Course ID **5G-TF1** Course Duration **4-5 days**	Course Title **5G Wireless Training: Layers 1, 2, 3**

Related Courses

- 5G Wireless Technology/Applications (5GTA, 5 days)
- Evolution of LTE to 5G Wireless (5G1, 5 days)
- SDN/NFV: Software Defined Networks & Network Functions Virtualization (SDN-NFV, 2 days)
- M2M Course with IoT and LTE (M2MIOTLTE, 3 days)
- IoT Training: In Depth (IOT3D, 3 days)
- WiFi Training in Depth: Technology, Security, Deployment … with M2M, IoT, 5G (WIFI-DIVE, 5 days)

Aimed At

Telecommunications equipment vendors, operators, and others whose job requires staying abreast with the evolving 5G wireless technology.

Prerequisites

- LTE / LTE-A Deep Dive: RAN and Core (LTE-DIVE, 4 days)

Course in a Nutshell

5G Wireless Training: Layers 1, 2, 3 opens with a review of the 5G wireless standardization history, key concepts from LTE and LTE-Advanced, 5G wireless objectives and requirements, and 5G wireless technology drivers. We will follow this with a deep dive into 5G Wireless Layer 1, Layer 2, and Layer 3. The course content is continually updated to keep it synched with the 5G wireless state-of-the-art. You will go away from the course having acquired a solid understanding of 5G Wireless Layers 1 to 3.

Customize It!

We can adapt *5G Wireless Training: Layers 1, 2, 3* to your specific needs or interests by including or excluding certain topics, making it shorter or longer, or by making it more or less technical as needed.

Course Outline

5G Wireless Training: History and Standardization of 4G Communications Systems

- 5G Business Opportunities
- ITU Requirements and Technologies
  - IMT-2000 Requirements and Technologies
  - IMT-Advanced Requirements and Technologies
- 3GPP LTE Standardization Process and Status

5G Wireless Training: Review of Key LTE and LTE-Advanced Concepts

- LTE Network Architecture and Components
  - UE
  - eNB
  - MME, S-GW, P-GW, PCRF, HSS
- LTE and LTE-Advanced Air Interface Basics
  - LTE Physical Layer
  - LTE RRC and RLC Layers
  - LTE Network Entry
- LTE-Advanced Specifications
  - LTE Release 11 Features
  - LTE Release 12 Features
  - LTE Release 13 Features
  - LTE Release 14 Features (LTE Advanced-Pro)

5G Wireless Training: 5G Requirements and Services

- ITU IMT 2020
  - Process and Timeline
  - ITU 5G Use Cases
  - IMT Technologies between 6 and 100 GHz
- 5G NGMN Requirements
  - User Experience
  - System Performance
  - Device Requirements
  - 5G Enhanced Services
  - Network Operation, Deployment, and Management
- METIS 5G Generic Services and Requirements
  - xMBB: Extreme Mobile BroadBand
  - uMTC: Ultrareliable Machine Type Communication
  - mMTC: Massive Machine Type Communication
- 5G Wireless Objectives
  - Capacity Increase
  - Variety of Services and Applications
  - Variety of Device Types

　　　　○ Saving Energy

5G Wireless Training: 5G Technology Drivers

- RAN Sharing
- Green Communications
- Network Densification
  - Small Cell Development
  - HetNet Development
- Millimeter Wave (mWave), High Frequencies
- Massive MIMO
- Software Defined Networking (SDN)
- Cloud RAN
- Device to Device Communications
- Internet of Things (IOT)
  - Machine to Machine (M2M)
- Backhaul Development
- Device Centric Architecture
- 3GPP LTE 5G Network Services
  - Massive Internet of Things (IOT)
  - Critical Communications
  - Enhanced Mobile Broadband
  - Network Operation
  - C-V2X Communications
  - Private LTE
  - Context Aware Networks
  - Self Backhaul
  - Energy Efficiency
  - NS-SS (Spectrum Sharing)
  - GigaBit LTE
  - Augmented Reality (AR)
  - Virtual Reality (VR)

5G Wireless Training: Overall Architecture

- Architecture
  - gNB and ng-eNB Functionalities
  - AMF Functionalities
  - AMF Functionalities
  - UPF Functionalities
  - SMF Functionalities
- 5G Network Interfaces
  - NG Interface
  - Xn Interface
- 5G Radio Protocol Architecture

- ◦ Control Plane
- ◦ User Plane
- Multi-RAT Dual Connectivity
- 5G: Channel Model
  - ◦ 5G Channel Models outside 3GPP
  - ◦ Coordinated Systems
  - ◦ Antenna Modeling
  - ◦ Path Loss
  - ◦ Penetration Loss
  - ◦ Fast Fading Models
  - ◦ Link Level Channel Model Evaluation
    - ▪ CDL Model (Clustered Delay Line)
    - ▪ TPL Model (Tapped Delay Line)
  - ◦ Map-Based Hybrid Channel Models

5G Wireless Training: 5G NR Radio Requirements

- 5G Spectrum
  - ◦ 5G Frequency Bands
    - ▪ Sub-6GHz
    - ▪ cmW
    - ▪ mmW
  - ◦ Spectrum Management
    - ▪ Spectrum Sharing
    - ▪ Dynamic Spectrum Access
    - ▪ Cognitive Radio
- UE 5G NR Radio Requirements
- Base Station 5G NR Radio Requirements
- Common UE and BS Radio Requirements

5G Wireless Training: 5G New Radio (NR) Layer 1

- 5G NR Waveform
  - ▪ Cyclic Prefix OFDM (CP-OFDM)
  - ▪ Cyclic Prefix OFDM (CP-OFDM) with DFT Spreading
- 5G NR Frame Structure
- 5G NR Numerology
- 5G NR DownLink
  - ◦ DL Transmission Scheme
  - ◦ DL PHY Shared Channels
  - ◦ DL PHY Control Channels
  - ◦ DL PHY Signals
  - ◦ DL PHY Synchronization Signals
  - ◦ 5G NR DL Procedures

- Power Control
- HARQ
- Cell Search
- Link Adaptation
  - 5G NR Modulation Techniques
    - π/2-BPSK
    - BPSK
    - QPSK
    - 16QAM
    - 64QAM
    - 256QAM
  - 5G NR Channel Coding
    - Coding Techniques
      - LDPC
      - Polar Coding
    - Small Block Channel Coding
    - CRC Calculation
    - Rate Matching
    - Control channel Coding
    - Broadcast Channel Coding
- 5G NR UpLink
  - UL Transmission Scheme
  - UL PHY Shared Channels
  - UL PHY Control Channels
  - UL Random Access
  - UL PHY Signals
  - UL Procedures
    - Link Adaptation
    - Power Control
    - HARQ
    - UL Timing Control
  - 5G NR Modulation Techniques
    - π/2-BPSK
    - BPSK
    - QPSK
    - 16QAM
    - 64QAM
    - 256QAM
  - 5G NR Channel Coding
    - Coding Techniques
      - LDPC
      - Polar Coding
    - Small Block Channel Coding
    - CRC Calculation

- Rate Matching
- Control channel Coding
- Random Access Channel Coding
- 5G NR Carrier Aggregation
  - Supplemental Channels
- 5G NR Transport Channels
- PHY Layer Measurement
- Duplexing in 5G NR
- LTE-5G NR Coexistence
- Dual Connectivity

5G Wireless Training: 5G NR Layer 2

- Layer 2 Overall Overview
- 5G NR MAC Sublayer
  - Services and Functions
  - Logical Channels
  - HARQ
  - Transport Channels
- 5G MAC Procedures
  - Random Access Procedure
  - DL Data Transfer
  - UL Data Transfer
  - Discontinuous Reception (DRX)
  - Semi Persistent Scheduling (SPS)
- MAC PDU Formats
- 5G NR Radio Link Control (RLC) Architecture
  - RLC ARQ Procedure
  - RLC PDU Format and Structure
- 5G NR Packet Data Convergence Protocol (PDCP) Architecture
- Service Data Protocol (SDAP) Sublayer
- New AS Sublayer
- Carrier Aggregation
- Dual Connectivity
- Bandwidth Adaptation
- Supplementary Uplink
- 5G NR Radio Resource Control
  - RRC States
    - RRC Idle State
    - RRC Inactive State
    - RRC Active State
- NG Identities
- NR Mobility
  - Intra-NR
  - Inter-RAT

- ◦ Roaming
- Scheduling
  - ◦ Basic Scheduling in 5G NR
  - ◦ DL Scheduling
  - ◦ UL Scheduling
- UE Power Saving
- 5G NR QoS Architecture
- 5G NR Security
- Self-Optimization (SoN) and Self-Configuration

5G Wireless Training: 5G NR Layer 3

- RAN-CN Interfaces
- 5G: The New Core
  - ◦ Standalone and Non-Standalone 5G Networks
    - ▪ Tight Interworking with LTE
  - ◦ Cloud RAN (C-RAN)
  - ◦ Collaborative Communications Protocols
  - ◦ Virtualization and Software Defined Networking (SDN)
    - ▪ The SDN Concept
    - ▪ OpenFlow Protocol
    - ▪ Network Functions Virtualization (NFV)
    - ▪ NFV MANO: Management and Orchestration
    - ▪ vRAN /C-RAN
    - ▪ RRH (BBU) – Remote Radio Head (Baseband Unit)
  - ◦ Internet of Things (IoT)
    - ▪ Alternative Technology Solutions
    - ▪ NB-IoT, Sigfox
    - ▪ Data Analytics
    - ▪ IoT Security Challenges and Solutions
  - ◦ Management and Orchestration for 5G Networks
    - ▪ Distributed Vs. Centralized Network Architecture Management
    - ▪ SON: Self Organized Network
    - ▪ Cloud Orchestration Platform (e.g., OpenStack and Ryu Controller)
  - ◦ ICN: Information Centric Networking
    - ▪ The ICN Concept
    - ▪ Novel Topologies to Support Edge-based Storage and Computing
    - ▪ NDN: Named Data Networking
    - ▪ CCN: Content Centric Network
    - ▪ Security Aspects
  - ◦ 5G Connectivity Concepts
    - ▪ D2D

- - V2X
  - Multi-connectivity
  - ◦ Tight Interworking with LTE
- NR Vertical Support
  - ◦ IMS Voice
  - ◦ Network Slicing
  - ◦ Resource Isolation and Management
  - ◦ PWS
  - ◦ URLLC

5G Wireless Training: 5G NR Advanced Features

- Advanced MIMO and Beamforming
  - ◦ 3D Beamforming and Diversity
  - ◦ Beam Management
  - ◦ CSI Management
  - ◦ MIMO Schemes
  - ◦ Reference Signals
  - ◦ Quasi Co-location (QCL)
- Network Coordination and Advanced Receiver
- Interference Management
- Millimeter-Wave Beamforming
- Cognitive Radio Small-Cells
- IOT Support
- eMTC Cat-M1
- NB-IOT Cat-B1

5G Wireless Training: 5G Advancement beyond NR (Release 16)

- - ◦ 5G Waveform Candidates
    - Generalized Frequency Division Multiplex (GFDM)
    - Cyclic Prefix OFDM (CP-OFDM)
    - Filter Bank Multicarrier (FBMC)
    - Filtered OFDM (f-OFDM)
    - Windowed OFDM (W-OFDM)
    - Universal Filtered Multicarrier (UFMC)
    - Sparse Code Multiple Access (SCMA)
    - Non-orthogonal Multiple Access (NOMA)
    - Resource Spread Multiple Access (RSMA)
  - ◦ NS-SS (Spectrum Sharing)
  - ◦ LAA / eLAA / MuLTEFire
  - ◦ IOT Advancements
    - LTE-based Evolution
      - FeMTC

- eFeMTC
  - NB-IOT evolution
    - eNB-IOT
    - FeNB-IOT

Wrap-up: Course Recap and Discussion