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The IP Multimedia Subsystem (IMS)
Architecture Details & System Engineering

Course Duration:

3 Days

Course Description:

▶ This course addresses the needs of engineers and technicians who need to understand the very details of the IMS architecture and its interworking with other networks and network entities.

▶ The course starts with the definition of the IMS as part of an overall NGN architecture and the description of IMS variations depending on operator type (e.g. fixed telecom, mobile operator, joint operation).

▶ One chapter is providing an overview of the various protocols that are used within the IMS environment like SIP/SDP and DIAMETER.

▶ The student is confronted with various practice-oriented questions and exercises to gain the maximum output from the course.

▶ Focus of the course is the extremely detailed analysis of the tasks, functions and operation of the IMS-internal network elements, namely of the different CSCF's, the MGCF or the MRF.

▶ This part also discusses the various implementation options like split- and centralized architecture and lines out their pros and cons.

▶ Another major of the course is the consideration of the various security threats and issues that an IMS may be suffering from but we also present potential solution strategies to securely address these issues.

▶ One chapter is dedicated to 3GPP-based mobile networks and the related SIP- and SDP-specifics. In this chapter we also cover the DIAMETER-Protocol and its use within 3GPP-networks.

▶ Note that this course represents the architectural and network view of the IMS. A more protocol related course about the IMS is also available.

As in all INACON courses we integrated several interactive exercises for a perfect learning experience.

Pre-Requisites:

▶ The student needs to have a solid background of the IP-protocol stack.

▶ Previous practical exposure to the design, setup and configuration or operation of SIP-servers or NGN-equipment is favorable.

▶ The student also needs practical experience with fixed or mobile telecom networks.

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Course Target:

▸ After the course the student will have a clear understanding of all architecture and network related details of the IMS.

▸ The student can address all typical questions and issues related to the design, engineering, dimensioning and operation of IMS-enabled networks.

Some of your questions that will be answered:

▸ What is the difference between stateful and stateless SIP-proxies, B2BUA's and SBC's?

▸ Can I use private IP-addresses and NAT within the IMS-environment?

▸ Which identifiers can be used to identify our users?

▸ How can we allow our users to securely roam to any IP-CAN and still access our IMS?

▸ How can we protect our IMS from the typical security risks like DoS- or masquerade attacks, spoofing and fraud?

▸ What are differences among the different IMS-versions like TISPAN and 3GPP?

▸ Under what circumstances is the implementation of the IMS in split or centralized architecture recommended?

▸ How can we realize functions like legal interception and IMS based charging?

Who should attend this class?

▸ Engineers, technicians and IP-professionals who are involved in the design and engineering of IMS-networks.

▸ Everybody who requires detailed knowledge about the IMS.

Table of Contents:

Principles and Motivation of LTE

- **Mobile Radio: Comparison between 3G and 4G**

  ⇒ Performance and Mobility Management related Issues

  ⇒ Architecture related Issues

  ⇒ Procedure and Radio related Issues

- **Kicking off LTE**

  ⇒ Situation for UMTS before the Start of LTE Investigations
  UMTS, HSDPA, HSUPA, CDMA2000 EV-DO Rev. B, DSL and WiFi, HSPA+

  ⇒ Competition for 4G Market
  WiBro and WIMAX, HiperMAN, iBurst, UMB

- **Requirements on LTE**

  ⇒ General Requirements
  Support of Enhanced Quadruple Play Services, Very High Data Rates @ flexible
  bandwidth deployment ((1.25) 5 – 20 MHz), AIPN and PS services only

  ⇒ Important Characteristics of LTE Physical Layer
  General Physical Layer Characteristics (OFDM , Scalable Bandwidth, Smart Antenna
  Technology, Fast scheduling and AMC, No Soft(er) handover), OFDM/OFDMA
  (Traditional narrowband communication, Problems for wideband signals, OFDM, OFDM
  and OFDMA, LTE and OFDM), Smart Antenna Technology in LTE (Categorization of
  Smart Antenna Technologies, Multiple Input Multiple Output (MIMO), Adaptive Antenna
  Systems (AAS)), Macro Diversity exploitation by SFN (Requirements for MBMS services,
  MBMS operation with a SFN, SFN for point to point services), The Frequency Bands
  Intended for LTE (Exclusive usage, Refarming, Licensed operation, Unlicensed
  operation), Flexible Bandwidths, Parameters (Fixed subcarrier separation, Usage of
  carriers in the middle of the bandwidth for BCH and SCH, Deployment Scenarios)

  ⇒ Important Characteristics of the LTE Layer 2 and 3
  Support of the new LTE L1, Simple IP centric protocols supporting AIPN, Support of
  various inter RAT handovers (GSM, UTRA, etc.)

- **The E-UTRAN Protocol Stack**

  ⇒ Control Plane Protocol Stack
  Air Interface protocols

  ⇒ User Plane Protocol Stack
  Air Interface protocols, S1 protocol

  ⇒ X2 Interface Control Plane Protocol Stack

  ⇒ X2 User Plane Protocol Stack

- **LTE and System Architecture Evolution (SAE)**

  ⇒ Overview
  Missing RNC, Interconnected eNB's, Separate entities for user plane and control plane in the EPC, Combined Serving Gateway and MME, Combined Serving and PDN Gateways, S1-flex, Used legacy elements, Roaming case

  ⇒ The eNB
  Selection of MME at attachment, Scheduling of paging messages, Routing of user plane data to SAE GW, PDCP, RRM/RRC, RLC, MAC, Complete L1 functionality

  ⇒ The MME
  NAS signaling, Inter CN node signaling (3GPP networks), Security management

  ⇒ The Serving GW
  Termination of U-plane packets for paging reasons, Support of UE mobility anchoring by switching U-plane during inter eNB handover, Mobility anchoring for inter-3GPP mobility, Lawful interception

  ⇒ The PDN GW
  Termination towards of PDN's, Policy enforcement, Charging support

  ⇒ Identifiers of the UE and the Network Elements
  PLMN ID, EPS Bearer ID, eNB/cell ID, TAI, C-RNTI, RA-RNTI, Random Value, IMSI, S-TMSI, and IMEI

- **Overview Channels of E-UTRAN**

  ⇒ Channel Types
  Logical Channels, Transport Channels, Physical Channels

  ⇒ Logical Channels of E-UTRAN
  BCCH, PCCH, CCCH, MCCH, DCCH, DTCH, MTCH

  ⇒ 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 or UL pilot symbol, Random Access Preamble

  ⇒ Mapping of Channels in E-UTRAN

- **History and Future of LTE Standardization**

  $\Rightarrow$ Past Work in 3GPP

  $\Rightarrow$ Working plan in 3GPP

- **Key development Trends manifested in LTE**

  $\Rightarrow$ Mapping of User Plane Packets to the Resources
  Method 1: Fast resource allocation on optimum resources, Method 2: Slow resource allocation on suboptimum resources, GSM, WCDMA, HSPA, LTE, General trend

  $\Rightarrow$ All IP Network and Simple Packet Service Driven Protocols
  Reduced User Plane Latency, Reduced Control Plane Latency

- **LTE Key Feature Summary**

  $\Rightarrow$ Air Interface Technology

  $\Rightarrow$ System Architecture

  $\Rightarrow$ Service Aspects

Key Technologies of the LTE Physical Layer

- **Introduction OFDM Technology**

  $\Rightarrow$ Impact of Orthogonality in the Frequency Domain – 3 Steps

  $\Rightarrow$ Practical Exercise: Physical Basics of OFDM / OFDMA

  $\Rightarrow$ Practical Exercise: Scaling of OFDM / OFDMA-Systems

  $\Rightarrow$ The In-Phase – Quadrature (I/Q) Presentation

  $\Rightarrow$ 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?

  $\Rightarrow$ Modulation Scheme Overview

  $\Rightarrow$ Using different Modulation Schemes on Different Subcarriers

  $\Rightarrow$ 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)

  $\Rightarrow$ Layout of a Typical OFDM System
  Remarks on the Brick Wall Image, Subchannelization , Pilot Subcarriers, Null Subcarriers

- **Introduction to MIMO Technology**

  ⇒ The Basics: Signal Fading Physics between TX and RX

  ⇒ Multiplexing Dimensions

  ⇒ The Multipath Dimension

  ⇒ Traditional Antenna Diversity Methods
  Traditional TX diversity, Traditional RX diversity

  ⇒ Categorization of Smart Antenna Technology
  Categorization of Smart Antenna Transmitters, Categorization of Smart Antenna Receivers

  ⇒ MIMO General Operation

- **Review of HARQ Technology**

  ⇒ Hybrid ARQ Techniques – Link Adaptation
  Type I Hybrid ARQ – Low UE Complexity, Type II Hybrid ARQ – High UE Complexity, Type III Hybrid ARQ – Medium UE Complexity

  ⇒ Turbo Coding – Systematic Bits, self decodable and non-self-decodable transmission (optional)
  Example Full IR, Example Partial IR, Example Chase Combining

- **Review of AMC technology**

  ⇒ Benefits of AMC
  Higher Throughput, Reduced Interference, Utilization of Short Term Fading

  ⇒ Adaptive Modulation and Coding – Principle
  AMC Scheduling Function, Layer 1 Processing Chain

The Physical Layer of E-UTRAN

- **The Use of OFDM/OFDMA in LTE**

  ⇒ Frame Structure
  The generic frame structure, The downlink slots, The uplink slots, The frame structure type 2

  ⇒ LTE Parameters
  The normal configuration, The extended configuration with 15 kHz subcarrier separation, The extended configuration with 7.5 kHz subcarrier separation

  ⇒ Resource Element and Resource Block Definition Downlink
  Definition Resource Element, Definition Resource Block, Definition Subframe

  ⇒ Choice of the UL Transmission Scheme
  What would happen if OFDM would be used in the UL, SC-FDMA is used for the UL

  ⇒ Resource Definition Uplink (PUSCH)

  ⇒ Frequency Hopping and other Details of the Uplink Signal Generation
  Input signal in the digital time domain, Transformation in the digital frequency domain, Interpolation in the baseband time domain, Addition of the cyclic prefix, Frequency hopping and avoidance of the DC carrier, Advantage of the SC-FDMA scheme

  ⇒ FDD and TDD Operation in E-UTRAN
  Reciprocity (Reciprocity of the mobile radio channel, Speed of scheduling decisions), UL / DL Asymmetry and Others (UL/DL symmetry, Interference scenarios, TRX architecture, Deployment in a given frequency band)

- **The DL Physical Channels and their Frame Structures**

  ⇒ PBCH
  Split of the BCH on the PBCH and the PDSCH

  ⇒ PCFICH and PDCCH
  Functions relating to DL transmission, Functions relating to UL transmission

  ⇒ The Downlink Processing Chain
  Transport block bits, Scrambling, Modulator, Layer Mapper, Precoding, OFDM signal generation, CP and IFFT

- **The UL Physical Channels and their Frame Structures**

  ⇒ Overview PUCCH

  ⇒ PUCCH mapping for ACK/NACK only

  ⇒ PUCCH mapping of CQI and other information

  ⇒ The Uplink Processing Chain
  Transport block bits, Scrambling, Modulator, DFT pre-coder, Resource element mapper, IFFT, CP

- **Overview all Physical Channels**

  ⇒ Special usage of the 6 RB around the DC carrier

  ⇒ Multiplexing of the PCFICH, PDCCH and the PDSCH/PMCH in the normal DL subframe.

  ⇒ Sounding reference signal

  ⇒ Modulation of the physical channels

  ⇒ Channel Coding

- **Physical Layer Procedures**

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

  ⇒ Single Frequency Network
  Review delay diversity, Marco diversity exploitation by SFN, SFN and MBMS, Practical Exercise: The Basics of MBSFN Physical Layer

  ⇒ Channel Estimation
  Channel Estimation Principle of LTE (The description of the mobile radio channel, Coping with a frequency selective mobile radio channel, Coping with the time variance of the mobile radio channel), Channel Estimation Downlink (Normal configuration with 4 TX antennas, Normal configuration with less than 4 TX antennas, Extended configuration with 15 kHz subcarrier spacing, Extended configuration with 15 kHz subcarrier spacing for MBSFN, Extended configuration with 7.5 kHz subcarrier spacing for MBSFN), Channel Estimation Uplink, Mathematics of Channel Estimation , Practical Exercise: The Basics of Pilot Symbol Dimensioning

  ⇒ Power Control
  Principle, Other Power Control

  ⇒ Antenna Processing
  Signalling and Processing Chain (Decision to perform MIMO and other smart antenna technologies, Layer mapper, Spatial multiplexing and code book, Cyclic Delay Diversity, OFDM signal generation, Preparation of the equalizer, Equalizer), The Transmission Diversity Problem (Receive diversity, Unsuccessful transmit diversity), AAS (Practical Exercise: Draw the Antenna Diagram of AAS), CDD (Delay diversity, Cyclic delay diversity), SFBC (Space Frequency Block Codes, Space Time Block Codes), MIMO (MIMO and AAS combined = multiple rank beamforming, When MIMO fails), The Codebook (Optimum beamforming weights, Signaling of sub-optimum beamforming weights)

  ⇒ Initial Cell Search
  Primary and Secondary Synchronization Signals, Procedure

  ⇒ Random Access
  PRACH Structure, Usage of the PRACH Preambles in LTE, Detection Effort of the PRACH Preambles in LTE, Random Access Procedure

$\Rightarrow$ Inter Cell Interference Mitigation
Traditional frequency reuse in LTE (Frequency reuse bigger than 1, Frequency reuse 1 with low initial load, Frequency reuse 1 strongly increased load, Frequency reuse 1 after "the party"), Fractional Frequency Reuse with Intercell Interference Coordination.

$\Rightarrow$ Measurement Procedures
UE Measurements (GERAN inter RAT measurements, UTRAN inter RAT measurements, E-UTRAN measurements), eNB Measurements (Agreed measurements, Measurements in discussion)

- **UE Classes**

  $\Rightarrow$ Overview
  Release 8 UE classes, Release 9 UE classes

  $\Rightarrow$ Calculation of the DL Peak Throughput for LTE UE Class 2

The Higher Layers of E-UTRAN

- **Overview**

  $\Rightarrow$ E-UTRAN Architecture Control Plane

  $\Rightarrow$ E-UTRAN Architecture User Plane

- **Features of MAC**

  $\Rightarrow$ Overview

  $\Rightarrow$ Data transfer logical channels ((transport channels

  $\Rightarrow$ Radio resource allocation

  $\Rightarrow$ MAC Random Access Procedure
  Contention based random access procedure, Non-contention based random access procedure

  $\Rightarrow$ HARQ in LTE

  $\Rightarrow$ Practical Exercise: The Basics of HARQ Protocols

  $\Rightarrow$ Structure of MAC-PDU

- **Features of RLC**

  $\Rightarrow$ Overview
  Data transfer, Error detection and recovery, Reset

  $\Rightarrow$ Structure of RLC PDU

  $\Rightarrow$ Structure of RLC AM PDCP PDU Segments

- **Features of PDCP**

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

  ⇒ 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
  No RRC state, RRC_IDLE, RRC_CONNECTED, RRC_MBMS_CONNECTED

- **Tasks of RRM**

  ⇒ Overview
  Radio Bearer Control (RBC), Connection Mobility Control (CMC), Inter-RAT RRM, Dynamic Resource Allocation (DRA) - Packet Scheduling (PS), Radio Admission Control (RAC), Inter-Cell Interference Coordination (ICIC), Load Balancing (LB)

- **NAS Protocol States and Transitions**

  ⇒ LTE_DETACHED

  ⇒ LTE_IDLE

  ⇒ LTE_ACTIVE

- **Mobility**

  ⇒ Mobility Management in the LTE_DETACHED State

  ⇒ Mobility Management in the LTE_IDLE State

  ⇒ Mobility Management in the LTE_ACTIVE State

  ⇒ Inter RAT Mobility Management
  Cell Reselection (LTE_IDLE), Handover (LTE_ACTIVE)

- **MBMS**

  ⇒ Operation

  ⇒ Protocol issues

- **QoS in LTE**
  - ⇒ Bearer Architecture
  - ⇒ QoS Parameters
    ARP, Label, GBR, MBR, AMBR
  - ⇒ QoS Classes Identifier
- **Security in LTE**

Selected E-UTRAN Scenarios

- **Initial Context Setup Procedure**
- **(Re)Attachment**
- **Tracking Area Update**
  - ⇒ Inter MME tracking area update
  - ⇒ Intra MME tracking area update
- **PDP Context Establishment**
- **Intra MME Handover**
  - ⇒ Practical Exercise: Intra eNB Handover
- **Inter MME Handover**
- **Inter RAT Handover**
  - ⇒ Common to all solutions
  - ⇒ Non-IP solution with separate intersystem mobility anchor
  - ⇒ Non-IP solution with intersystem mobility anchor inside Serving GW
  - ⇒ MIP solution with separate intersystem mobility anchor
  - ⇒ PMIP solution with separate intersystem mobility anchor
- **How a TCP MTU is reaching the UE**