS Tunneling Protocol (GTP)
- GTP interfaces and versions
- The ‘tunnel’ concept
- GTP messages (per interface)

DIAMETER Protocol
• DIAMETER interfaces
• Procedures, commands and AVPs
• Baseline protocol and extension applications
• S6a/S6d procedures and HSS data
• Rx/Gx procedures

Interworking & Roaming
• Idle mode signaling reduction (ISR)
• Inter-RAT PS handover scenarios
• Non-3GPP interworking
• CS Fallback and the SGs-interface
• SR-VCC and the Sv-interface
• Roaming interfaces (S8, S9 etc)

Signaling Flows
• Initial Attach and establishment of default bearer
• Dedicated bearer establishment
• Tracking Area Update with MME relocation
• S1-based handover with SGW relocation
• Inter-RAT handover to S4-SGSN
LTE Radio Network Planning and Design (2 Days)

LTE Radio Technology Overview

- The LTE framing architecture
- Resource Blocks
- The physical layer of LTE
- OFDMA (LTE downlink) and SC-FDMA (LTE uplink)
- Significant Radio Planning Differences from UMTS

RF Fundamentals for LTE Design

- Planning Expectations
- RSRP and RSRQ measurements in LTE
- Noise and Interference
- Thermal Noise Calculations
- LTE receiver’s noise floor based on bandwidth and Noise Figure
- Use of Cascade analysis to determine a system Noise Figure
- Determination system performance based on C/N and C/I+N

Antennas for LTE

- Basic Antenna Types: isotropic and dipole
- Antenna Gain: dBi and dBd
- Antenna diversity techniques
- MIMO
- Adaptive Arrays
- Beamforming
- Antenna Selection for LTE

Performing an LTE Link Budget Analysis

- EIRP (Effective Isotropic Radiated Power)
- MAPL (Maximum Allowable Path Loss)
- Log Normal shadow fade probability for NLOS deployments
- Link budgets, based on manufacturer's equipment parameters and system configuration, to determine the (MAPL)
- Free Space Path Loss for LTE Backhaul
- Building Penetration Losses
- Compare different path loss models based on type, frequency range and operating distance

Frequency Reuse in LTE Networks

www.nanocellnetworks.com
Designing the frequency reuse plan for your LTE network
Fractional Frequency Reuse
Frequency Reuse Options for LTE networks

Timing and Synchronization for LTE Networks

- Timing Needs: Frequency and Synchronization
- FDD and TDD Differences

LTE Performance and Coverage Considerations

- Coverage Planning
- Capacity Planning
- Morphology Classes
- Using a simple model for initial business plan inputs
- Matching cell density with customer demand

RF Propagation Modeling Tools

- The Overall RF design process
- Propagation models
- Databases Required
- Model Outputs
- Coverage prediction
- Radio Base Site selection criteria
- Search Rings
- Site Candidate Information packages
- Model tuning process
- Drive Testing
LTE Radio Network Performance Management and KPI

E-UTRAN Performance Management solution

- Introduction to Initial Tuning and Optimization
- RAN Counters and its significance

Measurement of LTE Accessibility performance

- E-RAB setup procedure and associated counters
- eNodeB counters and its relation with E-RAB Accessibility KPIs
- eNodeB parameters and Features that influence Accessibility

Measurement of LTE Retainability performance

- E-RAB release procedure and associated counters
- eNodeB counters and its relation with E-RAB Retainability KPIs
- eNodeB parameters and Features that influence Retainability

Measurement of LTE Integrity performance

- Counters to measure LTE Radio Bearer LTE throughput
- eNodeB counters to create E-UTRAN Integrity KPIs
- eNodeB parameters and Features that influence Integrity

Measurement of LTE Mobility performance

- Various LTE mobility procedures and associated counters
- eNodeB counters to create E-UTRAN Mobility KPIs
- eNodeB parameters and Features that influence Mobility

Measurement of LTE Cell Availability and Utilization

- Counters to measure LTE Cell Availability
- eNodeB counters for Cell Availability and Utilization KPIs
- eNodeB parameters that influence Cell Availability and Utilization
LTE Advanced (LTE-A) – Explained (2 Days)

Overview of LTE-Advanced

- Expectations of 4G wireless technology
- IMT-Advanced specifications
- 3GPP Evolution
- Key components of LTE advanced (R10 and future)
- UE categories
- Deployment Aspects

Air-interface enhancements

- Carrier Aggregation
  - Intra-band and inter-band aggregation
- Control plane protocols
- Cross carrier scheduling
- User plane protocols
- Acquisition and connection establishment
- Component carrier management
- UL MAC enhancements
- UL transmitter and receiver enhancements

MIMO advances and their impact

- DL MIMO schemes; 8-antenna MIMO and enhanced MU-MIMO
- Enhanced reference signals
- CoMP – principle, challenges, and scenarios

HetNets

- Types of HetNets in LTE-Advanced
- Relay operation with self backhaul
  - Relay protocol architecture
  - Backhaul physical channels and scheduling
• Backhaul HARQ
• Pico eNB / small cells support
  o Enhanced Inter-cell interference coordination (EICIC)
  o Almost blank sub frames (ABS) and their usage
  o X2 interface enhancements for EICIC
  o Interference cancellation methods
• Home eNB
  o Managing interference in Home eNB deployments
  o CSG issues and their management
• Remote radio heads

Data Transmission Aspects

• System acquisition and synchronization signals
• PDCCH changes from LTE to LTE-A
• DL data transmission; reference signals, MIMO modes
• UL data transmission; MIMO modes
• Data rate calculations in DL and UL

Other topics

• Self-organizing networks (SONs) and their role
  o Automatic neighbour discovery
  o Physical cell ID management
  o RACH optimization
  o Minimization of drive testing
  o Energy savings
• Location services in LTE networks
  o ECID, OTDOA, A-GNSS, and other methods
  o LPP and SUPL protocol
  o New elements in EPC
• Release update summary
• Migration from LTE to LTE-Advanced
VoLTE, IMS and SIP – Overview (3 Days)

IMS Evolution

- What is IMS?
- How IMS related to convergence – which convergence?
- How IMS is related to 3GPP Initiative?
- Multimedia over IP – can we discuss those design challenges?
- Are we not doing Multimedia communication already, why then IMS?
- What/whose purpose does IMS serve – SSP, end user, vendor, CSP,…
- Are we bringing IP and Mobile together with IMS, or we doing more?
- What are the big design challenges of IMS?
- What are IMS Objectives and Requirements?

IMS Services

- Presence
- Push To Talk over Cellular
- Multimedia Messaging
- Conferencing
- Group management Services
- On-line real-time games
- Some Service usage scenario

IMS Big Picture

- Internet, PLMN, IMS, PSTN, Enterprise Networks
- PLMN and IMS – why not others?
- PLMN Access Network Entities
- PLMN Domains
- PLMNS Core Network Entities
- PSTN
- Broadband Networks
• Enterprise Networks
• Internet Backbone

IMS and Interfaces
• IMS Entities and IMS Reference Points
• IMS Architecture
• Call Session Control Functions (CSCFs)
• IP Transport
• Application Servers
• Gateways – media and signaling
• Other Related Servers – DNS, AAA servers, LDAP Server, ...

Protocols and their role in IMS
• Signaling – SIP
• Session Description – SDP, XML, ...
• Transport  RTP, RTCP
• QoS – COPS, RSVP, LDAP
• Address Mapping – DNS, ENUM (NAPTR), DHCP
• AAA – Diameter
• Security – IPSec

Some IMS Procedures
• Short Overview of IMS Registration and IMS Session
• Establishing a session when UE#1 and UE#2 need to reserve resources
• Establishing a session when UE#1 needs to reserve resources while UE#2 has resources already available
• Establishing a session when UE#1 need to reserve resources and UE#2 is non-IMS
• Establishing a session when UE#1 is non-IMS and UE#2 needs to reserve resources
• Establishing a session when UE#1 and UE#2 do not need to reserve resources
LTE-U / LAA – Overview (1 Day)

- Why unlicensed bands for service providers
- Wi-Fi, its evolution and its role including Wi-Fi calling
- LTE in unlicensed bands – motivation
- LTE-U Technology
  - Carrier Aggregation in LTE-evolution (A key technology for LTE-U)
  - Bands of operation
  - Coexistence with Wi-Fi; CSAT
  - Some results from various experiments
  - LTE-U forum
  - LTE-U forum requirements
  - Debates around LTE-U
  - Wi-Fi alliance coexistence plans with LTE-U
- 3GPP LAA
  - Differences with LTE-U
  - Status of standardization
  - Bands of operation
  - LAA technical details; LBT protocol
  - Some simulation results analysis
  - LAA coexistence requirements
- 3GPP LWA; LTE-Wi-Fi aggregation
  - Differences from LTE-U and LAA
  - Differences between earlier cellular Wi-Fi approaches
  - Mobile phone side considerations
  - Requirements on the Wi-Fi AP
- Qualcomm MuLTEfire
  - Motivation
  - General idea and challenges
- Conclusions

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VoLTE Implementation and Performance Management (4 Days)

VOLTE Network Readiness Assessment

LTE/IMS Overview

- LTE Network Overview
- LTE Air-interface and QoS Basics
  - ROHC
  - TTI Bundling
  - Semi Persistence Scheduling
  - QCI & Bearer for VoLTE
- IMS network components
  - IMS Network Architecture & Interfaces
  - IMS Nodes Functionality
- VoLTE Basics
  - Types of Call
  - Sample call flow MO/MT

KPIS/KQI/Capacity factors for prelaunch and post launch as VOLTE operator

KPIs for VoLTE

- Accessibility KPI
  - Initial Registration Success Rate of S-CSCF
  - Session Setup Time (Mean)
  - Session Establishment Success Rate
  - Third Party Registration Success Rate
  - Re-registration Success Rate of S-CSCF
  - Session Setup Time Originated from IMS (Mean)
  - Session Setup Time Originated from CS (Mean)
  - Immediate Messaging Success Rate
- Retainability KPI
  - Call Drop Rate of IMS Sessions
- Utilization KPI
  - Mean Session Utilization
- RTP Jitter/Latency/Packet Loss
- Test Case for VoLTE Readiness Check
  - UE Initial Attach with default bearer establishment and IMS SIP registration
  - UE Initiated IMS call setup(LTE to LTE)
  - UE Initiated IMS call termination(LTE to LTE)
  - IMS Voice Session Establishment (between LTE UE in Home N/W & LTE UE in Visited N/W)
  - Communication Barring of All Incoming Calls
  - Communication Barring of All Outgoing Calls
- Barring of Incoming Calls – When Roaming
- Communication Hold

**Capacity Assessment and Optimization**

- Number of UEs with Voice Services
- Number of PRBs Used by Voice Services

**Assess operator’s readiness for VOLTE (MOS/JITTER/BLER Measurement techniques)**

- MOS measurement for VoLTE
- Jitter requirement for VoLTE
- BLER requirements for VoLTE

**VOLTE Troubleshooting**

- VOLTE Call Flow for different Scenarios with PCAP Trace (S1-U/S1-C/S11/S6a/Gx/Rx/Gm/Cx/Mw/Mg/ISC)
  - SIP REGISTER Flow
  - LTE to LTE Call Flow (MO/MT) Analysis
  - LTE to PSTN Call Flow Analysis
  - LTE to UMTS Call Flow Analysis
- Voice quality improvement (includes One way audio, low MOS, SIP 481 and RTP Timeout failures)
  - Speech Quality Impacted by Codec
  - Voice Quality (e.g. POLQA algorithms, for wideband or narrowband codecs)
  - Packet Loss & Delay Drive QoE for VoLTE
  - SIP Timers
  - RTP Timeout Issue
IoT Wireless - Cat M0/eMTC/NB-IoT - Explained (2 Days)

Introduction

- What is IOT/IOE?
- Components of a typical IOT system
- Wireless Standards relevant to IOT/IOE; BT, BLE, Wi-Fi, 802.15.4, cellular
- Non-standard WAN technologies for IOT; LORa, Sigfox, weightless
- Frequency bands and ranges relevant for IOT

IOT and Cellular

- Release 12 LTE MTC evolution
- Cat 0 radio parameters; bandwidths, data rates, duplexing, antenna requirements, modulation types supported
- Power saving mode (PSM) for Cat 0
- Impact on power consumption and complexity
- Rel 13 IOT choices in LTE; eMTC and NB-IOT
- eMTC details; bandwidth of operation, data rates support
- Coverage enhancement techniques; repetition, modulation
- Channels; traffic and control; MPDCCH
- HARQ handling
- eDRX
- NB-IOT; what is it and how is it related to LTE?
- NB-IOT deployment modes; coexistence with LTE carrier
- NB-IOT control and data channels; NBPDSCH, NBPDCCH
- Subcarrier spacing possibilities for different channels and transmissions
- NB-IOT System information
- EC-GSM; GSM enhancement for IOT