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NB-IoT
Design Details & System Engineering

Course Duration:

- 2 days

Course Description:

- This course addresses the needs of technical engineering staff who require deep inside knowledge of the PHY, RF and also upper layers and applications of the NB-IoT technology.
- The course has been designed to meet the requirements of chipset verification, integration and testing staff.
- It is also targeted at technical engineering staff who are supposed to select the optimum IoT-technology for a given application.
- The course starts out with a technical introduction of NB-IoT and depicts the IoT-playground as such with respect to applications and potential QoS-parameterization of an IoT-technology.
- Important alternatives and competing technologies are introduced, namely LoRa, SigFox and the 3GPP-technologies CAT-M1 and EC-EGPRS.
- The next chapter is dedicated to a deep dive into the PHY- and RF-layers of NB-IoT.
- We clarify which coverage to expect from an LTE-cell and by which means NB-IoT achieves a larger and deeper coverage.
- We also clarify how eDRX and PSM operate and how they differ from each other.
- Next we explain in detail the operation of the new channels like the NDPSCH or NPUSCH and the NB-IoT specific random access procedure and system information delivery.
- Another focus in on channel coding in NB-IoT and ARQ/HARQ.
- The next chapter is dedicated to the upper layers and the detailed operation of NB-IoT and we elaborate on the differences between legacy LTE/LTE-A protocols on one hand and the related protocols in NB-IoT on the other hand.
- Two other highlights of this chapter are the optimizations that 3GPP introduced for CIoT in both the user plane and the control plane plus the description as to when and how data can be delivered through the control plane..
- The final chapter may be the target of many students as we conduct a performance analysis of NB-IoT in terms of energy consumption, throughput etc. under different conditions and for different use cases.

Prerequisites:

- The student must possess detailed knowledge about the PHY in LTE, especially on the OFDMA-grid and its layout!
- Detailed knowledge of general RF-issues like link budget, receiver sensitivity is strongly recommended!

Some of your questions that will be answered:

- How can NB-IoT provide for the impressive coverage enhancements compared to legacy LTE?
- Why are there 3 different uplink implementations in NB-IoT? Single-tone 3.75 kHz and 15 kHz and multi-tone 15 kHz?
- On which bands does NB-IoT operate?
- How does the OFDMA-grid look like with NB-IoT? Where are the NPDCCH etc. located?
- Why does NB-IoT deploy so-called blind repetitions and what are the implications of using them in terms of throughput rate and latency?
- What are typical battery life times of NB-IoT under different conditions? How to calculate them?
- How can short messages be delivered to NB-IoT UE's without telephone number?
- Which performance in terms of coverage and throughput rate does NB-IoT provide under different conditions?
- Does NB-IoT use turbo coding and HARQ?
- Which new channels does NB-IoT introduce and how do they differ from their wide band ancestors?
- What are the differences between PSM and eDRX and how do both operate?
- How does NB-IoT provide for downlink access to the UE? What are typical delay times?
- To which degree can the operation of NB-IoT be controlled by the UE and by the operator?
- Which new BCCH-messages does NB-IoT introduce and what is their content?

Course Target:

- The student is enabled to differentiate in detail NB-IoT from its ancestors in LTE and LTE-A.
- The student can respond to detailed technical questions about NB-IoT and its technical and physical characteristics. This is very important to take considered technology decisions!
- Students are enabled to engineer and analyze NB-IoT equipment in development, test and integration.

Table of Content:

Chapter 1: Introduction, Playground and Alternatives of NB-IoT (1 – 2 h)

- **The IoT-marketplace in terms of use cases, numbers and volume**
- **Long range vs short range IoT-technologies**
- **Differences among NB-IoT, EC-GSM and CAT-M1**
- **How to define and determine the QoS in IoT-environments**
- **Introducing NB-IoT network architecture**
- **High level operation of selected use cases in NB-IoT**
  Pet tracking, metering and others, considering IoT-specifics like high latency communication HLComm, eDRX and PSM

Chapter 2: Diving into the Physical Layer of NB-IoT (4 – 5 h)

- **Introducing Maximum Coupling Loss, Link Budget, Receiver Sensitivity and Signal to Noise Ratio**
  MCL in genuine LTE for different channels, MCL in NB-IoT for different channels
- **How to determine the coverage area of a radio system**
- **Coverage enhancements in NB-IoT**
  Focus is on the use, simulation and operation of blind repetitions
- **The Downlink OFDMA-grid in NB-IoT**
- **Allocation and Permutation of physical signals and channels to the OFDMA-grid**
  e.g. PSS; SSS, NPDSCH, NPDCCH, ...
- **Uplink options and their operation and characteristics**
  Single-tone 3.75 kHz, single-tone 15 kHz and multi-tone 12x15 kHz, reference signals, modulation and symbols
- **Operation of the NPRACH**
  The random-access procedure in the PHY of NB-IoT
- **Channel coding and HARQ in NB-IoT**
  TBCC and turbo coding

Chapter 3: Protocol Stack and Operation of NB-IoT (3 – 4 h)

- **Protocol Stack of NB-IoT**
  Control Plane and User Plane
- **Cell Search, Random Access and RRC-connection establishment in NB-IoT**
- **Changes to protocols and their functions**
  MAC, RLC, PDCP, …
- **Attachment of an NB-IoT UE to the network**
  Basic procedure, specifics of NB-IoT, discussion of options and timer values for PSM and eDRX
- **eDRX and PSM in operation**
  Specifics and differences
- **Device triggering**
  MSISDN-less operation
- **Data transfer through the user plane**
  User plane CIoT Optimizations
- **Data transfer through the control plane**
  Control plane CIoT Optimizations
- **Security in NB-IoT**
  Use of SIM and future, key generation, distribution and update, operation

Chapter 4: Performance Analysis and Use Cases (3 – 4 h)

- **Calculating the real user throughput rates under ideal conditions**
  taking the previous chapters into account
- **Calculating battery lifetimes for different use cases**
- **Calculating throughput rates and latencies for different conditions**
- **Applicability of NB-IoT or alternative technologies like CAT-M1 for different use cases and different conditions**