5G Training Brochure

New Radio (NR) : NG-RAN : NFV : SDN : Network Slicing : NB-IoT: MIMO : Spectrum: Architecture

5G Training: A NanoCell-CEWiT Partnership Project

The unique partnership is a combination of skills from two expert organizations; NanoCell Networks is an organization with decade old experience in organizing and delivering training on Communication Technologies across the world and CEWiT is an autonomous research society of IIT Madras that has 5G Test Bed and specializes in participating and contributing towards standardization activities apart from participating in various 5G related research activities.

Under this initiative, experts at NanoCell and CEWiT will jointly develop and deliver a comprehensive 5G Knowledge Management Solutions to meet the requirement of various organizations in addition to standard training courses listed below (click on each course for more details).

1. 5G Essentials for Business Leaders – 1 day
2. 5G Overview – 1 day
3. 5G Networks and Services Overview – 2 days
4. 5G NG-RAN Explained – 2 days
5. 5G NR Explained – 2 days
6. SDN/NFV Explained – 4 days
7. NB-IoT and Cat-M1 – 1 day

Course 1: 5G Essentials for Business Leaders

Course Objective: This course is targeted for business leaders industry who would like to understand 5G from overview perspective. The participants will get good idea of 5G Network Applications & Use cases, Network Overview and various new approaches to be taken by Telcos for implementing 5G. The course will also equip participants with an idea of how the network will be designed and implemented

Course Duration: 7 Hours

Course Delivery: Instructor Led Class room training with presentation, practical scenarios, quiz along with tests

Course Pre-requisite: Overview understanding of Mobile Networks, Wireless Technologies, Telecom Market

Target Audience: Managers, Business Leaders

Course Outline

- Quick review of 1G to 4G

- What is 5G and why 5G
- 5G Use cases, Services and applications
- Overview of 5G Network Features (Massive MIMO, mmWave, NFV, SDN, MEC, C-RAN, NR, etc)
- 5G Spectrum
- 5G and IoT (NB-IoT and Cat-M1)
- 5G and Cloud/ Data Analytics/ML/AI
- 5G Network Architecture
    - 5G Radio Interface overview
    - 5G Core Network Overview
    - 5G OSS/BSS Overview
- Network Slicing Overview
- 5G Implementation by Telcos
    - Non Standalone (NSA) 5G Network
    - Standalone 5G Network
- 5G Impact to other industries (Manufacturing, HealthCare, Automobile, etc)
- 5G Global Scenario with Telcos (US, Europe, Korea, China, etc)

Course 2: 5G Overview

Course Objective: To provide good understanding of the latest in the 4G evolution to 5G. The course also covers key technologies of 5G standard along with 5G applications.

Duration: 1 day (7 Active Learning Hours)

Learning Objectives:

1. State of 4G wireless and upgrades
2. 5G application scenarios
3. Key 5G technologies
4. 5G spectrum
5. Timeline for standardization

Prerequisites: Cellular Systems, exposure to 2G-4G systems

Training Delivery Mode: Instructor led live classroom session OR live online session for remote locations

Target audience: R&D Engineers, Management Teams, Technical Managers, Technical Members, Leadership Teams

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Course Outline

Module 1: Introduction and basics

This module will cover some of the advanced 4G concepts which are being introduced and will form a key part of the evolution to 5G. It will also address some of the 5G use cases and objectives which are a natural extension of the advanced 4G use cases.

- Evolution of cellular systems; 1G to 4G (brief summary)

    - Air-interface technology evolution
    - Network related evolution
    - Key technologies and services related evolution
- 4G status update; technologies, releases, important features
- LTE to LTE-Advanced to LTE-Advanced-Pro; LTE Release and feature summary
- LTE in unlicensed bands; LTE-U/LAA/LWA/LWIP
- Future wireless challenges; higher rates, lower latencies, IOT applications
- Why 5G?
- New applications; connected cars, low-power IOT, Gbps/latency requirements
- 5G use cases and service scenarios; XMBB, URLLC, MMTC
- 3gpp 5G standardization Status update; groups, key meetings, timeline etc.

Module 2: 5G technology aspects

This module will address some of the new technology choices being considered for 5G. Coexistence of 4G and 5G will also be discussed along with how the new technology choices will impact applications and use cases.

- 5G NR and NGC requirements
- 5G NR Frequency Bands
- 5G enablers; DyRAN, Lean Control, Spectrum toolbox; Localization
- mm-waves and their potential usage; challenges in mm-wave systems
- Massive MIMO and its role; Technology behind beamforming
- Latency reduction challenges
    - Shorter frames
    - New protocols for accessing data
- Core Network Technologies for 5G
    - NFV and SDN
    - Localized Operation
- Pre-5G network announcements and parameters
- Time-lines for potential development and deployment of 5G

Course 3: 5G Networks and Services Overview

Course Objective: To provide good understanding of the latest in 5G Networks. The course also covers key components of 5G Network along with 5G applications.

Duration: 2 days (6 Active Learning Hours per day)

Learning Objectives:

6. 5G Requirements
7. 5G application scenarios
8. Key 5G technologies (SDN, NFV, Network Slicing, MEC, C-RAN,
9. 5G spectrum
10. 5G Network Architecture
11. Timeline for standardization and current trials

Prerequisites: Cellular Systems, exposure to 2G-4G systems, 5G Overview

Training Delivery Mode: Instructor led live classroom session OR live online session for remote locations

Target audience: R&D Engineers, Management Teams, Technical Managers, Technical Members, Leadership Teams

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Course Outline

Module 1: 5G Introduction

- Evolution of cellular systems; 1G to 4G (brief summary)
  - Air-interface technology evolution
  - Network related evolution
  - Key technologies and services related evolution
- Future wireless challenges; higher rates, lower latencies, IOT applications
- 5G Requirement
- 5G use cases and service scenarios; XMBB, URLLC, MMTC
- 5G Network Architecture

Module 2: 5G technology aspects

- 5G New Radio (gNB)
- 5G NG-RAN (C-RAN, D-RAN, Small Cells, etc)
- C-RAN Overview
- Core Network Technologies for 5G
  - RAN and Core Network Interfaces
  - NFV and SDN
  - Localized Operation
  - Control Plane and User Plane
  - Interworking with LTE
- 5G Network Implementation Plan
  - Non Standalone mode
  - Standalone Mode

Module 3: 5G UE Operations

- Registration
- Idle Mode Behavior
- Session Establishment and Mobility
- QoS
- Data Transfer
- 5G Security

Module 4: Key Technologies in 5G

- mmWave
- Cloud and Virtualization
- Network Slicing

- Multi Access Edge Computing
- SON

Module 5: 5G Deployment Plan

- Pre-5G network announcements and readiness
- Time-lines for potential development and deployment of 5G
- Dual Connectivity
- Migration Plan from 4G-5G (NSA, SA)
- Current Industry Status

Course 4: 5G NG-RAN Explained

Course Objective: To provide good understanding of 5G RAN with NR. 5G RAN implementation aspects along with New Radio aspects will be covered in this course. The course is expected to cover the procedures and processes of 5G UE in NG RAN.

Duration: 2 days

Learning Objectives:

12. NG-RAN Architecture
13. New Radio Air Interface
14. Access and Connection Set-up Procedure
15. DL and UL Data Transfer
16. Connected Mode Operation

Prerequisites: Legacy Cellular Networks, 5G Overview, LTE Air Interface

Training Delivery Mode: Instructor led live classroom session OR live online session for remote locations

Target audience: R&D Engineers, Network Engineers, Technical Managers, Technical Members, Leadership Teams

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Course Outline

Introduction to 5G

- 5G Evolution
- 5G Requirements and Use Cases
- 5G Key Technologies
- Deployment Options

NG-RAN Architecture

- 5G network architecture
- Multi-RAT dual Connectivity
- gNB-CU and gNB-DU

- Protocols for NG-RAN interfaces
- NG-RAN and UE identifiers
- Cloud RAN

New Radio (NR) Air Interface

- mmW and sub-6 GHz spectrum
- Massive MIMO
- Multiplexing and multiple access
- Numerology and frame structure
- Physical signals and channels
- RRC states, and state transitions
- Air interface protocol stack

5G Network Acquisition, Random Access, and Connection Setup

- DL synchronization
- Minimum SI and Other SI
- Random access procedure
- Connection establishment with gNB-CU and gNB-DU

5G Registration and Session Setup

- Overview of registration Process
- Overview of Network slicing
- PDU session establishment
- QoS in 5G

DL and UL Data Transfer

- Overview of data transfer
- Measurements
- Scheduling
- Data transmission
- H-ARQ
- RLF: detection and resolution

Operations in Connected, Inactive, and Idle Modes

- Cell- and Beam-level mobility
- Handover Process
- Inter-DU/Intra-CU mobility
- LTE mobility with dual connectivity
- Cell reselection
- Paging

Course 5: 5G NR (New Radio) Explained

Course Objective: The course is designed to provide good understanding 5G NR. It is focused on the PHY layer aspects of Downlink and Uplink. The course covers all the basics related to 5G NR

Duration: 2 days

Learning Objectives:

17. 5G NR Overview
18. DL Transmission schemes
19. DL PHY Layer Procedures
20. UL Transmission schemes
21. UL PHY Layer Procedures

Prerequisites: Legacy Cellular Networks, 5G Overview, LTE Air Interface

Training Delivery Mode: Instructor led live classroom session OR live online session for remote locations

Target audience: R&D Engineers, Network Engineers, Technical Managers, Technical Members, Leadership Teams

Course Outline

Introduction to 5G

- 5G Evolution
- 5G Requirements and Use Cases
- 5G Key Technologies
- 5G Network Architecture

New Radio PHY Layer

- Duplexing options
- Forward compatibility
- Numerologies and frame structure
- LTE-NR co-existence
- Carrier aggregation / Dual connectivity

New Radio - DL Concepts

Basic transmission scheme

- Modulation scheme
- Physical layer channel
    - Physical resource multiplexing
    - Data channel
    - Control channel
- Multiple access scheme
- Channel coding
    - LDPC
    - Polar coding
- Multi-antenna scheme
    - Beam management
    - MIMO schemes
    - CSI measurement and reporting
    - Reference signal related to multi-antenna scheme

        - CSI-RS
        - DMRS
        - Phase-tracking RS (PT-RS)
    - Quasi-colocation (QCL)
    - Network coordination and advanced receiver

Physical layer procedure

- Scheduling
- HARQ
- Initial access and mobility
    - Synchronization signal and DL broadcast signal/channel structure
    - Mobility
    - Paging

New Radio - UL concepts

Basic transmission scheme

- Modulation scheme
- Physical layer channel
    - Data channel
    - Control channel
- Multiple access scheme
- Channel coding
    - LDPC
    - Polar coding
- Multi-antenna scheme
    - Beam management and CSI acquisition
    - MIMO schemes
    - Reference signal related to multi-antenna scheme
        - SRS
        - PT-RS

Physical layer procedure

- Random access procedure
    - Preamble
    - Procedure
- Scheduling
- Power control
- HARQ

Course 6: Software Defined Network (SDN) & Network Function Virtualization (NFV) Explained

Course Overview: This course includes two major modules (3 in all) – **SDN** and **NFV**. At the end of this course, participants will acquire (1) the skill set needed to develop *SDN Controller scripts* (with *Python*) and test/debug them with *Mininet* simulator, *Wireshark*, *OVS*, etc; (2) skill set needed to create and work with Virtualized Networking functions and develop Orchestration specification for *NFV*. This course provides

sufficient knowledge of *Mininet, SDN, OpenFlow, OVS*, and other tools needed for SDN development and testing. At the end of this module, operation of a *4-port SDN-switch* is demonstrated. For the *NFV* module, a case study of virtualizing a network function is presented with Multi-Service *Broadband Network CPE and PE*. This case study provides various design options of virtualizing a networking function. The *ETSI MANO* architecture is presented with *OpenStack and TOSCA* specifications. Some simple *TOSCA* scripts are presented with *NFV examples*. Some of the other related areas presented: *ONAP, SD-WAN, MEF LSO, and Open Daylight.*

Note: All those items in blue colour font (in below course outline) are hands-on or demonstration.

Course Objective: To provide a sound understanding of Software Defined Network and Network Function Virtualization with hands-on (SDN) and TOSCA Scripts

Duration: 4 days

Pre-Requisite: Networking and Overview of Cellular Networks

Target Audience: Telecom Networking Professionals who work with both carrier and enterprise networks.

Module 1: Introduction & Logistics

1. Understanding SDN and NFV
    - Modularity, Abstraction, and Virtualization in IT
    - Virtual Machines (VM)
    - Understanding VM with Mininet Appliance
    - Virtual Switch
    - Virtual Router, Virtual Device
    - Virtual Network Function
    - SDN, SDN with Virtualization
    - Benefits/Issues of SDN and NFV
    - Installing and using SDN VM

Module 2: SDN (Software Defined Network)

2. SDN Overview with *Mininet* Demo
    - What is SDN?
    - What problem does it solve and what are its benefits?
    - Open Network Foundation (ONF)
    - OpenFlow Architecture
    - SDN controller as Network Hypervisor or NOS
    - Open VSwitch, Mininet, OVS Controllers

- Commercial/Open Source Controllers
- Demo/Hands-on: Mininet with OpenFlow Controller
- Demo/Hands-on: OpenFlow messages with Wireshark

3. Introduction to SDN & OpenFlow
    - OpenFlow Switch architecture
    - OpenFlow Ports
    - OpenFlow Pipeline Processing
    - Flow Table & Flow Entry Management
    - Packet Matching and Flow Table Miss
    - Flow Table Instructions and Actions
    - Flow Table Counters and Meters
    - Group Table and Group Entry
    - Ingress and Egress Processing
    - Channels, Auxiliary Connection
    - Open Flow Control Messages and Message Formats
    - Multiple Controllers
    - Bootstrapping a new switch
    - Capturing and understanding Controller-Switch interaction with Wireshark
    - OpenFlow utilities: dpctl, ofctl, vsctl
    - Demonstration of some simple controllers developed Python
    - Operation of OVS
    - Proactive Controller and Reactive Controller
4. Mininet
    - What is Mininet?
    - Launching Mininet – Command line arguments
    - Information Commands
    - Configuring Host
    - Ping and Xterm commands
    - Configuring Link, Link Performance with Iperf
    - Exit and cleanup
5. Mininet with Python Script
    - Creating a network with Mininet Python Scripting
    - Two different ways to use the Script
    - Some simple networks with Python Scripts
    - Scripts to create more complex networks
6. SDN Eco System
    - Initiatives, Standards (ONF)
    - NFV, Cloud, and SD-WAN

- Enterprise Solutions
- Service Provider Solutions – OpenDay Light, ONOS OpenStack, Tacker, ONAP, …

7. Demonstration with 4-port SDN Switch

Module 3: Network Function Virtualization (NFV)

1. Virtualizing PE and CPE Functions
    - Understanding Virtualization with Border Gateway Virtualization
    - Various Architectural options with Virtualized CPE – Pros/Cons
    - Choosing CPE functions to Virtualize with some examples
    - Options to deploying Virtualized functions – Pros/Cons
    - Virtualizing and adding Software Defined Controls to PE and CPE
2. Developing Orchestration with Virtualized PE and CPE Functions
    - ETSI NFV MANO - Reference Architecture – Scope – Single Provider
        - Functional Components – MANO, NFVM, VIM, …
        - Realization of those functional components with
            - OpenStack, OpenTacker, EMS, Controllers (SDN, …), TOSCA, and TOSCA NFV Templates and their use in orchestration
            - Some TOSCA NFV Examples
        - Reference Points and realization of those interfaces
            - SDN OpenFlow, NetConf, SNMP, REST API, …
3. MEF LSO - Reference Architecture – Scope – Multi Provider
    - MEF LSO – Functional components – Edge, Gateway, Controller, Orchestrator, OSS/BSS, UI
        - Realization of those functional components with PE/CPE
        - Orchestration with multi-level controllers
        - OSS/BSS Interaction
        - Use Case

Course 7: NB-IoT and Cat-M1

Course Objective: The course is designed to provide good understanding IoT implementation on 5G Network. The focus of this course is on NB-IoT and Cat-M1 details. This course will provide a good understanding of changes in Radio for offering connectivity solutions to IoT.

Duration: 1 day

Learning Objectives:

22. Connectivity requirement for IoT
23. Cellular Technologies for IoT
24. Overview of Cat-M1, NB-IoT, EC-GSM
25. NB-IOT details
26. IoT Implementation aspects on 5G

Prerequisites: IoT Overview, Mobile Network Overview, LTE Air Interface

Training Delivery Mode: Instructor led live classroom session OR live online session for remote locations

Target audience: R&D Engineers, Network Engineers, Technical Managers, Technical Members, Leadership Teams

Course Outline

Module 1: Introduction

- What is IOT/IOE?
- Critical components of a typical IOT system
- Wireless Standards relevant to IOT – Short Range and Long Range
- Non-standard WAN technologies for IOT; LoRa, SigFox, weightless
- 5G Overview and 5G mMTC requirements
- Frequency bands and ranges relevant for IOT

Module 2: 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