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 Plan 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
    - LTE to other 3GPP technologies
    - LTE to CDMA/EVDO
    - 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

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

- 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
    - Enhanced Inter-cell interference coordination (EICIC)
    - Almost blank sub frames (ABS) and their usage
    - X2 interface enhancements for EICIC
    - Interference cancellation methods
- Home eNB
    - Managing interference in Home eNB deployments
    - 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
    - Automatic neighbour discovery
    - Physical cell ID management
    - RACH optimization
    - Minimization of drive testing
    - Energy savings
- Location services in LTE networks
    - ECID,OTDOA, A-GNSS, and other methods
    - LPP and SUPL protocol
    - 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), DCHP
- 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

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