v 3.210

LTE from A-Z - Reloaded

Course Duration:

- 2 days.

Course Description:

- This course addresses the needs of everybody who needs to understand the technology and concepts of LTE as the future 4G standard of 3GPP.
- After the general introduction to 4G standards is given, the course starts with an introduction of the requirements of LTE, as well it provides insight to the most relevant changes to L1/L2/L3 and the network architecture of E-UTRAN compared to UMTS, HSDPA, and HSUPA.
- This part ends with an overview of the basic technology trends visible in LTE.
- The following part presents important characteristics of the key layer 1 technologies: OFDM and MIMO.
- The course continues with a detailed description of the LTE L1. Among others we evaluate in detail the application of essential technologies like OFDMA for the downlink and SC-FDMA for the uplink in LTE as well as the LTE frame structure.
- This part concludes with the discussion of the physical layer procedures like power control (PC), timing advance control, cell search, random access, and the used antenna technology.
- The next chapter evaluates in detail the higher layer protocols of E-UTRAN such as MAC (Medium Access Control), RLC (Radio Link Control), RRC (Radio Resource Control), PDCP (Packet Data Convergence Protocol) as well as security and quality of service in LTE.
- This part includes the discussion of NAS (Non- Access Stratum) procedures such as mobility management and the various kinds of handover to be supported by LTE.
- The final chapter is presenting selected E-UTRAN scenarios which should give the participants an understanding how the protocols of LTE work together across the different network elements. We are focusing on RRC connection establishment, PDP context establishment, sell reselection, and handover scenarios. Finally the journey of a TCP MTU through the protocol layers is described in detail.
- After that an optional chapter is focusing on LTE-TDD.
- As in all our courses, we integrated several interactive exercises for a perfect learning experience.

Prerequisites:

- The student should possess detailed knowledge of wireless communications, particularly within the area of digital signal processing in wireless communications.
- This experience should stem from hands-on work in the area of design, integration, test or troubleshooting of GSM, CDMA or WCDMA-equipment.
- Comprehension of different digital modulation schemes like QAM or PSK and of different multiple access schemes like TDMA, FDMA and CDMA is required.

Course Target:

- The student will obtain detailed understanding of the LTE / E-UTRAN standard and the related procedures and network operation and architectures.
- The student is enabled to access the LTE technology with regard to deployment issues.
- After the course the student will be enabled to design, test and operate LTE networks and UE's.

Some of your Questions that will be answered:

- What is LTE and why it is introduced in the first place?
- What are the requirements for LTE and how do they differentiate from those of UMTS?
- What are the key characteristics of LTE's (E-UTRAN's) layer 1 and layer 2/3?
- How does the LTE and SAE (System Architecture Evolution) evolved mobile radio network look like?
- What key development trends are manifested in LTE?
- How do the basic physical layer technologies of LTE like OFDM and MIMO work?
- How the physical frame structure is facilitating the use of a flexible bandwidth allocation?
- How do the digital signal processing chains of uplink and downlink look like and what is their difference with respect to conventional mobile radio systems?
- How the physical layer procedures work in LTE?
- How the throughput of the UE categories can be calculated?
- What are the tasks of the higher layer protocol entities and functions of the enhanced node B: MAC, RLC, PDCP, and RRC?
- What are the used concepts for mobility in LTE?
- How does LTE manage the most relevant scenarios like initial context setup, PDP context establishment and hand over?

- How in detail the TCP packets travel through the protocol layers?
- What is the difference in-between LTE-FDD and LTE TDD?

Who should attend this Course:

- Everybody who needs to design Long Term Evolution capable UE's and network equipment.
- Operators who need a detailed understanding of Long Term Evolution.
- Test engineers who need to integrate Long Term Evolution equipment and UE's.

Table of Content:

Principles and Motivation of LTE

BCCH, PCCH, CCCH, MCCH, DCCH, DTCH, MTCH

⇒ Introducing Transport Channels of E-UTRAN
RACH, UL-SCH, BCH, PCH, MCH, DL-SCH

⇒ Physical Channels of E-UTRAN
PBCH, PDCCH, PCFICH, PUCCH, PRACH, PHICH, PDSCH, PMCH, PUSCH, Downlink Reference Signal, Primary- and Secondary- Synchronization Signal, Uplink Reference Signal , Uplink Sounding Reference Signal (SRS), Random Access Preamble

⇒ Mapping of Channels in E-UTRAN

- **Conclusion**

⇒ All IP Network

⇒ Latency
User Plane Latency, Reduced Control Plane Latency

- **LTE Key Feature Summary**
Air Interface Technology, System Architecture, Service Aspects

The LTE Physical Layer

- **Frequencies in LTE**

⇒ Frequency Bands
Frequency Allocation

⇒ ITU-R Regions
The ITU-R, LTE Deployments

⇒ Frequency Allocation Example (Germany)
Auction 2010, Digital Dividend, Time Division LTE (TD-LTE)

⇒ Flexible Bandwidths, Parameters
Fixed Subcarrier Separation, PBCH and Synchronization Signals, Deployment Scenarios, Carrier Aggregation (Release 10), Measurement Consequences of Flexible Bandwidth

- **Physical Basics of the Multipath Dimension**

⇒ Signal Fading and Alteration between Tx and Rx
Scattering, Refraction, Reflection, Diffraction, Consequences for the different Signal Paths, Macro-Diversity vs Micro-Diversity, Increased Performance, Single User- vs Multi User-MIMO

⇒ STBC and SFBC
SFBC in LTE

⇒ Transmit Beamforming

⇒ Smart Antenna Techniques in LTE
Overview, Receive Diversity, SFBC, SU-MIMO, MU-MIMO, Transmit Beamforming, Processing Chain and Terminology, The Term: "Codeword", The Term: "Layer", The Term: "Precoding", The Term: "Antenna Port", Antenna Port vs Antenna

- **Introduction to OFDM/OFDMA Technology**

⇒ Impact of Orthogonality in the Frequency Domain – 3 Steps

⇒ Practical Exercise: Physical Basics of OFDM / OFDMA

⇒ OFDM / OFDMA and IFFT
Considering the Discrete Oscillator Array Option, Details of the IFFT Option, Why is it called F a s t Fourier Transformation?

⇒ Modulation Scheme Overview

⇒ Tackling Inter-Symbol Interference (ISI)
Introduction, Delay Spread, Cyclic Prefix, Variable Duration and other Assets of the Cyclic Prefix, Cyclic Prefix in OFDMA in LTE

⇒ From generic OFDM/OFDMA to the LTE-Implementation
The OFDM-"Brickwall", OFDM versus OFDMA, Remarks on the Brick Wall Image, Subchannelization , Pilot Subcarriers, Null Subcarriers, OFDM versus OFDMA continued, Time / Frequency View on OFDM: The "Grid", Subcarrier Spacing in LTE, Transmission Bandwidth in LTE, Frames, Subframes and Slots, Cyclic Prefix Options in LTE, Definition of Slot, Subframe and Radio Frame, Resource Blocks and TTI in LTE, Virtual vs Physical Resource Blocks, System Bandwidth and Resource Blocks, Number of RB's, FFT-Size and Bandwidth

⇒ UL Modualtion
Why SC-FDMA?, PAPR of Single-Carrier vs. Multi-Carrier Systems

⇒ Introducing CAZAC-Sequences
Reviewing Autocorrelation Properties, Zadoff-Chu Sequence Generation

- **UE Categories**
  Release 10 Categories, UE Power Classes

Physical Layer Details

- **Mapping Channels to the OFDMA-Grid**

⇒ Problem Description
Important Constraints for Permutation Rules

⇒ Mapping of Downlink Channels and Signals
Primary & Secondary Synchronization Signals and PBCH, Content and Meaning of PSS and SSS, Content and Meaning of the PBCH, Downlink Reference Signals, PCFICH, PHICH, PDCCH, Relationship between PDCCH and PDSCH, Range of DCI formats and possible RNTI's, Transmission Mode and DCI, Example for Downlink Resource Allocation, Relationship between PDCCH and PUSCH, Example for Uplink Resource Allocation:
DCI-Format 0 / Resource Allocation Type 2, FDD Frequency Grid in downlink, Reference Signals - Pilot RE's, Synchronization Signals

⇒ Mapping of Uplink Channels and Signals
Time-Frequency Grid for SC-FDMA, PUCCH, PUCCH Format 1, 1a and 1b, PUCCH Format 2, 2a and 2b, PUSCH

- **Important Physical Layer Procedures**
  Cell Search with Basic NAS and AS Procedure's

⇒ Random Access
PRACH Structure Format 0, Random Access Procedure

⇒ Timing Advance Control
Principle, Procedure, TA while the UE is not synchronized to the eNB, TA while the UE is synchronized to the eNB

⇒ Power Control Principle (PUSCH)

The Higher Layers of E-UTRAN

- **Features of MAC**

  ⇒ Overview
  Data Transfer , Radio Resource Allocation, Special procedures

  ⇒ MAC Random Access Procedure
  Contention based random access procedure, Non-contention based random access procedure

  ⇒ Structure of MAC-PDU
  MAC Control Element, Normal (non-transparent) MAC SDU, Transparent MAC SDU

  ⇒ MAC Control Elements
  Contention resolution ID, Timing Advance, DRX, Padding, Power Headroom Report (PHR), C-RNTI, Short, long and truncated buffer status reports

  ⇒ HARQ
  DL HARQ, Scheduling of first transmission, NACK first transmission, Scheduling of second transmission, ACK of second transmission, UL HARQ, Scheduling of first transmission, NACK first transmission, Scheduling of second transmission, ACK of second transmission

- **Features of RLC**

  ⇒ Overview
  Data transfer, Error detection and recovery, Reset

  ⇒ Structure of RLC PDU

  ⇒ Structure of RLC AM with PDCP PDU Segments

- **Features of PDCP**

  ⇒ Overview
  RoHC, Numbering of PDCP PDU's, In-sequence Delivery of PDU's, Duplicate deletion, Encryption, Integrity Protection

  ⇒ Structure of PDCP PDU

- **Features of RRC**

  ⇒ Overview
  Transmission of broadcast information, Establish and maintain services, QoS control, Transfer of dedicated control information

  ⇒ State Characteristics of RRC
  RRC_IDLE, RRC_CONNECTED, System Information

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

  ⇒ EPS Mobility Management (EMM)
  Important EMM-Procedures, Common Procedures, Specific Procedures, Connection Management Procedures, State Machine, Relationship between EMM and ECM

  ⇒ EPS Session Management (ESM)
  Important ESM-Procedures, MME-initiated, UE-initiated, State Machine

- **Bearer Concept & QoS-Architecture in SAE**

  ⇒ SAE-Bearers, Classification and Policy Enforcement
  Default Bearer, Dedicated Bearer

  ⇒ The QoS-Profile of the SAE-Bearer
  GBR - Guaranteed Bit Rate, MBR - Maximum Bit Rate, AMBR - Aggregate Maximum Bit Rate, ARP - Allocation Retention Priority, QCI-Values and their Meanings, Mapping between Rel. 8 QoS and earlier Releases, Non specified QCI Values

- **Security in LTE**

Selected E-UTRAN Scenarios

- **Important EMM-Scenarios**

  ⇒ Attachment through E-UTRAN / new MME

  ⇒ Tracking Area Update (Inter-MME / with new S-GW)
  Initial Conditions, Detailed Description

  ⇒ The Mobile's Way to SIP Registration and SIP-Sessions

- **Dedicated EPS Bearer Establishment**

  ⇒ Network Initiated (IMS triggered during Call Establishment)
  Initial Conditions, Detailed Description, Detailed Description

- **X2-based Handover Scenario**
  Initial Conditions, Detailed Description

- **S1-based Handover Scenario**
  Initial Conditions, Detailed Description

Voice in LTE

- **Introduction**

  ⇒ VoLTE and Alternatives
  CSFB, VoLGA, SVLTE, Over The Top (OTT), IMS based VoLTE, SRVCC

  ⇒ The Voice Evolution
  LTE for data only, VoLTE, Extending VoIP to other RATs

  ⇒ Rich Communication Suite (RCS)
  RCS and RCS-e, Embedded or downloadable Client, Joyn

- **Circuit Switched Fallback (CSFB)**

  ⇒ The SGs Interface
  The Principle of CSFB, Interfaces and Protocols

  ⇒ Procedures
  The Principle of CSFB, Periodic LA Updates