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5G

ON-DEMAND - EXPRESS
Welcome to 5G
Bienvenidos a 5G (Spanish)
RF and Radio Network Fundamentals
5G Core Network Overview
5G NR Air Interface Overview - Part I
Welcome to MIMO and Beamforming in 5G
5G NR Air Interface Overview - Part II
Welcome to RF Planning and Design

ON-DEMAND - EXPANDED
Wireless Technologies and Network Operations
LTE-M and NB-IoT
5G Services and Network Architecture
5G Radio Technologies and Deployments
VRAN and Open RAN Overview
Multi-Access-Edge Computing (MEC)
Network Slicing in 5G
5G Core Network (SA) Overview
O-RAN Architecture Overview

EXPERT-LED
5G Services and Network Architecture
5G Radio Technologies and Deployments
VRAN and Open RAN Overview
Multi-Access-Edge Computing (MEC)
Network Slicing in 5G
5G for Business
Integrated Access and Backhaul (IAB) Overview
5G Core Network (SA) Overview
O-RAN Architecture Overview
MEC Architecture and Operations Overview
Network Slicing Architecture and Operations Overview
5G Networks and Services
O-RAN Architecture and Operations
5G NR Air Interface
5G NR Air Interface
5G Voice Solutions – VoNR and EPS Fallback
LTE-M and NB-IoT Signaling and Operations
5G RF Planning and Design
5G (NSA) RAN Signaling and Operations
5G (SA) RAN Signaling and Operations
5G Core Network Signaling and Operations
5G (NSA) RAN Performance Workshop: Part 1
5G (NSA) RF Performance Workshop (UE Based)

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Welcome to 5G

5G promises to enable a wide variety of new wireless communications services and capabilities, ranging from high-speed, high-capacity broadband access to extremely reliable low-latency communications to machine-type communications on a massive scale. To deliver on these promises, everything about the wireless network must change, including the devices, the radio interface, the radio access network (RAN), and the core network. This self-paced eLearning course is for both technical and non-technical students, offering a high-level end-to-end overview of 5G networks. It explores use cases for different verticals, 5G network architecture, 5G device types, 5G air interface including the use of mmW spectrum and massive MIMO, and deployment scenarios.

Intended Audience
This course provides an end-to-end overview of 5G networks and is targeted for a broad audience—both technical and non-technical. This includes those in sales, marketing, deployment, operations, and support groups.

Objectives
After completing this course, the learner will be able to:

- Identify the motivations and goals for 5G networks
- Sketch the end-to-end architecture of a 5G network
- Describe the types of devices supported in 5G networks
- Summarize the basic concepts of 5G air interface while using various spectrum bands
- Sketch the high-level architectures of the 5G NG-RAN and 5GC/NGC
- List various services being supported in 5G networks
- Illustrate the deployment and interworking solutions for 5G

What You Can Expect
- Self-Paced Duration: 1 HOUR

Outline

1. Motivations for 5G
   1.1 5G use cases
   1.2 eMBB
   1.3 URLLC
   1.4 mMTC
   1.5 5G goals and targets
   1.6 5G building blocks

2. 5G Devices
   2.1 Multiplicity of devices
   2.2 IoT devices and non-IoT devices
   2.3 Device capabilities

3. 5G Network Architecture Overview
   3.1 5G architecture goals
   3.2 5G network components
   3.3 5G NG-RAN
   3.4 5G core network
   3.5 Network slicing
   3.6 MEC

4. 5G NR Air Interface
   4.1 Variety of spectrum bands for 5G
   4.2 Massive antennas for mmW
   4.3 Reuse of OFDM/OFDMA concepts
   4.4 Flexible OFDM numerologies
   4.5 Flexible frame and slot structure

5. 5G NG-RAN
   5.1 Split architecture
   5.2 gNB-CU and gNB-DU
   5.3 Transport network

6. 5G Core Network
   6.1 5G Core Network functions
   6.2 Control and User Plane separation
   6.3 Service-based architecture

7. 5G Deployment
   7.1 NSA and SA deployment options
   7.2 Interworking with 4G LTE
   7.3 Deployment considerations

Putting It All Together
Bienvenidos a 5G

Las redes 5G proporcionarán una gran variedad de servicios de telecomunicaciones. Entre ellos se encontrarán servicios de banda ancha y de alta velocidad, servicios de comunicaciones ultra confiables y de bajo retardo de transmisión, así como comunicaciones entre máquinas a escala masiva. Para la implementación de estos tipos de servicios, todos los componentes, características y tecnologías de las redes actuales de 4G tienen que cambiar. Este curso ofrece un panorama general de las redes de 5G, mismo que incluye: los tipos de servicios que se proporcionarán, la arquitectura de la red, la interfaz aérea, su implementación en bandas milimétricas, y la utilización de MIMO masivo en dichas bandas.

Outline

1. Motivaciones de la Red 5G
   1.1 Principales Tipos de Servicios
   1.2 eMBB
   1.3 URLLC
   1.4 mMTC
   1.5 Objetivos de la Red
   1.6 Subredes que Conforman a la red 5G

2. Dispositivos 5G
   2.1 Variedad de Dispositivos
   2.2 Teléfonos Celulares y Dispositivos IoT
   2.3 Características de los Tipos de Dispositivos

3. Arquitectura de la Red 5G
   3.1 Objetivos de la Arquitectura
   3.2 Componentes Principales
   3.3 5G NG-RAN
   3.4 Red Fija 5G (Core Network)
   3.5 Distribución de Recursos de la Red (Network Slicing)
   3.6 Procesamiento al Borde de la Red Móvil de Acceso Múltiple (MEC)

4. Interface Aérea NR 5G
   4.1 Bandas de Frecuencias Disponibles para 5G
   4.2 Antenas Masivas para Ondas Millimétricas
   4.3 Reutilización de los Conceptos de OFDM/OFDMA
   4.4 Numerologías Flexibles OFDM
   4.5 Estructuras Flexibles de Trama y de Ranuras de Tiempo

5. Arquitectura de la Red 5G NR-RAN
   5.1 La Arquitectura Dividida
   5.2 gNB-CU y gNB-DU
   5.3 Red de Transporte

6. Red Fija de 5G (Core Network)
   6.1 Las Funciones de la Red Fija 5G
   6.2 Separación de los Planos de Control y de Datos
   6.3 Arquitectura Basada en Servicios

7. Implementación
   7.1 La Implementación Independiente vs. la Co-dependiente
   7.2 Interconexión con la red 4G LTE
   7.3 Consideraciones para su Implementación

Resumen
RF and Radio Network Fundamentals

This course provides a technical introduction to RF fundamentals. You’ll learn RF concepts such as frequency spectrum, bandwidth considerations, the propagation of radio signals from transmitter to receiver, key RF measurements, and types of interferences. You’ll learn the fundamentals of wireless networks and the evolution of networks to centralized and virtualized RANs. Lastly, you’ll expand your skills and knowledge in antenna theory basics, the network impact from various antenna types, and key antenna techniques such as beamforming and MIMO for improving network performance and capacity.

Intended Audience
This course is designed for a broad audience of personnel working in the wireless industry.

Objectives
After completing this course, the learner will be able to:
■ Describe how radio signal propagates to carry information
■ Define key RF terminologies and measurement
■ Identify different radio frequency spectrum used in cellular networks
■ Identify key components of the cell sites
■ List antenna types and key parameters and techniques related to antenna

What You Can Expect
■ Self-Paced Duration: 1.5 HOUR

Outline
1. RF Fundamentals
   1.1 Radio Signals and Frequency spectrum
   1.2 Propagation over the air
   1.3 Digital modulation for data transfer
   1.4 Spectrum for cellular networks
   1.5 Low, Mid, High frequency bands
   1.6 Relationship of frequency bands and bandwidth
   1.7 Coverage and Capacity
   1.8 RF terminology
   1.9 RF measurements

2. Wireless Network Fundamentals
   2.1 Cellular technology evolution - from 1G to 5G
   2.2 End-to-end Wireless Network

3. Antenna and Radio Propagation
   3.1 Cellular antenna evolution
   3.2 Antenna parameters
   3.3 Transmit and Receive chains
   3.4 Advanced antenna techniques
   3.5 MIMO techniques
   3.6 Beamforming

Putting It All Together

View Curriculum
5G Core Network Overview

5G promises to enable a wide variety of new wireless communications services and capabilities, ranging from high-speed, high-capacity broadband access to extremely reliable low-latency communications to machine-type communications on a massive scale. To deliver on these promises, everything about the wireless network must change, including the devices, the radio interface, the radio access network (RAN), and the core network. This course focuses on the principles of the 5G core network, its connectivity to the radio network and interworking with the 4G EPC. Topics such as Service-Based Architecture (SBA), PDU Session Establishment, Network Slicing and Multi-Access Edge Computing (MEC) as they relate to 5G are described.

Outline

1. Principles of the 5G Core Network
   1.1 Control and User Plane separation
   1.2 Modularization
   1.3 Virtualization
   1.4 Service-based Architecture
   1.5 Network Slicing
2. 5G Core Network Architecture
   2.1 Key network functions and their roles
   2.2 Network connectivity
   2.3 Interworking with 4G EPC
3. Service-Based Architecture
   3.1 Network interfaces and services
   3.2 Network Exposure Function
   3.3 Protocols
4. Multi-Access Edge Computing (MEC)
   4.1 Defining MEC
   4.2 Need for MEC
   4.3 MEC in action in 5G network
5. Network Slicing
   5.1 Defining network slicing
   5.2 Need for network slicing
   5.3 Network Slice Selection Function
   5.4 Network slicing in action
6. Network Operation: Registration of UE
   6.1 Authentication
   6.2 Security framework
   6.3 UE states
7. QoS Framework in 5G
   7.1 QoS flow
   7.2 Roles of 5QI and QFI
   7.3 QoS mapping with 4G
8. PDU Session Establishment
   8.1 Components of PDU session
   8.2 IP and Ethernet addressing
Putting It All Together

Intended Audience

This course is designed for a broad audience of wireless network engineers. This includes those in network planning, engineering, operations, troubleshooting and support groups.

Objectives

After completing this course, the learner will be able to:
- List the key principles behind the evolving 5G core network
- Sketch the 5G core network, its connectivity to the radio network and interworking with the 4G EPC
- Describe the purpose behind Service-Based Architecture (SBA)
- Describe the QoS framework of 5G and compare it with 4G
- Step through the network operations of registration and PDU session establishment
- Describe network slicing and how it is used in 5G
- Describe MEC and how it can be used in 5G

What You Can Expect

- Self-Paced Duration: 1 HOUR
5G NR Air Interface Overview - Part I

5G promises to enable a variety of new services, ranging from high-speed, high-capacity broadband access to ultra reliable low-latency communications to massive machine-type communications. To deliver on these promises, the wireless network must change, including the devices, the radio interface, the radio access network (RAN), and the core network. Part I of this on-demand course offers a high-level technical overview of 5G NR (New Radio) air interface – its features, the use of low-mid-high band spectrum, the reuse of the principles of OFDM/OFDMA, and the use of massive antennas for beamforming and MIMO. Part II covers the flexible numerologies, channels and frame/slot structure, and steps through the life of a 5G UE.

Intended Audience
This course is designed for a broad audience of wireless network engineers. This includes those in RF, RAN planning, engineering, operations, troubleshooting and support groups.

Objectives
After completing this course, the learner will be able to:
- List the performance goals of the 5G network
- Compare the different 5G frequency spectrums and their characteristics
- Describe MIMO and the beamforming techniques used in 5G
- List the key features of the 5G NR air interface
- Sketch the flexible frame and slot structure of 5G NR

What You Can Expect
- Self-Paced Duration: 1 HOUR

Outline
1. 5G Scenarios and Performance Targets
   1.1 Higher data rates
   1.2 Lower latency
   1.3 Higher connection density
2. 5G NR Air Interface Enhancements
   2.1 Key features of 5G air interface
   2.2 Flexible numerologies
   2.3 Air interface protocol stack
3. Frequency Spectrum for 5G
   3.1 Spectrum considerations
   3.2 Low, mid, and high bands
   3.3 Channel bandwidths
   3.4 Radio signal propagation
4. MIMO and Beamforming
   4.1 Massive antenna
4.2 Beamforming and beam tracking
5. Protocol Stack of 5G NR
   5.1 Protocol Stack Enhancements
   Exercise: Protocol Stack
6. 5G Operating Bandwidth
   6.1 Channel bandwidths
   6.2 Use of OFDM
7. 5G NR Frame and Slot Structure
   7.1 Flexible sub-carrier spacing
   7.2 Flexible frame and slot structure
   7.3 Carrier bandwidth part
8. Numerology
   8.1 Importance of numerology in 5G NR
   Putting It All Together
Welcome to MIMO and Beamforming in 5G

This course provides a technical introduction to MIMO and beamforming in 5G. You will learn the role of antennas in wireless communications, the evolution of antenna techniques and the difference between passive and active antenna systems. The concepts of MIMO and Massive MIMO will be explained along with the utilization of SU-MIMO and MU-MIMO to increase throughput and capacity, respectively, in wireless systems. Lastly, you will learn the types of beams used in 5G NR and the techniques used to produce them as well as beam management techniques such as beam sweeping, beam selection, beam switching and beam failure recovery so that you are better equipped to configure beamforming parameters and monitor beam performance.

Intended Audience
This course is designed for a broad audience of personnel working in the wireless industry.

Objectives
After completing this course, the learner will be able to:
- Describe the types of antenna techniques
- Differentiate between passive and active antennas
- Explain the concept of MIMO
- Explain Massive MIMO and its uses
- Describe SU-MIMO and MU-MIMO
- Describe beamforming
- Differentiate the beamforming techniques
- Explain beam management in 5G systems

What You Can Expect
- Self-Paced Duration: 1.5 HOUR

Outline
1. MIMO Fundamentals
   1.1 Transmit and Receive Diversity
   1.2 MIMO: What and why?
   1.3 Single-User MIMO (SU-MIMO)
   1.4 Multi-User MIMO (MU-MIMO)
   1.5 DL and UL MIMO in 5G
   1.6 Massive MIMO

2. Beamforming
   2.1 Beamforming: What and why?
   2.2 Analog, digital and hybrid beamforming
   2.3 Beamforming in 5G

3. Beamforming in 5G
   3.1 Introduction to beam management
   3.2 SSB-Block and traffic beams in 5G
   3.3 Beam sweeping
   3.4 Beam selection
   3.5 Beam change
   3.6 Beam failure recovery

Putting It All Together
5G NR Air Interface Overview - Part II

5G promises to enable a variety of new services, ranging from high-speed, high-capacity broadband access to ultra reliable low-latency communications to massive machine-type communications. To deliver on these promises, the wireless network must change, including the devices, the radio interface, the radio access network (RAN), and the core network. Part I of this self-paced course offers a high-level technical overview of 5G NR (New Radio) air interface. Part II covers the flexible numerologies, channels and frame/slot structure, and steps through the life of a 5G UE, concluding with how the technologies and standards converge to meet the performance goals set for 5G.

Intended Audience
This course is designed for a broad audience of wireless network engineers. This includes those in RF, RAN planning, engineering, operations, troubleshooting and support groups.

Objectives
After completing this course, the learner will be able to:
- Identify key channels and their usage in the downlink and uplink
- Step through the life of a 5G UE at a high level in non-standalone architecture
- Step through the life of a 5G UE at a high level in standalone architecture
- Identify ways in which 5G NR meets the performance goals of 5G

What You Can Expect
- Self-Paced Duration: 1 HOUR

Outline
1. Key Signals and Channels of 5G NR
   1.1 Downlink signals and channels
   1.2 Uplink signals and channels
2. Life of a 5G UE
   2.1 NSA vs. SA operations
   2.2 Non-Standalone operations
   2.3 Network acquisition
   2.4 Attach
   2.5 Data transfer
   2.6 Standalone Operations
   2.7 Network acquisition
   2.8 Registration
   2.9 PDU session setup
   2.10 Data transfer
3. Meeting 5G Performance Goals
   3.1 Ways to achieve higher data rates
   3.2 Ways to achieve lower latency
   3.3 Ways to achieve higher connection density
Putting It All Together
Welcome to RF Planning and Design

This course provides an overview of the concepts of RF design. It defines the steps taken to create an accurate and reliable design. A number of inputs are required for the RF design. The cell coverage area is determined by the chosen frequency and its propagation characteristics as defined by the terrain (made up of natural or man-made obstructions), the traffic conditions expected to be encountered and the choice of possible candidate antenna sites. This course discusses how each of these inputs are characterized in the design exercise and what tools are used to aid in the design. The design process is iterative. In summary, this course provides the foundation necessary for understanding RF design and role it plays in wireless networks.

Intended Audience
This course is designed for a broad audience of personnel working in the wireless industry.

Objectives
After completing this course, the learner will be able to:
- Define the key steps in the RF design process
- Define key measurements used in network design
- Identify the tools used in network design
- Explain the propagation models applied
- Explain the differences between fast and slow fading and their influence
- Outline the influence of different morphologies on RF design
- Describe the role of link budgets in RF design

What You Can Expect
- Self-Paced Duration: 1 HOUR

Outline
1. Wireless Network Design Fundamentals
   1.1 RF design fundamentals
2. Propagation Characterization
   2.1 Propagation models and path loss
   2.2 Multipath and fast fading
   2.3 Shadowing and slow fading
3. Modeling Process
   3.1 UE RF measurements
   3.2 Coverage and capacity modeling
   3.3 Link budget planning
4. Design Outputs
   4.1 Cell size
   4.2 Site selection
5. RF Planning Tools
   5.1 RF planning tool
   Putting It All Together
Wireless Technologies and Network Operations

Wireless networks and related technologies are becoming ubiquitous in everyday life. Everyone who is in the field of telecom needs to have foundation knowledge of the wireless network and its operations and offered services. This training covers the end-to-end wireless architecture, connectivity of radio, core and transport networks, various types of cell sites such as macro, micro, small cells, etc. It also covers the foundations of radio technology such as frequency spectrum, channel bandwidth, role of antennas, and signal propagation. It gives an overview of key operations of the wireless network such as registration, voice/data call setup, and covers the KPIs used to monitor the health of the network.

Intended Audience
Everyone who needs a technical overview of wireless networks.

Objectives
After completing this course, the learner will be able to:

- Effectively use key terms and concepts of wireless networks
- Sketch wireless network elements such as LTE RAN, LTE Core, Transport, and IMS service network
- Understand role of frequency spectrum, channel bandwidth, and antenna on data rates
- Step through key procedures like Registration, Voice/Data call setup, Handovers
- Identify Key Performance Indicators (KPIs) to measure the performance of a wireless network

What You Can Expect
- Self-Paced Duration: 4 HOUR

Outline

1. End-to-End Wireless Network
   1.1 Evolution of wireless networks
   1.2 Cells, sectors and carriers
   1.3 Cell site and base station evolution
   Exercise: Knowledge check

2. Radio Technology Essentials
   2.1 Spectrum and antennas
   2.2 Signal generation and measurement
   2.3 Factors affecting radio signals
   Exercise: Knowledge check

3. Wireless Network Operations
   3.1 Connecting to a wireless network

Exercise:
4. Services and Key Performance Indicators
   4.1 IMS network and VoLTE calls
   4.2 Key Performance Indicators (KPIs)
   Exercise: 4G VoLTE Call Flow
   Exercise: Knowledge check

Putting it all together
Final assessment

3.2 Idle mode and paging
3.3 Handover and roaming
Exercise: 4G UE Attach
Exercise: Knowledge check
LTE-M and NB-IoT

This course high-level technical overview cellular Internet of Things (IoT) defined by 3GPP - LTE-M and NB-IoT. Fundamental concepts of IoT-centric optimizations for a wireless network are explained. IoT-specific characteristics of the wireless network and relevant UE categories (e.g., M1, M2 and NB1 and NB2) are described.

Intended Audience
Technical and product marketing personnel working for wireless operators, equipment and device manufacturers, as well as IoT architects and designers.

Objectives
After completing this course, the learner will be able to:
- Describe the meaning and motivation behind IoT and MTC
- Give examples of LPWA technologies and their characteristics
- Describe how Cellular IoT requirements are met in 4G LTE
- Describe the characteristics of Cat-M and Cat-NB devices
- Describe air interface characteristics for Cat-M and NB-IoT operations
- Describe different modes for data delivery for cellular IoT
- Sketch an end-to-end architecture and bearer paths for cellular IoT

What You Can Expect
- Prerequisite: LTE Overview
- Self-Paced Duration: 4 HOUR

Outline
1. IoT Basics
   1.1 IoT: What and Why?
   1.2 Wireless Optimizations for IoT
      Exercise: Knowledge Checks
2. LTE Enhancements for IoT
   2.1 Capacity Management and Enhancements
   2.2 Coverage Enhancements
   2.3 Battery Life Enhancements
      Exercise: Knowledge Checks
3. Network Features
   3.1 Device Positioning
   3.2 Network enhancements and Data delivery
      Exercise: Knowledge Checks
4. UE Categories and Operations
   4.1 UE categories in LTE-M and NB-IoT
   4.2 LTE-M operations
   4.3 NB-IoT operations
      Exercise: Knowledge Checks
Putting it all together
Final Assessment
5G Services and Network Architecture

This course is an overview of the 5G network and its targeted services. Starting with 5G services and performance targets, the 5G network architecture and building blocks are explored. Then, the evolution of the 5G RAN is discussed. An overview of key components for a 5G wireless network is given and fundamental technologies for a 5G network architecture are then discussed. Afterwards, potential deployment and evolution scenarios are summarized. Finally, RAN and core technologies converge with the exploration of network slicing, Mobile Edge Computing (MEC) and solutions for voice services in 5G.

Outline

1. 5G Services and Key Building Blocks
   1.1 5G Service categories and performance targets
   1.2 Key building blocks for 5G networks
   1.3 Features and capabilities of 5G networks
      Exercise: Knowledge check

2. 5G RAN and Core Network Architecture
   2.1 5G RAN evolution and split architecture
   2.2 vRAN and ORAN in 5G RAN
   2.3 5G Core network architecture
      Exercise: Knowledge check

3. 5G Operations and Deployment
   3.1 5G network deployments
   3.2 Life of a device in 5G NSA Option 3x networks
   3.3 Life of a device in 5G SA networks
      Exercise: Knowledge check

4. MEC and Network Slicing
   4.1 What is Multi-Access Edge Computing (MEC) and Why?
   4.2 Network slicing in 5G
   4.3 Voice solutions in 5G
      Exercise: Knowledge check

Putting it all together

Final Assessment

Intended Audience
A high-level technical overview to personnel involved in product management, marketing, planning, design, engineering, and operations.

Objectives
After completing this course, the learner will be able to:
■ Identify 5G use case families and related performance targets for 5G networks
■ Describe key building blocks of 5G that help achieve higher data rates and lower latency
■ Sketch the end-to-end 5G network architecture, including 5G NG-RAN and 5G Core (5GC)
■ Step through the life of a UE in 5G NSA and SA networks
■ Define MEC and network slicing and identify benefits in 5G networks
■ Identify voice solutions in 5G networks

What You Can Expect
■ Prerequisite: Welcome to 5G
■ Self-Paced Duration: 4 HOUR
5G Radio Technologies and Deployments

This training provides a technical overview of 5G Air Interface (New Radio) fundamentals and 5G Radio Access Network (RAN). The use of different frequency spectrums including mmW and their impact to coverage and capacity are described. The split architecture of gNB and how 5G RAN can be deployed for 5G Standalone (SA) and Non-Standalone (NSA) networks is explained with multiple learning activities and periodic knowledge checks for improved learning retention.

Intended Audience
A high-level technical overview for product management, marketing, planning, design, engineering, and operations

Objectives
After completing this course, the learner will be able to:
- Give examples of spectrum bands for 5G
- Summarize RF propagation differences between sub-6 GHz signals and mmW signals
- Explain how massive MIMO facilitates beamforming
- List the key features of 5G NR including the air interface, frame structure, and related numerology
- Sketch the 5G NG-RAN architecture
- Illustrate potential 5G deployment scenarios

What You Can Expect
- Prerequisite: Familiarity with 5G
- Self-Paced Duration: 4 HOUR

Outline
1. 5G NR Air Interface and 5G RAN
   1.1 Drivers for 5G NR and 5G RAN
   1.2 Low, mid, high frequency spectrum for 5G
2. 5G RAN evolution
   Exercise: Knowledge Check
3. 5G NR Air Interface Features
   3.1 Frame structure and numerology
   3.2 Beamforming and massive MIMO
   3.3 Downlink and uplink channels operations
   Exercise: Knowledge Check
4. 5G RAN Evolution
   4.1 Split architecture of gNB
4.2 Virtualization and Open RAN
4.3 Transport for 5G RAN
   Exercise: gNB split architecture
   Exercise: Knowledge Check
5. RF Planning and Deployment
   5.1 5G RAN planning for coverage
   5.2 5G RAN planning for capacity
   5.3 5G NSA and SA deployment
   Exercise: Knowledge Check
Putting it all together
Final Assessment

What You Can Expect
- Prerequisite: Familiarity with 5G
- Self-Paced Duration: 4 HOUR

Outline
1. 5G NR Air Interface and 5G RAN
   1.1 Drivers for 5G NR and 5G RAN
   1.2 Low, mid, high frequency spectrum for 5G
2. 5G RAN evolution
   Exercise: Knowledge Check
3. 5G NR Air Interface Features
   3.1 Frame structure and numerology
   3.2 Beamforming and massive MIMO
   3.3 Downlink and uplink channels operations
   Exercise: Knowledge Check
4. 5G RAN Evolution
   4.1 Split architecture of gNB
4.2 Virtualization and Open RAN
4.3 Transport for 5G RAN
   Exercise: gNB split architecture
   Exercise: Knowledge Check
5. RF Planning and Deployment
   5.1 5G RAN planning for coverage
   5.2 5G RAN planning for capacity
   5.3 5G NSA and SA deployment
   Exercise: 5G NSA and SA architecture
   Exercise: Knowledge Check
Putting it all together
Final Assessment
VRAN and Open RAN Overview

The virtualized RAN and Open RAN initiative of the O-RAN Alliance are introduced into the 5G RAN to support 5G use cases of mobile broadband, edge computing, and IoT. This training presents an overview of 5G RAN and gNB split architecture, concepts of virtualization in RAN, role of RU, gNB-DU and gNB-CU and their connectivity of CPRI, eCPRI and Ethernet.

Intended Audience
This course is intended for planning, engineering, operations, and systems performance teams.

Objectives
After completing this course, the learner will be able to:
- Sketch the network architecture of 5G RAN and understand the placement of RAN components
- Draw the connectivity of RAN components and identify the role of CPRI and Ethernet
- Highlight the benefits of virtualization in RAN and potential use cases of virtualization
- Sketch O-RAN architecture for 5G RAN and define role of Split Option 7-2x
- Define RAN slicing and step through RAN slicing deployment using O-RAN

What You Can Expect
- Prerequisite: Welcome to 5G
- Self-Paced Duration: 4 HOUR

Outline
1. 5G RAN Architecture and Transport
   1.1 5G RAN evolution
   1.2 5G RAN (gNB) architecture
   1.3 Transport connectivity in 5G RAN
   Exercise: 5G RAN evolution
   Exercise: Knowledge check
2. Virtualization in 5G RAN
   2.1 Benefits of Virtualizing RAN
   2.2 Examples of V-RAN
   Exercise: Virtualization in 5G RAN
   Exercise: Knowledge check
3. Open RAN and O-RAN
   3.1 What is Open RAN and O-RAN?
   3.2 O-RAN architecture for 5G
   3.3 O-RAN Open Fronthaul Split Option 7-2x
   Exercise: O-RAN network
   Exercise: Knowledge check
4. RAN Slicing and O-RAN
   4.1 RAN slicing in 5G RAN
   4.2 RAN slicing using O-RAN
   Exercise: Knowledge check
Putting it all together
Assessment
Multi-Access Edge Computing (MEC)

Multi-Access Edge Computing (MEC) pushes cloud-computing capabilities closer to the user across multiple access network domains. This course provides an overview of the MEC framework, the underlying technology and its use cases.

Outline

1. What and Why MEC?
   1.1 What is MEC and Why?
   1.2 Benefits of MEC
   1.3 Location considerations for MEC deployment
   Exercise: Knowledge check

2. Enabling Technologies for MEC
   2.1 Enablers for MEC - Edge cloud, NFV, SDN
   2.2 5G RAN and 5G Core for MEC
   2.3 Role of Service-Based Interface (SBI) and API
   Exercise: Knowledge check

3. MEC Architecture
   3.1 MEC architecture of ETSI and 3GPP

4. MEC Operations and Deployment Scenarios
   4.1 MEC operations
   4.2 MEC deployment scenarios
   Exercise: Step through MEC operations
   Exercise: Knowledge check

Putting it all together
Final assessment

Intended Audience

A high-level technical overview to personnel involved in product management, marketing, planning, design, engineering, and operating wireless (4G, 5G) and wireline access networks

Objectives

After completing this course, the learner will be able to:
- Define Multi-Access Edge Computing (MEC)
- List the key use cases and benefits of MEC
- Illustrate the ETSI reference architecture for MEC
- Identify key technology enablers for MEC
- Describe how MEC interacts with the rest of the 5G network

What You Can Expect

- Prerequisite: 5G Core Network Overview
- Self-Paced Duration: 4 HOUR

Multi-Access Edge Computing (MEC) pushes cloud-computing capabilities closer to the user across multiple access network domains. This course provides an overview of the MEC framework, the underlying technology and its use cases.
Network Slicing in 5G

Network slicing is one of key components that provide logical virtual network slices to support diversified services like mobile broadband, massive IoT, and ultra-reliable low latency services by leveraging the technology of SDN and NFV. This course provides an overview of Network slicing across Core, RAN and Transport networks in 5G, its operation and deployment. The course also provides an insight into how Network slicing in 5G works better as compared to techniques used in 4G LTE.

Intended Audience
A high-level technical overview to personnel involved in product management, marketing, planning, design, engineering, and operations

Objectives
After completing this course, the learner will be able to:
- List examples of 5G usage scenarios and their unique needs
- Define a Network Slice and describe how slicing is applied across 5G networks
- Describe the limitations of Network slicing in 4G LTE networks
- Describe the procedures involved to operate a Network slice
- Explain the Life-cycle Management of Network slice

What You Can Expect
- Prerequisite: 5G Core Network Overview
- Self-Paced Duration: 4 HOUR

Outline
1. What and Why Network Slicing?
   1.1 5G Usage Scenarios
   1.2 Needs of Service Provider
   1.3 What is Network slice?
   1.4 Network Slicing today and its limitations
   1.5 Network slicing in 5G
2. Network Slicing in 5G Networks
   2.1 Core network
   2.2 Transport network
   2.3 Radio Access network
   2.4 Cloud Infrastructure (Multi-Tenancy)
3. Network Slicing Operations
   3.1 Selection of Network slice by UE
   3.2 Registration
   3.3 Session establishment
4. Network Slicing Deployment
   4.1 Network Slice Management Framework
   4.2 Deployment scenarios

Putting it all together
Final Assessment
5G Core Network (SA) Overview

This training provides a high-level technical overview of the 5G Core network, which is essential to deploy an end-to-end 5G Standalone (SA) network and exploit new services like network slicing, MEC, and Voice over NR (VoNR). It provides an overview of the Service-Based Architecture (SBA) of 5G Core, interworking with the 4G Core, and steps through the life of a wireless device in 5G SA networks. Topics have knowledge checks and hands-on learning activities improves learning retention.

Intended Audience
This course is intended for planning, engineering, and operations personnel.

Objectives
After completing this course, the learner will be able to:

■ Sketch the end-to-end 5G Standalone (SA) network architecture focusing on 5G Core (5GC)
■ Identify roles and connectivity of 5GC NFs such as AMF, SMF, UPF, UDM, PCF, etc.
■ Step through the essential operations like Registration and Data Session Setup
■ Sketch deployment of MEC, network slicing, and voice solutions in a 5G SA network

What You Can Expect
■ Prerequisite: Familiarity with 5G
■ Self-Paced Duration: 4 HOUR

Outline

1. 5G Core Network Architecture
   1.1 Key characteristics of 5G Core
   1.2 Key functions of 5G Core
   1.3 Mapping of 4G Evolved Packet Core (EPC) to 5G Core
   Exercise: Knowledge check

2. 5G Core Network Functions
   2.1 Essential Network Functions: AMF, SMF, UPF, etc.
   2.2 Service-Based Architecture (SBA) overview
   2.3 Interworking with 4G EPC
   2.4 Security in 5G
   2.5 5G Core reference architecture
   Exercise: Build 5G Core network
   Exercise: Knowledge check

3. Life of a UE using 5GC
   3.1 UE registration
   3.2 PDU session establishment
   3.3 QoS in 5G and comparison with 4G
   Exercise: Life of a device in 5G Standalone (SA) network
   Exercise: Knowledge check

4. Services in 5G
   4.1 Enabling Multi-Access Edge Computing (MEC) using 5G
   4.2 Network slicing in 5G
   4.3 Voice solutions in 5G
   Exercise: Knowledge check

Putting it all together
Final Assessment
O-RAN Architecture Overview

The Open RAN initiative of the O-RAN Alliance defines an O-RAN architecture that facilitates the deployment of 5G RAN to support use cases of mobile broadband, edge computing, and IoT. This training presents an overview of the O-RAN architecture, the components of the 5G RAN and its interfaces and likely deployment scenarios.

Outline
1. Drivers for Open RAN and O-RAN Alliance
   1.1 5G RAN evolution
   1.2 Open RAN: What and Why?
   1.3 O-RAN Alliance
   1.4 Role of Open Fronthaul
   Exercise: Knowledge check
2. O-RAN architecture for 5G
   2.1 O-RAN reference architecture
   2.2 Role of SMO and O-Cloud
   2.3 RAN Intelligent Controllers (RIC) and rApps/xApps
   2.4 AI and Automation in O-RAN
   Exercise: Build O-RAN-based 5G RAN
   Exercise: Knowledge check
3. O-RAN Operations
   3.1 Service instantiation and management
   3.2 E2 Service Models
   3.3 RAN policy and control
   Exercise: Step through O-RAN operations
   Exercise: Knowledge check
4. O-RAN Deployment Scenarios
   4.1 Deployment considerations and location strategy
   4.2 RAN slicing using O-RAN
   Exercise: Knowledge check
Putting it all together
Final Assessment

Intended Audience
This course is intended for planning, engineering, and systems integration teams.

Objectives
After completing this course, the learner will be able to:
- Identify key drivers for 5G RAN based on O-RAN architecture
- Sketch O-RAN architecture for 5G RAN and describe role of each logical function
- Describe SMO architecture and its role in interfacing with external applications
- Identify the importance of Open Interface Split Option 7-2x
- Define RAN slicing and step through RAN slicing deployment using O-RAN

What You Can Expect
- Prerequisite: Welcome to 5G
- Self-Paced Duration: 4 HOUR

What You Can Expect
- Prerequisite: Welcome to 5G
- Self-Paced Duration: 4 HOUR
5G Services and Network Architecture

This course is an overview of the 5G network and its targeted services. Starting with 5G services and performance targets, the 5G network architecture and building blocks are explored. Then, the evolution of the 5G RAN is discussed. An overview of key components for a 5G wireless network is given and fundamental technologies for a 5G network architecture are then discussed. Afterwards, potential deployment and evolution scenarios are summarized. Finally, RAN and core technologies converge with the exploration of network slicing, Mobile Edge Computing (MEC) and solutions for voice services in 5G.

Intended Audience
A high-level technical overview to personnel involved in product management, marketing, planning, design, engineering, and operations.

Objectives
After completing this course, the learner will be able to:
- Identify 5G use case families and related performance targets for 5G networks
- Describe key building blocks of 5G that help achieve higher data rates and lower latency
- Sketch the end-to-end 5G network architecture, including 5G NG-RAN and 5G Core (5GC)
- Step through the life of a UE in 5G NSA and SA networks
- Define MEC and network slicing and identify benefits in 5G networks
- Identify voice solutions in 5G networks

What You Can Expect
- Prerequisite: Welcome to 5G
- Expert-Led Live Duration: 4 HOUR

Outline
1. 5G Services and Key Building Blocks
   1.1 5G Service categories and performance targets
   1.2 Key building blocks for 5G networks
   1.3 Features and capabilities of 5G networks
      Exercise: Knowledge check
2. 5G RAN and Core Network Architecture
   2.1 5G RAN evolution and split architecture
   2.2 vRAN and ORAN in 5G RAN
   2.3 5G Core network architecture
      Exercise: Knowledge check
3. 5G Operations and Deployment
   3.1 5G network deployments
   3.2 Life of a device in 5G NSA Option 3x networks
   3.3 Life of a device in 5G SA networks
      Exercise: Knowledge check
4. MEC and Network Slicing
   4.1 What is Multi-Access Edge Computing (MEC) and Why?
   4.2 Network slicing in 5G
   4.3 Voice solutions in 5G
      Exercise: Knowledge check
Putting it all together
Final Assessment
5G Radio Technologies and Deployments

3GPP is evaluating various technologies to determine specific elements of a 5G wireless network. These technologies enable the 5G wireless network to achieve the 5G performance goals defined by ITU as part of IMT2020 requirements. This course describes potential spectrum for 5G including millimeter wave spectrum. 5G RF Planning based on the new spectrum is covered. Furthermore, the course discusses enhancements to advanced antenna techniques such as massive MIMO are explained as well as the new frame structure being investigated by 3GPP. Finally, potential deployment and evolution scenarios are summarized.

Intended Audience
A high-level technical overview to personnel involved in product management, marketing, planning, design, engineering, and operations

Objectives
After completing this course, the learner will be able to:
- Give examples of spectrum bands for 5G
- Summarize RF propagation differences between sub-6 GHz signals and mmW signals
- Explain how massive MIMO facilitates beamforming
- List the key features of 5G NR including the air interface, frame structure, and related numerology
- Sketch the 5G NG-RAN architecture
- Illustrate potential 5G deployment scenarios

What You Can Expect
- Prerequisite: LTE Overview
- Prerequisite: 5G Services and Network Architecture
- Expert-Led Live Duration: 4 HOUR

Outline
1. 5G Spectrum
   1.1 Performance Targets
   1.2 Low, Mid, High Spectrum
2. 5G RF Planning Considerations
   2.1 Propagation Characteristics
   2.2 Inputs to RF Design
3. Massive MIMO and Beamforming
   3.1 Beamforming Techniques
   3.2 Full Dimension MIMO
4. 5G NR Frame Structure and Numerology
   4.1 Frame Structure Enhancements
   4.2 5G NR Parameter Relationships
5. 5G RAN Evolution
   5.1 gNB Split Architecture
   5.2 RAN Transport Connectivity
6. 5G Deployment Scenarios
   6.1 NSA and SA Deployment
   6.2 NSA Architecture

View Curriculum
VRAN and Open RAN Overview

The virtualized RAN and Open RAN initiative of the O-RAN Alliance are introduced into the 5G RAN to support 5G use cases of mobile broadband, edge computing, and IoT. This training presents an overview of 5G RAN and gNB split architecture, concepts of virtualization in RAN, role of RU, gNB-DU and gNB-CU and their connectivity of CPRI, eCPRI and Ethernet.

Intended Audience
This course is intended for planning, engineering, operations, and systems performance teams.

Objectives
After completing this course, the learner will be able to:

- Sketch the network architecture of 5G RAN and understand the placement of RAN components
- Draw the connectivity of RAN components and identify the role of CPRI and Ethernet
- Highlight the benefits of virtualization in RAN and potential use cases of virtualization
- Sketch O-RAN architecture for 5G RAN and define role of Split Option 7-2x
- Define RAN slicing and step through RAN slicing deployment using O-RAN

What You Can Expect
- Prerequisite: Welcome to 5G
- Expert-Led Live Duration: 4 HOUR

Outline
1. 5G RAN Architecture and Transport
   1.1 5G RAN evolution
   1.2 5G RAN (gNB) architecture
   1.3 Transport connectivity in 5G RAN
   Exercise: 5G RAN evolution
   Exercise: Knowledge check

2. Virtualization in 5G RAN
   2.1 Benefits of Virtualizing RAN
   2.2 Examples of V-RAN
   Exercise: Virtualization in 5G RAN
   Exercise: Knowledge check

3. Open RAN and O-RAN
   3.1 What is Open RAN and O-RAN?
   3.2 O-RAN architecture for 5G
   3.3 O-RAN Open Fronthaul Split Option 7-2x
   Exercise: O-RAN network
   Exercise: Knowledge check

4. RAN Slicing and O-RAN
   4.1 RAN slicing in 5G RAN
   4.2 RAN slicing using O-RAN
   Exercise: Knowledge check

Putting it all together
Multi-Access Edge Computing (MEC)
Multi-Access Edge Computing (MEC) pushes cloud-computing capabilities closer to the user across multiple access network domains. This course provides an overview of the MEC framework, the underlying technology and its use cases.

Outline
1. What and Why MEC?
   1.1 What is MEC and Why?
   1.2 Benefits of MEC
   1.3 Location considerations for MEC deployment
      Exercise: Knowledge check

2. Enabling Technologies for MEC
   2.1 Enablers for MEC - Edge cloud, NFV, SDN
   2.2 5G RAN and 5G Core for MEC
   2.3 Role of Service-Based Interface (SBI) and API
      Exercise: Knowledge check

3. MEC Architecture
   3.1 MEC architecture of ETSI and 3GPP
   3.2 MEC and 4G-5G together
      Exercise: Design and deploy MEC in 5G
      Exercise: Knowledge check

4. MEC Operations and Deployment Scenarios
   4.1 MEC operations
   4.2 MEC deployment scenarios
      Exercise: Step through MEC operations
      Exercise: Knowledge check

Putting it all together

Intended Audience
A high-level technical overview to personnel involved in product management, marketing, planning, design, engineering, and operating wireless (4G, 5G) and wireline access networks

Objectives
After completing this course, the learner will be able to:
- Define Multi-Access Edge Computing (MEC)
- List the key use cases and benefits of MEC
- Illustrate the ETSI reference architecture for MEC
- Identify key technology enablers for MEC
- Describe how MEC interacts with the rest of the 5G network

What You Can Expect
- Prerequisite: 5G Core Network Overview
- Expert-Led Live Duration: 4 HOUR

Multi-Access Edge Computing (MEC) pushes cloud-computing capabilities closer to the user across multiple access network domains. This course provides an overview of the MEC framework, the underlying technology and its use cases.
Network Slicing in 5G

Network slicing is one of key components that provide logical virtual network slices to support diversified services like mobile broadband, massive IoT, and ultra-reliable low latency services by leveraging the technology of SDN and NFV. This course provides an overview of Network slicing across Core, RAN and Transport networks in 5G, its operation and deployment. The course also provides an insight into how Network slicing in 5G works better as compared to techniques used in 4G LTE.

Outline
1. What and Why Network Slicing?
   1.1 5G Usage Scenarios
   1.2 Needs of Service Provider
   1.3 What is Network slice?
   1.4 Network Slicing today and its limitations
   1.5 Network slicing in 5G
2. Network Slicing in 5G Networks
   2.1 Core network
   2.2 Transport network
   2.3 Radio Access network
   2.4 Cloud Infrastructure (Multi-Tenancy)
3. Network Slicing Operations
   3.1 Selection of Network slice by UE
   3.2 Registration
   3.3 Session establishment
4. Network Slicing Deployment
   4.1 Network Slice Management Framework
   4.2 Deployment scenarios
Putting it all together

Intended Audience
A high-level technical overview to personnel involved in product management, marketing, planning, design, engineering, and operations

Objectives
After completing this course, the learner will be able to:
- List examples of 5G usage scenarios and their unique needs
- Define a Network Slice and describe how slicing is applied across 5G networks
- Describe the limitations of Network slicing in 4G LTE networks
- Describe the procedures involved to operate a Network slice
- Explain the Life-cycle Management of Network slice

What You Can Expect
- Prerequisite: 5G Core Network Overview
- Expert-Led Live Duration: 4 HOUR
5G - A Business Perspective

5G is generating a lot of discussion as the successor to 4G LTE. This primer looks carefully at 5G and provides a well-reasoned view of the technology and its potential. It brings a practical clarity to the question 'What is 5G?', defining 5G and covering important 5G terms and concepts. It helps participants explain why not all 5G is created equal, and explores the inherent flexibility built into the 5G specification. It also provides a perspective on the applications and monetization potential for this new technology.

Intended Audience
Those in business roles who need to speak accurately and confidently about 5G and its applications.

Objectives
After completing this course, the learner will be able to:
■ Concisely define 5G
■ Describe three areas of flexibility designed into 5G
■ Explain the benefits and challenges of deploying 5G in millimeter-wave and low-band spectrum
■ Describe different approaches that operators will take in deploying 5G
■ List and defend several key applications of 5G
■ Describe the 5G landscape in terms of the ecosystem and major players

What You Can Expect
■ Expert-Led Live Duration: 4 HOUR

Outline
1. 5G in a Nutshell
   1.1 5G: What and why
   1.2 5G performance targets
   1.3 5G flexibility: three key applications
   1.4 The 5G roadmap
   1.5 5G New Radio (NR)
2. 5G: The Radio Side
   2.1 5G, spectrum implications and millimeter wave spectrum
   2.2 Massive MIMO and beamforming
   2.3 5G: How fast?
   2.4 Low latency: How low, and who cares?
   2.5 Edge Computing and Multi-Access Edge Computing (MEC)
   2.6 What does ultra-reliable mean in 5G?
   2.7 5G: Separating hype from reality
3. 5G: The Network Side
   3.1 5G Non-Standalone (NSA) New Radio
   3.2 5G Standalone (SA) New Radio
   3.3 The virtualized core
   3.4 Network slicing
4. 5G Deployment Approaches
   4.1 5G for coverage
   4.2 5G for speed
   4.3 5G for fixed access
5. Monetizing 5G
   5.1 Applications enabled by 5G
   5.2 5G business models
   5.3 5G for fixed wireless
   5.4 5G for the enterprise
   5.5 5G and IoT
Integrated Access and Backhaul (IAB) Overview

This training is a high-level technical overview of Integrated Access and Backhaul (IAB) - a 3GPP solution to explore higher frequencies including mmW to provide access to end devices as well as offer a backhaul transport solution for dense 4G and 5G radio networks.

Intended Audience
This course is intended for planning, engineering, and operations personnel.

Objectives
After completing this course, the learner will be able to:
- Define IAB and why it is needed
- Sketch the IAB architecture
- Step through the key operations of IAB
- Identify deployment scenarios of IAB for improving coverage and capacity

What You Can Expect
- Expert-Led Live Duration: 4 HOUR
- 3.1 Multiplexing access and backhaul
- 3.2 Route management
- 3.3 IAB resource management
- 3.4 Backhaul bearer setup
- Exercise: Knowledge check
- 4.1 Cell densification
- 4.2 Coverage fill
- 4.3 Coverage extension
- Exercise: Knowledge check
- Putting it all together
- Final Assessment
5G Core Network (SA) Overview

This training provides a high-level technical overview of the 5G Core Network, which is essential to deploy an end-to-end 5G Standalone (SA) network and exploit new services like network slicing, MEC, and Voice over NR (VoNR).

**Intended Audience**
This course is intended for planning, engineering, and operations personnel.

**Objectives**
After completing this course, the learner will be able to:
- Sketch the end-to-end 5G Standalone (SA) network architecture focusing on 5G Core (5GC)
- Identify roles and connectivity of 5GC NFs such as AMF, SMF, UPF, UDM, PCF, etc.
- Step through the essential operations like Registration and Data Session Setup
- Sketch deployment of MEC, network slicing, and voice solutions in a 5G SA network

**What You Can Expect**
- Prerequisite: 5G Core Network Overview (On-Demand)
- Expert-Led Live Duration: 4 HOUR

**Outline**

1. 5G Core Network Architecture
   1.1 Principles of 5G Core - Virtualization and CUPS
   1.2 Service-Based Architecture (SBA)
   1.3 5G Core network architecture for SA
   1.4 Network functions and services
   Exercise: Build a 5GC network
   Exercise: Knowledge check

2. Deeper Dive on 5G Network Functions
   2.1 AMF, SMF, UPF
   2.2 Subscriber Management: UDM, UDR, AUSF
   2.3 Charging and Policy Functions: PCF, CHF, etc.
   2.4 Unique functions: NRF, NEF, NSSF
   2.5 Interworking and roaming architecture of 5G
   Exercise: Knowledge check

3. Life of a UE using 5GC
   3.1 UE registration
   3.2 PDU session setup
   3.3 QoS in 5G and comparison with 4G
   Exercise: Message flow for life of a UE
   Exercise: Knowledge check

4. Services in 5G
   4.1 Enabling Multi-Access Edge Computing (MEC) using 5G
   4.2 Network slicing in 5G
   4.3 Voice and SMS in 5G
   Exercise: Knowledge check

Putting it all together

View Curriculum
O-RAN Architecture Overview
The Open RAN initiative of the O-RAN Alliance defines O-RAN architecture that facilitate deployment of 5G RAN to support use cases of mobile broadband, edge computing, and IoT. This training presents an overview of O-RAN architecture, components of 5G RAN and its interfaces and likely deployment scenarios.

Outline
1. Drivers for Open RAN and O-RAN Alliance
   1.1 Need for Open RAN
   1.2 Industry initiative and role of O-RAN Alliance
   1.3 Virtualization in 5G RAN
   1.4 Role of artificial intelligence and automation
   Exercise: Knowledge check
2. O-RAN architecture for 5G
   2.1 O-RAN reference architecture
   2.2 Functions of O-CU-CP, O-CU-UP, O-DU, O-RU
   2.3 Role of Service Management and Orchestration (SMO)
   2.4 RAN Intelligent Controllers (RIC)
   2.5 O-RAN interfaces - A1, E1, E2, ...
   2.6 O-RAN Open Fronthaul Split Option 7-2x
3. O-RAN Operations
   3.1 Service instantiation and management
   3.2 Interactions between xApps and E2 nodes
   3.3 RAN usage scenarios
   Exercise: Knowledge check
4. O-RAN Deployment Scenarios
   4.1 Location strategy for Near RT-RIC, O-CU, O-DU, O-RU
   4.2 RAN slicing using O-RAN
   Exercise: Knowledge check
Putting it all together

Intended Audience
This course is intended for planning, engineering, and systems integration teams.

Objectives
After completing this course, the learner will be able to:
- Identify key drivers for 5G RAN based on O-RAN architecture
- Sketch O-RAN architecture for 5G RAN and describe role of each logical function
- Describe SMO architecture and its role in interfacing with external applications
- Identify the importance of Open Interface Split Option 7-2x
- Describe O-RAN slicing and step through RAN slicing deployment using O-RAN

What You Can Expect
- Prerequisite: Welcome to 5G
- Expert-Led Live Duration: 4 HOUR
MEC Architecture and Operations Overview

Multi-Access Edge Computing (MEC) pushes cloud computing capabilities closer to the user across multiple access network domains. This course provides an overview of MEC framework, underlying technology and its use cases. The course starts with the definition of MEC, its characteristics, benefits, and business drivers. The MEC architecture defined by ETSI is illustrated. Technology enablers for MEC such as the cloud infrastructure, NFV, SDN, CUPS, Microservices, and 5G core are discussed. MEC location strategies are summarized. The course concludes with a discussion on challenges faced by MEC.

### Intended Audience
A high-level technical overview to personnel involved in product management, planning, design, engineering, and operation.

### Objectives
After completing this course, the learner will be able to:
- Define Multi-Access Edge Computing (MEC)
- List the key use cases and benefits of MEC
- Illustrate the ETSI reference architecture for MEC
- Identify key technology enablers for MEC
- Describe how MEC interacts with the rest of the 5G network

### What You Can Expect
- Prerequisite: Welcome to SDN and NFV - Foundations
- Expert-Led Live Duration: 7 HOUR

### Outline

1. *Edge Computing and Enablers*
   1.1 Defining MEC
   1.2 Business drivers
   1.3 Key enablers of MEC
   1.4 Cloud infrastructure
   1.5 CUPS Architecture in 4G LTE
   1.6 Virtualizing Core
   1.7 Software-Defined Networking (SDN)

2. *Network Architecture for MEC*
   2.1 4G EPC and 5G Core Networks
   2.2 Service Based Architecture (SBA) in 5G
   2.3 Role of NSSF and NEF
   2.4 MEC standardization (e.g., ETSI and 3GPP)
   2.5 ETSI reference architecture
   2.6 Mobile Edge Host (platform, infrastructure, applications)
   2.7 MEC management (host-level, system level)

3. *MEC Enablers in 5G*
   3.1 5G NR features for lower latency
   3.2 5G RAN features for lower latency
   3.3 Virtualizing RAN
   3.4 Selective Routing for MEC
   3.5 MEC in 5G (CAPIF, LADN, PDU Session)
   3.6 Cloud native Microservices
   3.7 Orchestration

4. *Deployment and Use Cases*
   4.1 MEC server location strategies
   4.2 Authentication and Security
   4.3 Example flow of MEC Operation
   4.4 Sample Use Cases
   4.5 Challenges and key considerations

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Network Slicing Architecture and Operations Overview

Network slicing is one of key components that provide logical virtual network slices to support diversified services like mobile broadband, massive IoT, and ultra-reliable low latency services by leveraging the technology of 5G, SDN and NFV. This course describes Network slicing across 5G Core, RAN and Transport networks, its operation and deployment. The course provides an insight into operational aspects for Network Slicing and how slice information is specified and used in various network procedures.

Intended Audience

A medium-level technical course for personnel involved in product management, marketing, planning, design, engineering, and operations

Objectives

After completing this course, the learner will be able to:

- List examples of 5G usage scenarios and their unique needs
- Define how slicing is applied to the 5G RAN, 5G Core and the transport network
- Illustrate the relationship between network slices, data networks and QoS
- Describe how slice information is used during NF selection and PDU Session setup procedures
- Explain the Life-cycle Management of Network slice

What You Can Expect

- Prerequisite: 5G Core Network Overview
- Expert-Led Live Duration: 7 HOUR

Outline

1. 5G Services and Network Slicing
   1.1 5G Usage Scenarios
   1.2 Why Network Slicing needed?
   1.3 What is a Network slice?
   1.4 Standardized Network slices

2. Network Slicing in 5G
   2.1 Core network functions and slicing
   2.2 Segment routing Transport network
   2.3 Radio Access network
   2.4 Orchestration and Slice Management

3. Defining Network Slices
   3.1 Subscriber Profile
   3.2 DNNs and QoS

4. Network Slicing Procedures
   4.1 UE Registration
   4.2 PDU Session establishment
   4.3 Session establishment
   4.4 Roaming and Network Slicing

5. Network Slicing Deployment
   5.1 Network Slice Management Framework
   5.2 Life Cycle Management
   5.3 Configuration Management
   5.4 Performance and Assurance
   5.5 Use cases

3.3 NF Registration and Discovery
5G Networks and Services

This course takes an in-depth look at the end-to-end 5G network (5GC, NG-RAN, and transport) and related operations including NSA and SA deployment scenarios. It provides key features and functionalities of the 5G NR, split architecture of NG-RAN, transport network options, 5G core network architecture based on SBA, and comparison with 4G EPC. Complementary technologies of network slicing, MEC as well as automation and orchestration are covered. It gives an overview of 5G operations through the life of a 5G device. Finally, 5G deployment scenarios of NSA and SA are captured.

Intended Audience
This technical course is intended for planning, design, engineering and operations personnel who need to get an understanding of the 5G core and radio network architecture and operations.

Objectives
After completing this course, the learner will be able to:

- Sketch 5G core (5GC) network architecture and identify network functions
- Sketch 5G RAN architecture and split architecture of gNB
- Describe various interfaces and related protocols of 5G end-to-end network
- Step through the life of a 5G device to understand key operations of 5G
- Identify technologies such as network slicing, edge computing, virtualization and orchestration
- Summarize the deployment status of 5G

What You Can Expect

- Prerequisite: 5G Core Network Overview
- Prerequisite: Introduction to 5G
- Expert-Led Live Duration: 14 HOUR

Outline

1. 5G in a Nutshell
   1.1 5G Services and performance goals
   1.2 End-to-end 5G network architecture
   1.3 Deployment options

2. 5G RAN Architecture
   2.1 RAN evolution for 5G
   2.2 5G RAN architecture, interfaces, and protocols
   2.3 Cloud and Open RAN

3. 5G Core Network Architecture
   3.1 Core network architecture
   3.2 Network functions and interfaces
   3.3 PDU sessions
   3.4 QoS in 5G
   3.5 Edge computing support
   3.6 Service-Based Architecture (SBA)
   3.7 Security framework in 5G
   3.8 LTE and 5G Interworking

4. Life of a UE in 5G
   4.1 Power up operation
   4.2 Registration
   4.3 IP connectivity
   4.4 QoS in 5G
   4.5 Data transfer
   4.6 Mobility
   4.7 Security in 5G

5. Supporting Technologies
   5.1 Cloud and virtualization
   5.2 Automation and orchestration
   5.3 Network slicing
   5.4 Multi-access Edge Computing (MEC)

6. 5G Deployments
   6.1 4G to 5G migration
   6.2 NSA Option 3x Connectivity
   6.3 Split bearer options
   6.4 NSA call flows

View Curriculum
O-RAN Architecture and Operations

This training is a technical overview of Open RAN as defined by the O-RAN Alliance. It sketches the O-RAN architecture, defines the RAN logical functions, their interfaces, and steps through the deployment operations.

Intended Audience
This course is intended for planning, engineering, operations, and systems performance teams.

Objectives
After completing this course, the learner will be able to:

1. Identify the key technology enablers for Open RAN initiatives
2. Sketch O-RAN architecture, describe role of each logical function and their open interfaces
3. Describe SMO architecture and functions
4. Describe the role of Non-RT RIC, Near RT-RIC towards network operations
5. Describe A1/E2 operations that helps to improve Network Performance for different usage scenarios
6. Identify the different location strategies of O-RAN components and its challenges

What You Can Expect

- Prerequisite: Welcome to 5G (On-Demand)
- Expert-Led Live Duration: 7 HOUR

Outline

1. Open RAN Drivers
   1.1 Need for Open RAN
   1.2 Industry Initiative and role of O-RAN Alliance
   1.3 Separation of user and control planes
   1.4 Virtualization in 5G RAN
   1.5 Role of artificial intelligence and automation
   Exercise: Open RAN drivers

2. O-RAN Network Architecture
   2.1 O-RAN reference architecture
   2.2 Role of Service Management and Orchestration (SMO)
   2.3 SMO using ONAP and OSM
   2.4 RAN Intelligent Controllers (Non-RT RIC, Near RT RIC)
   2.5 Functionalities of O-CU-CP, O-CU-UP, O-DU, O-RU
   2.6 O-Cloud services
   2.7 O-RAN interfaces

3. O-RAN Operations
   3.1 Network service instantiation and management
   3.2 O-Cloud management and orchestration
   3.3 Non-RT RIC Services Framework
   3.4 A1/E2 interface protocol stack and procedures
   3.5 Interaction between xAPPs and E2 nodes
   3.6 RAN usage scenarios
   3.7 Fronthaul transport and synchronization
   Exercise: Operations in O-RAN

4. O-RAN Deployment Scenarios
   4.1 Near RT-RIC, O-DU, O-CU, O-RU location strategies
   4.2 Challenges and key considerations
   4.3 O-RAN slicing

2.8 O-RAN Split Option 7-2x Interface
2.9 APIs in O-RAN
Exercise: O-RAN architecture

What You Can Expect

- Prerequisite: Welcome to 5G (On-Demand)
- Expert-Led Live Duration: 7 HOUR

View Curriculum
5G NR Air Interface
This learning takes an in-depth look at the 5G New Radio (NR) Air Interface and key operations that enable a 5G Standalone (SA) network to support the 5G services.

Intended Audience

Objectives
After completing this course, the learner will be able to:
■ Describe the frame structure with numerology of the 5G NR air interface
■ List downlink and uplink signals and channels and describe their function
■ Identify key steps of network acquisition, random access, and connection setup
■ Explain how data is transferred in the downlink and the uplink
■ Step through the handover and idle/inactive mode operations

What You Can Expect
■ Prerequisite: Introduction to 5G
■ Self-Paced Duration: 14 HOUR

Outline
1. 5G NR Foundation
   1.1 Key features of 5G NR Air Interface
   1.2 5G Network Deployments
   1.3 5G Radio Access Network
   Exercise: 5G Radio Access Network
2. Spectrum and Numerology of 5G NR
   2.1 Frequency Spectrum
   2.2 OFDM and Numerology Overview
   2.3 5G NR Frame Structure
   2.4 Overview and Configuration of DSS
3. Spectral Efficiency
   3.1 Massive MIMO
   3.2 Beamforming Overview
   3.3 SDMA and Frequency Reuse
4. Meeting Service Requirements
   4.1 RAN Slicing
   4.2 Bandwidth Adaptation
   4.3 Low Latency
5. Channels and Signals
   5.1 5G Channels and Signals
   5.2 Sync Signals and PBCH
   5.3 SSB and Random Access in 5G
6. 5G Operations
   6.1 5G NSA Operations
   6.2 SA Network Acquisition
   6.3 Registration and PDU Session
   6.4 Overview of DL and UL Data
   Exercise: SA Network Acquisition
7. Mobility Operations
   7.1 Beam Switching
   7.2 Xn Handover
   7.3 Idle and Inactive in 5G
   Exercise: 5G Xn Handover
Final Assessment

View Curriculum
5G NR Air Interface

This learning takes an in-depth look at the 5G New Radio (NR) Air Interface and key operations that enable a 5G Standalone (SA) network to support the 5G services.

Intended Audience

Objectives
After completing this course, the learner will be able to:
- Describe the frame structure with numerology of the 5G NR air interface
- List downlink and uplink signals and channels and describe their function
- Identify key steps of network acquisition, random access, and connection setup
- Explain how data is transferred in the downlink and the uplink
- Step through the handover and idle/inactive mode operations

What You Can Expect
- Prerequisite: Introduction to 5G
- Total Expert-Led Live Duration: 3 HOUR
- Total Self-Paced Duration: 11 HOUR

Outline
1. 5G NR Foundation
   1.1 Key features of 5G NR Air Interface
   1.2 5G Network Deployments
   1.3 5G Radio Access Network
   Exercise: 5G Radio Access Network
2. Spectrum and Numerology of 5G NR
   2.1 Frequency Spectrum
   2.2 OFDM and Numerology Overview
   2.3 5G NR Frame Structure
   2.4 Overview and Configuration of DSS
3. Spectral Efficiency
   3.1 Massive MIMO
   3.2 Beamforming Overview
   3.3 SDMA and Frequency Reuse
4. Meeting Service Requirements
   4.1 RAN Slicing
   4.2 Bandwidth Adaptation
   4.3 Low Latency
5. Channels and Signals
   5.1 5G Channels and Signals
   5.2 Sync Signals and PBCH
   5.3 SSB and Random Access in 5G
6. 5G Operations
   6.1 5G NSA Operations
   6.2 SA Network Acquisition
   6.3 Registration and PDU Session
   6.4 Overview of DL and UL Data
   Exercise: SA Network Acquisition
7. Mobility Operations
   7.1 Beam Switching
   7.2 Xn Handover
   7.3 Idle and Inactive in 5G
   Exercise: 5G Xn Handover

Final Assessment
Week 1
- Session 1 (1 hrs)

Week 2
- Session 2 (1 hrs)

Week 3
- Session 3 (1 hrs)
5G Voice Solutions - VoNR and EPS Fallback

This learning takes an in-depth look at the architecture and operation of voice solutions in 5G networks such as VoNR and EPS Fallback. This flexible training combines instructor-led and self-paced activities to enhance the learning experience and effectiveness.

Intended Audience
Planning, design, engineering and operations personnel

Objectives
After completing this course, the learner will be able to:
- Sketch the architecture for voice services in 5G
- Describe the VoNR and EPS fallback services
- Illustrate the signaling flow for VoNR calls in 5G
- Describe the codecs used for VoNR
- Sketch the signaling procedures for EPS fallback
- Identify call flows for emergency services in 5G

What You Can Expect
- Prerequisite: 5G Networks and Services
- Prerequisite: Working knowledge of VoLTE, LTE and IMS operations
- Required Equipment: PC with access to Wireshark
- Total Expert-Led Live Duration:  9 HOUR
- Total Self-Paced Duration:         5 HOUR

Outline

1. Voice services in 5G
   1.1 4G, 5G, and IMS network architecture
   1.2 Introduction to EPS Fallback
   1.3 Introduction to VoNR
   Exercise: Voice Services in 5G

2. 5G and IMS Registration
   2.1 5G Architecture and Operations
   2.2 PDU Session, IMS Registration Call Flows
   2.3 Voice with IMS and VoNR
   2.4 IMS Pre-Call Functions
   2.5 IMS Registration
   Exercise: 5G and IMS Registration

3. EPS Fallback Operations
   3.1 LTE Interworking
   3.2 EPS and RAT Fallback
   3.3 Call Origination with EPS Fallback
   3.4 Call Termination with EPS Fallback
   3.5 Ending the Call
   3.6 EPS Fallback Call Flows
   Exercise: EPS Fallback

4. Voice over NR (VoNR) Operations
   4.1 VoNR call model
   4.2 Call Setup
   4.3 Resource Establishment
   4.4 Call Termination
   Exercise: VoNR call setup

5. Emergency calls in 5G
   5.1 E-Call in 5G with VoNR
   5.2 Call Setup – Pre-conditions Assumed
   5.3 E-Call Using EPS Fallback
   Exercise: Emergency calls in 5G

Final Assessment
LTE-M and NB-IoT Signaling and Operations

LTE-M and NB-IoT in the Low Power Wide Area (LPWA) cellular deployment have requirements such as low cost, enhanced coverage, high capacity, and long battery life. This course describes network architecture enhancements in LTE networks for IoT such as NIDD and SCEF. The fundamental operations such as network acquisition, random access, RRC connection setup, data transfer, and mobility are covered. This course requires message traces provided by the customer to step through various scenarios and exercises.

Outline

1. Network and Device Architecture
   1.1 MTC, eMTC, NB-IoT, & EC-GSM
   1.2 LTE network enhancements (e.g., NIDD and SCEF)
   1.3 APIs toward customer AS: OMA, OneM2M, and RESTful APIs
   1.4 External device identifiers
   1.5 UE module industry overview
   1.6 UE architecture

2. LPWA IoT-centric Features
   2.1 Wireless optimizations for IoT
   2.2 Power Save Mode (PSM)
   2.3 eDRX in Connected and Idle modes
   2.4 High latency communication
   2.5 Extended Access Barring (EAB)
   2.6 Optimized TAU signaling
   2.7 Half Duplex (HD) FDD
   2.8 eMBMS for IoT

3. LTE-M: A Closer Look
   3.1 Characteristics of UE category M1
   3.2 CE Mode A and CE Mode B
   3.3 MIB, SIB1-3, and SIB2
   3.4 LTE-M Random Access
   3.5 RRC Connection Setup for LTE-M
   3.6 LTE-M Attach enhancements
   3.7 MPDCCH configuration
   3.8 Using PDSCH, PUCCH, & PUSCH for LTE-M data transfer
   3.9 LTE-M KPIs

4. NB-IoT: A Closer Look
   4.1 Overview of UE category NB1
   4.2 Deployment scenarios (in-band, guard band, and standalone)
   4.3 Category NB1 multicarrier support
   4.4 Network acquisition in NB-IoT
   4.5 MIB-NB and System Information
   4.6 Random Access in NB-IoT
   4.7 NB-IoT RRC Connection Setup
   4.8 NB-IoT Attach enhancements
   4.9 NPDCCH configuration
   4.10 NPDSCH, NPUCH & NPUSCH for NB-IoT data transfer
   4.11 NB-IoT KPIs

5. Additional Material
   5.1 APIs (OMA, OneM2M, & RESTful) and IoT Protocols (MQTT-SN, CoAP, & Non-IP)
   5.2 UE location determination methods
   5.3 IoT enhancements in EC-GSM

Intended Audience
Technical personnel working for wireless operators, equipment and device manufacturers, who need a detailed look at LTE-M/eMTC and NB-IoT.

Objectives
After completing this course, the learner will be able to:
   ■ Describe key features of LTE-M and NB-IoT
   ■ Illustrate the network architecture with LPWA enhancements
   ■ Explain how of PSM and eDRX help increase UE battery life
   ■ Describe how EAB and optimized TAU reduce the signaling load
   ■ Summarize key parameters of System Information messages for LTE-M and NB-IoT
   ■ Discuss Attach enhancements for LTE-M and NB-IoT
   ■ Describe key operational configurations of LTE-M and NB-IoT physical channels
   ■ List main KPIs for LTE-M and NB-IoT

What You Can Expect
   ■ Prerequisite: LTE Overview
   ■ Prerequisite: LTE-M & NB-IoT
   ■ Expert-Led Live Duration: 21 HOUR
   ■ Additional development and customization fees apply
5G RF Planning and Design

This course takes an in-depth look at the RF planning and design aspects of 5G. It summarizes the essentials of the 5G air interface. MIMO and beamforming in 5G and suitable propagation models are discussed. The link budgets for 5G for different scenarios are calculated and compared with the LTE link budget. The RF cell configuration and RF operational parameters are discussed. Finally, the overall process of the RF design for 5G is described including traffic mapping and propagation modeling. The use of an RF planning tool to carry out the RF design is illustrated.

Intended Audience
This detailed technical course is intended for design, engineering, performance optimization and related job functions.

Objectives
After completing this course, the learner will be able to:

- Describe how the 5G air interface and the network infrastructure help deliver target 5G services
- Explain beamforming and MIMO concepts and list propagation models suitable for mmWave
- Specify key 5G RF design inputs and calculate the downlink and uplink cell capacity and throughput
- Explain components of a 5G link budget for different services and compare with LTE link budget
- Summarize the planning process for different RF configuration and operational parameters
- Illustrate steps of 5G RF design process, including traffic mapping and propagation modeling
- List the steps for 5G RF design using an RF Planning tool

What You Can Expect
- Prerequisite: 5G NR Air Interface
- Required Equipment: Laptop with RF propagation tool supporting 5G NR
- Expert-Led Live Duration: 21 HOUR

Outline

1. 5G Air Interface Essentials
   1.1 5G Use Cases and Performance Goals
   1.2 5G NR Technology
   1.3 5G NR Numerology
   1.4 DL and UL Channels and Signals

2. MIMO, Beamforming and Propagation Models
   2.1 MIMO and Beamforming in LTE
   2.2 MIMO Techniques in 5G NR
   2.3 Propagation Models

3. 5G Throughput and Capacity
   3.1 DL Throughput and Cell Capacity
   3.2 UL Throughput and Cell Capacity

4. 5G NR Link Budget
   4.1 Principles of Link Budget
   4.2 UL Link Budget for 5G
   4.3 DL Link Budget for 5G
   4.4 Factors Affecting Link Budget

5. 5G RF Parameter Planning
   5.1 PCI Planning
   5.2 Random Access Planning
   5.3 NR Carrier Add/Mod
   5.4 Uplink Power Control
   5.5 TA and RNA Planning

6. 5G RF Design
   6.1 5G RF Design Process
   6.2 5G RF Planning Tool Process
   6.3 5G RF Design – Site Selection

7. RF Planning Tool
   7.1 Key Parameters in RF Planning Tool
   7.2 Project Configuration
   7.3 Site Configuration
   7.4 5G Analysis

What You Can Expect

- Prerequisite: 5G NR Air Interface
- Required Equipment: Laptop with RF propagation tool supporting 5G NR
- Expert-Led Live Duration: 21 HOUR

View Curriculum
5G (NSA) RAN Signaling and Operations

This course takes an in-depth look at the life of a 5G device in the context of Non-Standalone (NSA) Option 3x deployment. It describes successful scenarios through signaling call flows. It steps through key operations such as power up and system acquisition, RRC connection setup, bearer setup with 4G LTE and 5G NR, and DL and UL operations on 5G NR. This course covers key operations through call flows with details of major messages and their key parameters. The course will help students with an in-depth understanding of successful call flows for Option 3x-based signaling and bearer paths.

Intended Audience
This detailed technical course is intended for engineering, systems performance, and operations related job functions who need to get an in-depth understanding of signaling procedures of NSA NR with the EPC deployment.

Objectives
After completing this course, the learner will be able to:

- Illustrate the architecture of Option 3x-based NSA deployment
- Sketch and describe the frame structure with numerology of the 5G NR air interface
- Identify key steps of preparing to monitor 5G cell and 5G network acquisition
- Identify key steps of random access and RRC connection setup
- Step through the data transfer operations in DL using different bearers (e.g., a split bearer)
- Step through the data transfer operations in UL using different bearers (e.g., a split bearer)
- Step through the handover and mobility operations for adding, modifying, and removing SgNB

What You Can Expect

- Prerequisite: 5G NR Air Interface
- Total Expert-Led Live Duration: 14 HOUR
- Total Self-Paced Duration: 7 HOUR

Outline

1. 5G NSA Network Architecture
   1.1 NSA Option 3x network architecture
   1.2 Signaling and data radio bearers in Option 3x
   1.3 Overview of EN-DC operations
   1.4 5G UE capability transfer
   Exercise: 5G NSA Operations

2. 5G Cell Acquisition
   2.1 Configuration for NR cell measurements
   2.2 SS/PBCH block
   2.3 NR cell measurements
   2.4 Measurement Report by 5G UE
   2.5 eNB-gNB X2 setup
   2.6 Overview of SgNB addition
   2.7 RRC Connection Reconfiguration for SgNB addition
   Exercise: 5G Cell Acquisition

3. Connecting to 5G gNB: Random Access
   3.1 Overview of random access
   3.2 PRACH configurations and radio resources
   3.3 Uplink synchronization in an NR cell
   Exercise: Random Access

4. DL Data transfer in 5G
   4.1 DL signals and UE measurements

5. UL Data Transfer in 5G
   5.1 Overview of UL traffic processing
   5.2 Scheduling requests
   5.3 Buffer status reports
   5.4 Resource allocation for UL
   5.5 UL data transmission
   5.6 Uplink power control
   Exercise: UL Data Transfer

6. Mobility and Idle Mode Operations
   6.1 Mobility and RRC states
   6.2 Mobility scenarios
   6.3 Measurements and handover signaling
   6.4 5G connection release
   6.5 Idle mode mobility
   Exercise: Mobility Operations

Final Assessment

Week 1
Session 1 (2 hrs)

Week 2
Session 2 (4 hrs)
Session 3 (4 hrs)

Week 3
Session 3 (4 hrs)
Session 4 (4 hrs)

Week 4
Session 4 (4 hrs)

View Curriculum

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5G (SA) RAN Signaling and Operations

This course takes an in-depth look at the life of a 5G device in the context of Standalone (SA) option 2 deployment. It describes successful scenarios through signaling call flows. It steps through key operations such as power up and system acquisition, RRC connection setup, bearer setup with 5G NR, and DL and UL operations on 5G NR. This course covers key operations through call flows with details of major messages and their key parameters. The course helps students with an in-depth understanding of successful call flows for Option 2 based signaling and bearer paths.

Outline

1. 5G SA (Option 2) Network
   1.1 End-to-end SA Architecture
   1.2 Use of Interfaces: NR, N1, N2, N3, Xn
   1.3 Role of protocols like PHY, MAC, RRC, PDCP, etc.
   1.4 NR Numerology and Frame structure
   1.5 Use of DL and UL Physical signals and Channels
   1.6 Role of Beamforming and MIMO
   Exercise: 5G SA Operations

2. 5G Cell Acquisition and RACH Procedure
   2.1 Synch Raster and Synchronization
   2.2 Cell ID and Beam ID Detection
   2.3 MIB and System Information Blocks (SIBs)
   2.4 Random Access Operation
   2.5 UE and gNB Timing Alignment
   2.6 RRC Setup and Indication for Network Slice
   Exercise: 5G Cell Acquisition

3. Registration and PDU Session Setup
   3.1 Registration and Authentication
   3.2 AMF, SMF and UPF Selection
   3.3 AS and NAS Security
   3.4 QoS Parameters in 5G
   3.5 PDU Session Setup

4. Traffic Operations in DL
   4.1 CSI-RS Measurement Configuration
   4.2 Feedback - CQI, PMI, RI, CRI, LI
   4.3 Resource Allocation for DL
   4.4 CSI-RS reports for Beam Selection and for MCS
   4.5 Carrier Aggregation and Band combinations
   Exercise: Traffic Operations in DL

5. Traffic Operations in UL
   5.1 Scheduling Request (SR) & BSR
   5.2 Resource Allocation for UL
   5.3 UL Power Control
   5.4 DCIs for UL operation
   Exercise: Traffic Operations in UL

6. Handover and Idle Mode Operations
   6.1 Beam Management - Switching, monitoring
   6.2 MAC CE changes of TCI state
   6.3 Xn and N2 based Handover
   6.4 Idle Mode Mobility
   Exercise: Handover and Idle Mode Operations

Final Assessment

Intended Audience
This detailed technical course is intended for engineering, RAN performance, and operations related job functions who need to get an in-depth understanding of signaling procedures of SA NR with the 5GC deployment.

Objectives
After completing this course, the learner will be able to:
- Step through the life of a 5G UE in SA (Option 2) deployment
- Identify steps of preparing to monitor 5G cell and 5G network acquisition
- Identify key steps of registering and setting up PDU session in SA
- Explore the role of beamforming in DL and UL traffic operations
- Step through the handover and mobility operations

What You Can Expect
- Prerequisite: 5G NR Air Interface
- Total Expert-Led Live Duration: 10 HOUR
- Total Self-Paced Duration: 11 HOUR

What You Can Expect
- Prerequisite: 5G NR Air Interface
- Total Expert-Led Live Duration: 10 HOUR
- Total Self-Paced Duration: 11 HOUR

Week 1
- Session 1 (2 hrs)

Week 2
- Session 2 (4 hrs)

Week 3
- Session 3 (4 hrs)
5G Core Network Signaling and Operations

The 5G Core (5GC) network architecture is a significant evolution from the 4G LTE EPC. Network functions have been de-composed and re-architected to enable more flexible usage of network resources. Network Slicing is a new capability that permits the operator to hone the network to meet specific applications’ requirements. The 5GC architecture enables implementation in virtualized networks. Students will step through various network operations and related call flows using actual logs where applicable and will be able to highlight key differences of 5G operations from LTE operations.

Intended Audience
This technical course is intended for planning, design, engineering and operations related job functions who require a detailed understanding of the 5G core network architecture and operations.

Objectives
After completing this course, the learner will be able to:
- Identify the Network Functions (NF) of the 5G core network and their roles in the 5GC
- Sketch the connectivity for the 5G network functions
- Describe the 5G UE registration procedure
- Describe PDU session setup procedures and the relationship to QoS in 5G
- Identify the 5G core components for user traffic routing
- Step through the procedures for Idle mode and connected mode mobility
- Describe the procedures for network slice assignment and selection for a 5G UE
- Illustrate the architecture for charging in 5G and how it is handled for a PDU session

What You Can Expect
- Prerequisite: 5G Core Network Overview
- Prerequisite: 5G Networks and Services
- Total Expert-Led Live Duration: 9 HOUR
- Total Self-Paced Duration: 12 HOUR

Outline
1. 5G Core Network Essentials
   1.1 End-to-end 5G NG-RAN to 5GC architecture
   1.2 5GC Network Functions - AMF, SMF, etc.
   1.3 SBA, APIs and NRF
   1.4 5G and virtualization technologies
   Exercise: 5GC Network Functions
2. Network Slicing
   2.1 3GPP defined use cases
   2.2 UE slice assignment and requests
   2.3 SMF and UPF assignment for slices
   Exercise: Network Slicing
3. UE Registration in 5G
   3.1 5G Identifiers and UE States
   3.2 Initial Registration
   3.3 Network slicing and AMF selection
   3.4 Authentication using AUSF and UDM
   3.5 AS and NAS Security
   Exercise: Registration call flow
4. PDU Session Establishment
   4.1 User Plane Traffic Path
   4.2 UE signaling for PDU Session Establishment
   4.3 SMF and UPF selection
   4.4 UE signaling for PDU Session Modification
4.5 UE signaling for PDU Session Release
4.6 UE signaling for UP deactivation/re-activation
4.7 UE signaling for UP
4.8 Charging framework in 5G and role of CHF
4.9 PDU session and charging
   Exercise: PDU Session Management call flows
5. QoS in 5G
   5.1 5G Quality of Service (QoS)
   5.2 PCF and QoS enforcement
   5.3 Use of multiple UPFs
   5.4 IMS Services in 5G and GBR flow establishment
   5.5 External application access and NEF
   Exercise: QoS Management
6. Mobility and Interworking with 4G EPC
   6.1 Idle Mode Mobility
   6.2 Connected Mode Mobility - Xn HO
   6.3 Connected Mode Mobility - N2 HO
   6.4 Session continuity
   6.5 Interworking with 4G EPC
   Exercise: Mobility Management
Final Assessment
5G (NSA) RAN Performance Workshop: Part 1

This workshop helps RAN engineers troubleshoot and optimize 5G NSA based RAN using market KPIs, vendor counters and parameter settings. Students use their tools for analyzing network performance. In addition, this workshop also introduces new features being deployed so students become familiar with the enhancements to their network. Instructor-led exercise sessions use signaling messages captured from live case studies (where available) to ensure the key learnings of the course material are reinforced. Note: This workshop requires UE and network traces of failure scenarios, RAN KPI definitions and network counters from the customer.

Intended Audience
This performance troubleshooting workshop is intended for Systems and RAN Performance engineers.

Objectives
After completing this course, the learner will be able to:
■ List the 5G NSA RAN KPIs that impacts network performance
■ Identify the factors and events that impact 5G NSA RAN KPIs
■ Analyze KPIs related to Accessibility, Retainability, Throughput, Handover
■ Understand the signatures that result into poor performance
■ Step through operations of features like Split bearer, PDCP Aggregation, etc.
■ Analyze various scenarios of poor performance and present the findings

What You Can Expect
■ Prerequisite: 5G NR Air Interface
■ Prerequisite: 5G (NSA) RAN Signaling and Operations
■ Required Equipment: Access to the KPI dashboards and network monitoring tools
■ Total Expert-Led Live Duration: 14 HOUR
■ Total Self-Paced Duration: 14 HOUR
■ Additional development and customization fees apply

Outline
1. 5G (NSA) RAN Performance Essentials
   1.1 5G (NSA) RAN KPIs
   1.2 Accessibility, Retainability, Integrity, Handovers
   1.3 Mapping call flow events to RAN KPIs
   1.4 Tools and KPI dashboards
   1.5 Key features - Split bearer, PDCP Aggregation, UL on NR
2. Accessibility Analysis
   2.1 SgNB Cell add success
   2.2 RACH success
   2.3 Call flow, Counter triggers, and KPIs
   Exercise: Accessibility problem analysis
   2.4 Impact of coverage of low, mid, high band for 5G
   2.5 Accessibility analysis walk-through
   Exercise: Case Studies: 5gNB Addition and RACH failure
   Exercise: Student Exercises
3. Retainability Analysis
   3.1 UE detected radio link failures
   3.2 eNB and gNB detected radio link failures
   3.3 Call flow, Counter triggers, and KPIs
   Exercise: Retainability problem analysis
4. Throughput and Latency Analysis
   4.1 UE and cell throughput and latency analysis
   4.2 Split bearer and PDCP Aggregation
   4.3 UL on 5G NR
   4.4 Call flow, Counter triggers, and KPIs
   Exercise: Throughput problem analysis
   4.5 Throughput and Latency analysis walk-through
   Exercise: Case Studies: Low Throughput
   Exercise: Student Exercises
5. Handover Analysis
   5.1 Intra-CU and Inter-CU Handovers
   5.2 Stages of Handover
   Exercise: Handover problem analysis
   5.3 Handover analysis walk-through
   Exercise: Case Studies: Anchor and SgNB HO failures
   Exercise: Student Exercises
   Student Presentations
   Final Assessment

Week 1
Session 1 (4 hrs)
Week 2
Session 2 (4 hrs)
Week 3
Session 3 (4 hrs)
Week 4
Session 4 (2 hrs)
**5G (NSA) RF Performance Workshop (UE Based)**

This workshop helps RAN and UE engineers analyze 5G NSA based RAN operations using actual UE logs. Students use the post processing tools to analyze LTE and NR messages, parameters, and their impact to user experience. Instructor-led exercise sessions use signaling messages captured from live case studies (where available) to ensure the key learnings of the course material are reinforced. Finally, students present one of their log analysis to reinforce the learning of this workshop.

**Intended Audience**
This performance troubleshooting workshop is intended for RAN and UE Performance engineers.

**Objectives**
After completing this course, the learner will be able to:
- List the 5G NSA RAN KPIs that impacts network performance
- Identify the factors and events that impact 5G NSA RAN KPIs
- Analyze UE logs to derive performance issues related to Setup, Radio link, Throughput, Handover
- Understand the failure signatures that result into poor performance
- Analyze various scenarios of poor performance and present the findings

**What You Can Expect**
- Prerequisite: 5G NR Air Interface
- Prerequisite: 5G (NSA) RAN Signaling and Operations
- Required Equipment: Access to the UE log post processing tool
- Total Expert-Led Live Duration: 10 HOUR
- Total Self-Paced Duration: 11 HOUR

**Outline**

1. **RF Performance Essentials**
   1.1 5G (NSA) RAN KPIs
   1.2 Accessibility, Retainability, Integrity, Handovers
   1.3 Mapping Call flow events and RAN KPIs
   1.4 Split bearer and PDCP Aggregation
   Exercise: UE log analysis

2. **Accessibility Analysis**
   2.1 SgNB Cell add success
   2.2 RACH success
   2.3 Call flow and event triggers
   2.4 Impact of coverage of low, mid, high band for 5G
   Exercise: Accessibility problem analysis
   Exercise: Student Exercises

3. **Retainability Analysis**
   3.1 UE detected radio link failures
   3.2 eNB and gNB detected radio link failures
   3.3 Call flow and event triggers
   Exercise: Retainability problem analysis
   Exercise: Student Exercises

4. **Throughput and Latency Analysis**
   4.1 UE and cell throughput and latency analysis
   4.2 Role of Dynamic Spectrum Sharing (DSS)
   4.3 Split bearer and PDCP Aggregation
   4.4 UL on 5G NR
   4.5 Call flow and event triggers
   Exercise: Throughput problem analysis
   Exercise: Student Exercises

5. **Handover Analysis**
   5.1 Intra-CU and Inter-CU Handovers
   5.2 Stages of Handover
   Exercise: Handover problem analysis
   Exercise: Student Exercises

Student Presentations
Final Assessment

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**Week 1**
Session 1 (2 hrs)

**Week 2**
Session 2 (4 hrs)

**Week 3**
Session 3 (4 hrs)
Network Virtualization Curriculum
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5G

Network Virtualization

LTE and VoLTE

Transport

Automation and Insights

ON-DEMAND - EXPRESS
Welcome to SDN and NFV Introductions
Welcome to SDN and NFV Foundations
Welcome to SDN and NFV Technologies
API Overview

ON-DEMAND - EXPANDED
Containers and Microservices in Telecom

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Containers and Microservices in Telecom
CNF and Kubernetes Orchestration Essentials
Cloud Native NFV Architecture and Operations Workshop
Kubernetes Orchestration Workshop

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Welcome to SDN and NFV - Introduction

Software Defined Networking and Network Functions Virtualization are reshaping what networks look like and how they are managed, and are providing significant competitive advantages for those providers who understand and deploy SDN and NFV based solutions. These solutions can improve customer response time and customer satisfaction, reduce errors and provide dynamic solutions that can automatically adjust to customer needs. This self-paced eLearning course provides a high-level understanding of the potential impact of SDN and NFV. It focuses on the business drivers behind the technology and an introduction into what is SDN and NFV without diving into too many details.

Intended Audience
The course is intended for all that are interested in understanding what are SDN and NFV, what are some key drivers, benefits and what the journey to SDN and NFV may look like.

Objectives
After completing this course, the learner will be able to:
- Summarize key drivers behind SDN and NFV
- Explain the fundamental shift that SDN and NFV enables
- Describe SDN and NFV each in a sentence
- Describe the differences between an SDN and NFV-based solution and a traditional approach
- Identify some key challenges involved with implementing SDN and NFV on a large scale

What You Can Expect
- Self-Paced Duration: 0.5 HOUR

Outline
1. The Why and What of SDN and NFV
   1.1 Why SDN and NFV
   1.2 What is SDN and NFV
   1.3 Impact to network operator
   1.4 SDN and NFV drivers
2. SDN and NFV
   2.1 The SDN and NFV shift
   2.2 NFV
   2.3 Define in Nine
   2.4 NFV at a Glance
   2.5 SDN
   2.6 Define in Nine
   2.7 SDN in actions
   2.8 Terminology and concepts
3. Benefits and Journey
   3.1 Key benefits
   3.2 Getting to SDN and NFV
Welcome to SDN and NFV - Foundations

Where did this technology shift come from? The enterprise IT space has made a dramatic shift with Web-scale IT, virtualization, DevOps, open source software and decomposing IT applications into smaller components to enable scaling. These same concepts are now moving into the network provider space and are the foundation for leveraging SDN and NFV. This foundations module will focus on understanding the new software paradigm, virtualization, DevOps, open source culture and application development approach.

Intended Audience
The course is intended for all that are interested in understanding the foundational concepts underlying SDN and NFV.

Objectives
After completing this course, the learner will be able to:
- Describe the power of software and the impact of virtualization
- Explain the concept of a Virtual Machine
- Define cloud computing and list its five key attributes
- Discuss the concepts of DevOps, open source software and Web-scale application development
- Differentiate between traditional service definition and cloud orchestration
- Relate the benefits of OpenStack

What You Can Expect
- Self-Paced Duration: 1 HOUR

Outline
1. Virtualization and Cloud Computing
   1.1 Define-in-Nine: Virtualization
   1.2 Define-in-Nine: Cloud Computing
   1.3 Key attributes of Cloud Computing
   1.4 Virtual Machines (VM)
   1.5 Containers
2. A New Approach to Software
   2.1 The shift towards software
   2.2 Open Source software
   2.3 Define-in-Nine: DevOps
   2.4 Decomposing application software for rapid scaling
3. Cloud Orchestration
   3.1 On-demand Cloud services
   3.2 Define-in-Nine: Orchestration
   3.3 Inter-Cloud
   3.4 Creating flexible networks
   3.5 OpenStack

Welcome to SDN and NFV - Foundations
Welcome to SDN and NFV - Technologies

Software Defined Networking (SDN) and Network Functions Virtualization (NFV) technologies are reshaping how telecom service providers’ networks operate resulting in more efficient operation that reduces costs and increases savings. Together, these solutions allow networks to operate at web-scale and provide customers with unprecedented levels of agility and flexibility.

Intended Audience
The course is for an audience interested in understanding how SDN and NFV provide optimal network solutions that not only provide customers with key benefits, but also improve the ability to respond to customer demands.

Objectives
After completing this course, the learner will be able to:
- Give examples of SDN and NFV in action
- Sketch an example of an SDN and NFV-based network
- Articulate how orchestration provides improved network management
- Explain how SDN, orchestration and NFV work together to improve the customer experience
- List some of the fundamental shifts due to SDN and NFV

What You Can Expect
- Prerequisite: Welcome to SDN and NFV - Foundations
- Self-Paced Duration: 1 HOUR

Outline
1. Today’s and Tomorrow’s Networks
   1.1 Complexity of today’s service provider’s network
   1.2 Physical and virtual network functions
   1.3 Conceptual model of tomorrow’s network
   1.4 Key concepts of Software-Defined Network
2. NFV and SDN
   2.1 NFV and SDN working together
   2.2 NFV
   2.3 NFV at a glance
   2.4 NFV in action
   2.5 NFV framework
   2.6 Benefits of NFV
   2.7 SDN

3. Automating the Network
   3.1 NFV orchestration at a glance
   3.2 Dynamic capacity scaling
   3.3 Service function chaining

4. Walkthroughs: Fine Dining and the Network

5. Applying SDN and NFV to Tomorrow’s Network
   5.1 New paradigms
   5.2 Fundamental shifts
API Overview

Wireless, wireline and cable service providers are on the cusp of a multitude of network and business transformation choices. A good conceptual understanding of the new networking and wireless, wireline and cable service provider business paradigms is essential for professionals in the communication industry. This course explores the technology behind Application Programming Interfaces (APIs), details the requirements and benefits of using APIs, and describes how to leverage APIs as part of network transformation.

Intended Audience
The course is intended for all that are interested in understanding what APIs are and how they will enable the transformation of the Wireless, Wireline and Cable service provider networks over the next few years.

Objectives
After completing this course, the learner will be able to:
- Outline the concept of Application Programming Interfaces (APIs)
- Describe how to leverage APIs as part of the Network Transformation
- Identify three possible examples of APIs

What You Can Expect
- Self-Paced Duration: 1 HOUR

Outline
1. What is an API?
   1.1 API defined
   1.2 What is an API?
2. Why APIs?
   2.1 Benefits of APIs
   2.2 Requirements of APIs
3. Using APIs
   3.1 API In action: End-to-end view of API
4. API Process
   4.1 Simplified API process
5. Technology Behind APIs
   5.1 RESTful APIs
5.2 OAuth2
6. APIs and Network Transformation
   6.1 APIs and network transformation
   6.2 Example: OpenStack APIs for VM Instantiation
   6.3 Example: APIs in Software-defined Networking
7. API Examples
   7.1 Data center example
   7.2 Wireless network example
   7.3 What is an API platform?
8. End of Course Assessment


Containers and Microservices in Telecom

This training provides a high-level technical overview of containers, cloud-native and microservices along with their applications and some use cases. The training explains container management and orchestration. In addition, the training describes Kubernetes functions and its high-level architecture, the role of container runtime and its options.

Outline

1. Server Host Virtualization
   1.1 Server Virtualization
   1.2 Virtual Servers - Challenges and Examples
   1.3 5G Containerized Network Functions
   Exercise: Knowledge Checks

2. Containers
   2.1 What is a Container?
   2.2 Role of Docker
   2.3 Container Security
   2.4 Open Container Initiative (OCI)
   Exercise: Knowledge Checks

3. Container Orchestration
   3.1 Container Management
   3.2 Kubernetes Overview
   3.3 Kubernetes Operations
   Exercise: Knowledge Checks

4. Microservice Architecture
   4.1 Microservices
   4.2 Software Decomposition
   Exercise: Knowledge Checks

Putting it all together
Final Assessment

Intended Audience
A high-level technical overview to personnel involved in product management, marketing, planning, design, engineering, and operations.

Objectives
After completing this course, the learner will be able to:
- Differentiate between light weight and heavy weight virtualization
- Illustrate the container management components
- Sketch microservice architecture and its relevance to containers
- Identify the key container lifecycle management concepts
- Step through the examples of uses of microservices

What You Can Expect
- Prerequisite: Welcome to SDN and NFV - Foundations
- Self-Paced Duration: 4 HOUR
Containers and Microservices in Telecom

This training provides a high-level technical overview of containers, cloud-native and microservices along with their applications and some use cases. The training explains container management and orchestration. In addition, the training describes Kubernetes functions and its high-level architecture, the role of container runtime and its options.

Intended Audience
A high-level technical overview for personnel involved in product management, marketing, planning, design, engineering, and operations.

Objectives
After completing this course, the learner will be able to:
- Differentiate between light weight and heavy weight virtualization
- Illustrate the container management components
- Explain the role of container runtime and its options
- Describe the microservice architecture and its relevance to containers
- Identify the key container lifecycle management concepts
- Describe an applicable use case of cloud native and microservices
- Sketch the high-level architecture of Kubernetes
- List the benefits of container orchestration

What You Can Expect
- Prerequisite: Welcome to SDN and NFV - Foundations
- Expert-Led Live Duration: 4 HOUR

Outline
1. Server Host Virtualization
   1.1 Server Virtualization
   1.2 Network Functions Virtualization Options
   1.3 5G Containerized Network Functions Use Case
   Exercise: Knowledge Checks
2. Containers and Container Runtime
   2.1 What is a Container?
   2.2 Role of Container Runtime and its Options
   2.3 Container Security
   2.4 Open Container Initiative (OCI)
   Exercise: Knowledge Checks
3. Container Orchestration
   3.1 Container Management
   3.2 Kubernetes Overview
   3.3 Kubernetes Operations
   Exercise: Knowledge Checks
4. Microservice Architecture
   4.1 Microservices Architecture
   4.2 Software Decomposition
   Exercise: Knowledge Checks
Putting it all together

What You Can Expect

■ Prerequisite: Welcome to SDN and NFV - Foundations
■ Expert-Led Live Duration: 4 HOUR
CNF and Kubernetes Orchestration Essentials

Networks such as 5G have been designed to better support containerization. Containerized Network Functions, CNFs, allow for higher capacity, but they have a number of challenges around networking, performance, isolation, and orchestration. The course provides a high-level introduction to deploying a containerized network in terms of the architecture, requirements, challenges, operations, and management. The course also discusses highlights of deployment, orchestration and operations considerations of cloud native functions, and microservices.

Intended Audience
This course is intended for personnel who are looking for a high-level introduction to Containers, Kubernetes and Docker-based cloud environments.

Objectives
After completing this course, the learner will be able to:
- Identify applications of containerized network and/or cloud native functions (i.e., 5G)
- Discuss CNF deployment options
- Identify key service deployment considerations
- Summarize the role of containerization in networks (i.e., 5G)
- Explain networking performance enhancement for containers
- List container runtimes and Kubernetes components and functions
- Discuss the role of container runtime and Kubernetes in enabling NFs CNFs
- List and describe containerized NF lifecycle management

What You Can Expect
- Prerequisite: Welcome to SDN and NFV Foundations
- Expert-Led Live Duration: 7 HOUR

Outline
1. Containers and Kubernetes In a Nutshell
   1.1 Need for cloud native network functions
   1.2 Containers and Microservices
   1.3 Role of Container Runtime and Kubernetes
2. Virtualized Infrastructure
   2.1 Network functions cloud deployment options
   2.2 Container Runtime Options and Components
   2.3 Kubernetes orchestration
   2.4 CNF deployment considerations
3. Network Functions Virtualization
   3.1 Service-Based Architecture
   3.2 Network functions as microservices considerations
4. Service Deployment Considerations
   4.1 Container performance considerations
   4.2 Container I/O performance enhancements
   4.3 Lifecycle management
Cloud Native NFV Architecture and Operations Workshop

Containerized Network Functions allow for higher capacity, but they have a number of challenges around networking, performance, isolation, and orchestration. The course provides a technical overview of deploying a containerized network – in terms of the architecture, requirements, challenges, operations, and management – and how they relate and complement one another. Containerized network functions use cases are used to explore the different options that are available in the containerized world. The course enables hands-on practice of some key concepts. Containerization has been in-use in the IT networks for a while and 5G network has been designed to better support containerization.

Intended Audience
This course is intended for a personnel in engineering and operations roles who are looking for a technical introduction to Containerized Network Functions and Kubernetes, containers, and OpenShift based cloud environments.

Objectives
After completing this course, the learner will be able to:
- Describe applications of containerization
- Compare Private, Public, and Hybrid cloud options
- Identify key service deployment considerations
- Discuss the role of containerization on networks
- Define network functions and network slice containerized deployment scenarios
- Define networking challenges of containerization
- List and describe Containerized NF Life Cycle Management
- Hands-on demonstration of some key containerized deployment concepts

What You Can Expect
- Prerequisite: Welcome to SDN and NFV Foundations
- Prerequisite: Containers and Microservices in Telecom
- Expert-Led Live Duration: 21 HOUR

Outline
1. Network Virtualization Using Containers
   1.1 Container and VM based Network Functions
   1.2 Containers Overview
   1.3 Containerized and Cloud Native NFs (CNFs)
   Exercise: Lab1: Lab-Setup and Containers
2. Virtualized Infrastructure
   2.1 Kubernetes Architecture
   2.2 OpenShift for Kubernetes
   2.3 Container Runtime Options
   Exercise: Lab2: Containers Resources
3. Service Deployment Considerations
   3.1 Containers Deployment Considerations
   3.2 Service Mesh in Kubernetes
   3.3 Service Based Architecture
4. Networking Considerations
   4.1 Containers Networking
   4.2 Kubernetes Service Routing
   4.3 Kubernetes Pod Routing
   4.4 SR-IOV and DPDK Considerations
   Exercise: Lab4: Container and K8s Networking
5. Orchestration and Deployment
   5.1 Kubernetes Orchestration Overview
   5.2 Kubernetes Package Manager
   5.3 Lifecycle Management
   Exercise: Lab5: Kubernetes Orchestration

3.4 Microservices for Network Functions
Exercise: Lab3: Build and Deploy A service
Kubernetes Orchestration Workshop

Competitive advantages of business agility drives the need for responsive and flexible IT infrastructure; which can be slow and expensive. The lead time to procure, install, configure, and commission new HW can take weeks. Containerization brings speed, agility, scalability, and availability with lower CapEx and OpEx. Hands-on operational exercises are provided with detailed explanations of Kubernetes component implementation, along with the basics of the technology that assist troubleshooting. Participants become Tenants and create multi-tiered network topologies and web service applications, enabling the participant to more adeptly deploy and support containerized applications in a Kubernetes environment.

Intended Audience
A hands-on in-depth technical training to personnel involved in design, engineering, and operations and monitoring telecom networks.

Objectives
After completing this course, the learner will be able to:
- Describe container orchestration
- Identify applications of Kubernetes in NFV
- Describe containers security and cloud-native tools
- Provision, manage and monitor Kubernetes resources
- Explain Kubernetes networking options
- Explore Kubernetes deployments and services
- Contrast the benefits of networking options
- Deploy CNFs and test their functionality

What You Can Expect
- Prerequisite: Cloud Native NFV Architecture and Operations
- Required Equipment: An additional monitor to run exercises is recommended
- Expert-Led Live Duration: 21 HOUR

Outline
1. Kubernetes Foundations
   1.1 Container overview and isolation
   1.2 Kubernetes components and architecture
   Exercise: Using security keys for users and tenants
   Exercise: Assign variable roles to K8s cloud tenants
   Exercise: Kubernetes namespaces and RBAC

2. Deployment of Pods
   2.1 Kubernetes capabilities and components
   2.2 Kubernetes deployments and services
   2.3 Realize the make up of containerized applications
   Exercise: Application scaling options
   Exercise: Tracing pods traffic
   Exercise: Deployments, services, logs, and scaling

3. Networking Services
   3.1 Networking capabilities and components
   3.2 Network policies and tenant isolation
   Exercise: Kubernetes pods intercommunication

Exercise: Apply network plugs and IP pools
Exercise: Assign deployments to certain namespaces
Exercise: Network plug, namespaces and policies

4. Using Repos and Helm - Lab Only
   Exercise: Image operations
   Exercise: Search Helm repos and packages
   Exercise: Use Helm Package Manager to deploy packages
   Exercise: Helm packages portability

5. Kubernetes Services
   5.1 Deploy Kubernetes applications and services
   5.2 Cloud-native service monitoring tools
   Exercise: Exposing K8s services options
   Exercise: Apply persistent data store to services

6. Additional Optional Labs
   Exercise: Ingress controller for multiple services
   Exercise: Applying datastore security
LTE and VoLTE
Curriculum
LTE and VoLTE

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Welcome to LTE
LTE Overview
Exploring LTE: Architecture and Interfaces
Exploring LTE: Signaling and Operations - Part I
Exploring LTE: Signaling and Operations - Part II
VoLTE Overview
Exploring VoLTE: Architecture and Interfaces
Exploring VoLTE: Signaling and Operations
Exploring VoLTE: KPIs and Error Codes
Overview of IPv6 in LTE Networks
LTE Air Interface Signaling Overview
Overview of OFDM
Multiple Antenna Techniques

EXPERT-LED
Overview of CBRS
Introduction to VoLTE
RF Design Workshop Part I - LTE
RF Design Workshop Part II - VoLTE and Small Cells
LTE RF Optimization Part I - Coverage and Accessibility
LTE RF Optimization Part II - DL and UL Throughput
LTE RF Optimization Part III - Mobility and Inter-RAT
LTE RF Optimization Part IV - Carrier Aggregation and Load Balancing
VoLTE Troubleshooting Workshop
VoLTE RAN Performance Workshop

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Welcome to LTE
Long Term Evolution (LTE) is one of the choices for next generation broadband wireless networks and is defined by the 3GPP standards as an evolution to a variety of 3G wireless networks, including both UMTS and 1xEV-DO; its high data rates enable a wide range of advanced multimedia applications. This on-demand offers a quick, high-level overview of LTE radio and Evolved Packet Core (EPC) networks.

Intended Audience
This course is an end-to-end overview of LTE networks and is targeted for a broad audience. This includes those in sales, marketing, deployment, operations, and support groups.

Objectives
After completing this course, the learner will be able to:

- Identify the motivations and goals for 4G networks
- Summarize the basic concepts of LTE Air Interface
- Sketch the high-level architectures of the E-UTRAN and EPC
- Describe the different categories of LTE UE
- Walk through a typical LTE call from power-up to service setup to disconnect
- Define the key services expected on LTE networks
- Illustrate the interworking solutions for GSM/UMTS and 1x/1xEV-DO networks
- Explain the important factors to consider when deploying LTE networks

What You Can Expect
- Self-Paced Duration: 1 HOUR

Outline
1. Motivations for 4G
   1.1 3G limitations
   1.2 LTE goals and targets
   1.3 4G building blocks
2. LTE Network Architecture
   2.1 LTE architecture goals
   2.2 LTE network components
   2.3 Evolved UTRAN (E-UTRAN)
   2.4 Evolved Packet Core (EPC)
3. LTE Devices
   3.1 Device categories
   3.2 Role of SIM card
4. LTE Air Interface
   4.1 Scalable bandwidth
   4.2 Supported radio bands
5. LTE Services
   5.1 Typical call setup sequence
   5.2 Basic and enhanced services
   5.3 Voice and SMS solutions
   5.4 IP Multimedia Subsystem (IMS)
   5.5 Policy and Charging Control (PCC)
6. LTE Deployment
   6.1 Interworking with GSM/UMTS
   6.2 Interworking with 1x/1xEV-DO
   6.3 Deployment considerations
   6.4 Backhaul options

OFDM/OFDMA concepts
Multiple antennas in LTE
Intended Audience
This course is an end-to-end overview of LTE networks, and is targeted for a broad audience. This includes those in design, test, sales, marketing, system engineering and deployment groups.

Objectives
After completing this course, the learner will be able to:
- Describe the state of wireless networks and trends for next generation wireless networks
- Sketch the System Architecture Evolution (SAE) for LTE and its interfaces
- Describe OFDM concepts and how it is used in LTE
- Define the key features of the LTE air interface
- Walk through the mobile device operations from power-up to service setup
- Explain how uplink and downlink traffic are handled in LTE networks
- Walk through a high level service flow setup on an end-to-end basis
- Explain deployment scenarios of LTE networks

What You Can Expect
- Self-Paced Duration: 3.5 HOUR

Outline
1. Setting the Stage
   1.1 Introduction to LTE
2. LTE Network Architecture
   2.1 Evolved Packet Core (EPC)
   2.2 E-UTRAN - eNodeB
   2.3 Network interfaces and protocol stacks
3. LTE Air Interface
   3.1 OFDM/OFDMA radio concepts
   3.2 SC-FDMA radio concepts
   3.3 Radio transmission frame structures
   3.4 Transport to physical channel mapping
4. LTE UE Operations
   4.1 System acquisition
   4.2 Idle mode operations
   4.3 Initial access procedures
4.4 QoS
4.5 Registration and traffic
5. LTE Traffic Handling
   5.1 Downlink traffic handling
   5.2 Uplink traffic handling
6. LTE Mobility
   6.1 Idle mode mobility
   6.2 Active mode mobility / handover
7. Deployment
   7.1 Typical LTE evolutionary path
8. Summary
   8.1 Put It All Together
   8.2 Assess the knowledge of the participant based on the objectives of the course

Long Term Evolution (LTE) is one of the choices for next generation broadband wireless networks and is defined by the 3GPP standards as an evolution to a variety of 3G wireless networks such as UMTS and 1xEV-DO. Its high data rates enable advanced multimedia applications. This on-demand course offers a quick and concise overview of LTE networks and the OFDM-based air interface. The LTE network architecture, network interfaces and protocols, air interface and mobility aspects are covered to provide an end-to-end view of the network.
Exploring LTE: Architecture and Interfaces

Long Term Evolution (LTE) is explicitly designed to deliver high-speed, high quality services to mobile subscribers. In order to achieve this, the LTE network architecture introduces a number of new network nodes and interfaces to implement the necessary functionality and manage the exchange of packets between mobile devices and external packet data networks. This on-demand class discusses the overarching goals of LTE networks and then defines the unique network functions needed to achieve those goals.

Outline

1. What is LTE?
   1.1 4G LTE
   1.2 Packet data networks

2. LTE Network Nodes and Functions
   2.1 E-UTRAN and EPC
   2.2 eNodeB
   2.3 MME
   2.4 HSS
   2.5 S-GW
   2.6 P-GW

3. Other Network Functions
   3.1 PCC
   3.2 DNS
   3.3 NAT/PAT
   3.4 Firewalls
   3.5 MSP
   3.6 OSS

4. LTE Network Interfaces and Protocols
   4.1 Internet Protocol (IP)
   4.2 S1-MME and S1-U
   4.3 S6a
   4.4 S11
   4.5 S5
   4.6 X2

5. EPC Bearers
   5.1 Default bearers
   5.2 Dedicated bearers

6. LTE Air Interface
   6.1 LTE-Uu protocol stack
   6.2 OFDMA and SC-FDMA
   6.3 OFDM and Cyclic Prefix
   6.4 Air interface physical layer
   6.5 Air interface physical channels
   6.6 Reference signals
   6.7 MIMO and diversity
   6.8 Basic traffic operations

Intended Audience

This course is intended for a technical audience looking for a detailed understanding of the important nodes, functions, and interfaces found in a typical LTE network.

Objectives

After completing this course, the learner will be able to:

- Discuss the rationale behind the 4G LTE network architecture
- Describe the critical network functions required in every LTE network
- Describe nodes and functions typically found in large commercial wireless networks
- Identify the key interfaces between LTE nodes and the protocols carried over each interface
- Define EPS bearers and describe their role in supporting user services
- Explain the structure and functions of the LTE air interface

What You Can Expect

- Self-Paced Duration: 1 HOUR
Exploring LTE: Signaling and Operations – Part I

The Long Term Evolution (LTE) network is designed to deliver services and content to mobile subscribers quickly and with high quality. To do this, the various elements within the network communicate with each other and with the mobile device using well-defined protocols and procedures to accomplish the tasks and operations required. This on-demand module is part one of the two-module package. Together, these two modules describe each of the key LTE operations.

Intended Audience
This course is intended for a technical audience looking for an in-depth understanding of the important signaling sequences and detailed operations used in a typical LTE network.

Objectives
After completing this course, the learner will be able to:
■ Describe how a UE accesses the LTE network on initial power-up
■ Explain the steps involved in attaching to the network and establishing PDN connections

What You Can Expect
■ Prerequisite: Exploring LTE: Architecture and Interfaces
■ Self-Paced Duration: 1.5 HOUR

Outline
1. RRC Connections
   1.1 Acquisition and downlink synch
   1.2 PCI and PCI planning
   1.3 MIB and SIBs
   1.4 RSRP, RSRQ, and SINR
   1.5 Cell selection and reselection
   1.6 Uplink synchronization
   1.7 PRACH configuration
   1.8 Preambles and RSIs
   1.9 RRC Connection setup
2. Network Attach
   2.1 Network Attach signaling
3. PDN Connections
   3.1 PDN connectivity
   3.2 IP addressing
   3.3 GTP tunneling
Intended Audience
This course is intended for a technical audience looking for an in-depth understanding of the important signaling sequences and detailed operations used in a typical LTE network.

Objectives
After completing this course, the learner will be able to:

■ Explain how user traffic is exchanged over the air interface under varying radio conditions
■ Define the physical layer functions needed to maintain an active radio connection
■ Discuss methods to track mobile location and maintain connection as it moves through a network
■ Describe the tasks the mobile must perform while in idle state

What You Can Expect
■ Prerequisite: Exploring LTE: Architecture and Interfaces
■ Prerequisite: Exploring LTE: Signaling and Operations – Part I
■ Self-Paced Duration: 1.5 HOUR

Outline
1. UL and DL Traffic Operations
   1.1 QCI and QoS parameters
   1.2 PCC
   1.3 CQI, RI, and PMI
   1.4 Downlink packet processing
   1.5 Uplink packet processing
   1.6 Error detection and recovery
2. Physical Layer Operations
   2.1 Timing alignment
   2.2 Power control
3. Mobility and Handover
   3.1 Handover measurements and events
   3.2 X2-based handover signaling
   3.3 S1-based handover signaling
4. Idle Mode Operations
   4.1 Paging
   4.2 Tracking area updates
VoLTE Overview

The LTE Evolved Packet Core (EPC) is an evolution of the 3GPP system architecture with the vision of an all-IP network finally realized. EPC in conjunction with IP Multimedia Subsystem (IMS) delivers various services such as VoIP, SMS, Video call, Picture share, IM and Presence. EPC and IMS support interworking with the existing 2G/3G wireless networks as well as PSTN to facilitate smooth migration, seamless mobility and service continuity across these networks. This on-demand module provides an overview of supporting voice services using LTE, which is known as Voice over LTE (VoLTE).

Intended Audience
This course is an overview of Voice over LTE, and is targeted for a broad audience. This audience includes those in planning, Integration, operations, and end-to-end service deployment groups.

Objectives
After completing this course, the learner will be able to:
- List various solutions for delivering voice in LTE networks
- Describe the role of LTE-EPC, PCC, and IMS in VoLTE
- Specify the roles of key IMS and PCC nodes
- Sketch inter-connectivity of LTE-EPC, IMS, and PCC nodes to deliver an end-to-end IMS call
- Summarize main steps of pre-call operations such as IMS registration
- Describe the main steps of setting up a VoLTE call
- Specify how SMS can be supported in LTE

What You Can Expect
- Prerequisite: LTE Overview
- Self-Paced Duration: 1.5 HOUR

Outline
1. Overview of EPS
   1.1 Supporting voice services in LTE
   1.2 Overall network architecture (EPS, IMS, PCC)
   1.3 Initial attach
   1.4 Default vs. dedicated EPS bearers
   1.5 Connectivity with IMS APN
2. Connectivity Among EPS, IMS, and PCC
   2.1 Overview of IMS elements
   2.2 Overview of PCC elements
   2.3 QoS model in LTE
   2.4 Connectivity of IMS, LTE-EPC & PCC
3. Pre-Call IMS Functions for VoLTE
   3.1 PDN connection to IMS
   3.2 P-CSCF discovery
   3.3 IMS registration
4. VoLTE Call Setup
   4.1 Overall steps for an all-IP call
   4.2 PCC-IMS interactions
   4.3 Dedicated bearer setup
5. VoLTE Scenarios
   5.1 LTE-PSTN interworking and role of IMS
   5.2 Overview of Single Radio Voice Call Continuity (SRVCC)
   5.3 Supporting SMS in LTE
6. Summary
7. Put It All Together
   7.1 Assess the knowledge of the participant based on the objectives of the course
Exploring VoLTE: Architecture and Interfaces

Long Term Evolution (LTE) network is optimized for delivering high-speed packet-oriented content and services to a large number of mobile users. However, some services, such as conversational voice over IP (VoIP), require special treatment in order to minimize end-to-end delay and provide a satisfactory user experience. The wireless industry has adopted the IP Multimedia Subsystem (IMS) architecture to implement real-time and multimedia services to LTE subscribers; Voice over LTE, or VoLTE, is the term given to voice services delivered over LTE. This on-demand course describes the network requirements for VoLTE and describes the IMS network components and interfaces needed to implement VoLTE and other IMS-based services.

Intended Audience
This course is intended for a technical audience looking for an in-depth understanding of the important nodes, functions, and interfaces found in a typical VoLTE/IMS network.

Objectives
After completing this course, the learner will be able to:

- Discuss the motivations and requirements for VoLTE and IMS
- Define the key nodes and functions needed in a typical IMS network
- Identify key interfaces between IMS nodes and define the protocols carried over each interface
- Illustrate the paths control signaling and voice media take through the LTE and IMS networks

What You Can Expect

- Prerequisite: Exploring LTE: Architecture and Interfaces
- Self-Paced Duration: 1 HOUR
Exploring VoLTE: Signaling and Operations

Long Term Evolution (LTE) use the IP Multimedia Subsystem (IMS) to implement and deliver Voice over LTE (VoLTE) services to mobile subscribers. IMS network elements communicate with each other and with the mobile device using well-defined protocols and procedures to execute the required operations. This on-demand course describes each of the key VoLTE operations in turn, starting with the mobile's initial registration with the IMS network, followed by the steps needed to initiate and receive VoLTE calls, and continuing with the challenges associated with interworking with non-VoLTE networks.

### Intended Audience
This course is intended for a technical audience looking for an in-depth understanding of the important signaling sequences and detailed operations used in a typical VoLTE network.

### Objectives
After completing this course, the learner will be able to:
- Describe the steps involved with registering with the IMS network
- Explain how VoLTE devices initiate and receive calls with each other
- Discuss the methods used to interwork with non-VoLTE networks
- Explain how supplementary services are implemented in VoLTE
- Describe the special requirements and operations needed for emergency calls
- Describe the air interface optimizations defined to improve VoLTE performance

### What You Can Expect
- Prerequisite: Exploring VoLTE: Architecture and Interfaces
- Prerequisite: Exploring LTE: Signaling and Operations Part I and II
- Self-Paced Duration: 1.5 HOUR

### Outline
1. **VoLTE Registration**
   1.1 P-CSCF and I-CSCF discovery
   1.2 S-CSCF selection
   1.3 Registration signaling
   1.4 De-registration signaling
2. **VoLTE Call Origination**
   2.1 Origination signaling
   2.2 Originating services and TAS
   2.3 Called party routing
   2.4 Preconditions
3. **VoLTE Call Termination**
   3.1 Termination signaling
   3.2 Terminating services and TAS
   3.3 SDP negotiation and alerting
   3.4 Dedicated bearer setup
4. **VoLTE Interworking**
   4.1 VoLTE-to-PSTN/3G signaling
   4.2 PSTN/3G-to-VoLTE signaling
5. **Supplementary Services**
   5.1 Telephony Application Server (TAS)
   5.2 Voicemail and MWI
   5.3 SMS and messaging
6. **Emergency Calling**
   6.1 Emergency numbers and sos APN
   6.2 E-CSCF selection and routing
7. **Air Interface Enhancements**
   7.1 Semi-Persistent Scheduling (SPS)
   7.2 TTI bundling
   7.3 RoHC
Exploring VoLTE: KPIs and Error Codes

Evaluating the performance of Long Term Evolution (LTE) and IP Multimedia Subsystem (IMS) networks can be challenging, given the complexity of the networks and the wide variety of services carried over them. The wireless industry has adopted a common set of Key Performance Indicators (KPIs) for LTE and VoLTE, allowing operators to develop a consistent set of monitoring tools independent of the specific vendors involved. This on-demand course defines these KPIs, discusses typical target values for each one, and describes typical failure scenarios for each of the metrics.

**Intended Audience**

This course is intended for a technical audience looking for an overview of the KPIs typically used to evaluate LTE and VoLTE networks, along with the more common error codes encountered in VoLTE signaling.

**Objectives**

After completing this course, the learner will be able to:

- Define the standard KPIs used to evaluate LTE and VoLTE performance
- Explain the common response and result codes reported in SIP and Diameter signaling messages

**What You Can Expect**

- Prerequisite: Exploring VoLTE: Signaling and Operations
- Self-Paced Duration: 0.5 HOUR

**Outline**

1. LTE KPIs
   1.1 Availability
   1.2 Accessibility
   1.3 Retainability
   1.4 Mobility
   1.5 Throughput

2. VoLTE KPIs
   2.1 Call Accessibility
   2.2 Call Retainability
   2.3 Call Mobility
   2.4 Mean Opinion Score (MOS)

3. SIP Error Codes
   3.1 Response codes

4. Diameter Error Codes
   4.1 Result codes
Overview of IPv6 in LTE Networks

Long Term Evolution (LTE) is universally accepted as the next generation broadband wireless system based on an All-IP network. Each LTE device would need at least one IP address to communicate and obtain services like web browsing, machine-to-machine communication, voice and video services, SMS, etc. As the number of IP connected nodes continue to grow, the current IPv4-NAT architecture no longer suffices and we must consider a transition to IPv6 protocol. This on-demand course explores the IPv6 protocol, its features and capabilities. It explains IPv6 address format, assignment of IPv6 address to LTE devices, dual-stack IPv4/IPv6 addressing to facilitate smooth transition, and IPv4-IPv6 interworking.

Intended Audience
This course is an overview of IPv6 addressing formats and IPv6 assignment operation, and is targeted for a broad audience. This includes those in planning, provisioning, operations, and end-to-end service deployment groups.

Objectives
After completing this course, the learner will be able to:

- Sketch LTE-EPC network architecture and identify the role of IPv6
- Analyze the limitations of IPv4 addresses
- List the key aspects of IPv6
- Sketch the IPv6 addressing architecture and addressing formats
- Discuss different UE IP address allocation schemes in LTE
- Describe the use of dual stack IPv4/IPv6 in LTE Networks
- Describe some IPv4 and IPv6 interworking scenarios
- Explain IPv6 address assignment scenarios of LTE networks

What You Can Expect
- Self-Paced Duration: 2 HOUR
LTE Network Architecture Overview
1. E-UTRAN architecture
2. EPC (MME, S-GW, P-GW, HSS)

LTE Air Interface Signaling Basics
1. LTE physical layer

System Acquisition
1. Power-up acquisition

Network Attachment and Default Bearer
1. Attachment steps
2. Default bearer setup

QoS and Dedicated Bearers
1. QoS classes
2. Dedicated EPS bearers

Uplink and Downlink Traffic
1. Downlink traffic operations
2. Uplink traffic operations

Idle Mode
1. Idle mode defined
2. Cell reselection
3. Tracking and paging

Handover
1. Handover types
2. Measurement
3. Handover stages

Summary
1. Put It All Together
2. Assess the knowledge of the participant based on the objectives of the course

Intended Audience
This course provides an overview of LTE signaling operations, and is targeted for a broad audience for a quick reference to LTE operations. This includes those in engineering, operations, and product sales/marketing.

Objectives
After completing this course, the learner will be able to:
- Sketch the key components of a typical LTE network and the interfaces between them
- List the key channels of DL and UL in LTE
- Provide an overview of call setup and related signaling in LTE
- Walk through the steps involved in a network attach
- Discuss the establishment of EPS bearers
- Explain how QoS requirements are managed in LTE
- Summarize the cell selection and reselection processes for idle UEs
- Illustrate how active connections are maintained during handovers

What You Can Expect
- Prerequisite: LTE Overview
- Self-Paced Duration: 3 HOUR

Long Term Evolution (LTE) is a leading contender for next generation broadband wireless networks, providing an evolution path for a variety of 3G wireless networks, such as UMTS and 1xEV-DO. LTE offers significantly higher packet data rates, enabling advanced multimedia applications and high-speed Internet access. This on-demand course takes a look at the LTE air interface and Non-Access Stratum (NAS) signaling operations used to establish and maintain LTE calls. The key LTE network components and interfaces are described, and then the steps involved in establishing and managing data calls are illustrated, highlighting the roles of each component and the flow of signaling and data across the network.
Overview of OFDM
Orthogonal Frequency Division Multiplexing (OFDM) is a transmission technique used to achieve very high data rates. OFDM is the technology of choice for all major wireless systems including Wireless LAN – 802.11, WiMAX – 802.16, digital audio/video broadcast systems, and the air interface evolution of 3G Wireless systems based on 3GPP and 3GPP2. OFDM facilitates higher data rates over a wireless medium, which is very exciting to wireless operators who are eager to deploy multimedia rich Internet content over a wireless medium with seamless access anywhere, anytime. This course describes key OFDM concepts and terminology.

Intended Audience
This is a technical course, primarily intended for those in system design, system integration and test, systems engineering, network engineering, operations, and support.

Objectives
After completing this course, the learner will be able to:
- Walk through the evolution of radio technologies
- Describe the evolution and applications of OFDM
- List the key attributes of OFDM and understand the frequency domain orthogonality
- Define various terms used in OFDM-based systems
- Describe challenges of radio propagation and how OFDM overcome these challenges
- Describe the key operation of cyclic prefix, FFT and IFFT
- List the basic transmitter and receiver components in an OFDM system
- Step through the operations of an end-to-end data transmission in an OFDM-based system

What You Can Expect
- Self-Paced Duration: 2 HOUR

Outline
1. Introduction
   1.1 Evolution of radio technologies
   1.2 Concepts of FDMA, TDMA, CDMA
   1.3 Need for OFDM for high data rates
2. Principles of OFDM
   2.1 Key attributes of OFDM
   2.2 Frequency domain orthogonality
   2.3 Time and frequency domain views
3. OFDM Basics
   3.1 Carrier and subcarrier
   3.2 Modulation and OFDM symbol
   3.3 Subcarrier spacing
   3.4 Guard period and cyclic prefix
4. Radio Propagation
   4.1 Multipath and doppler shift
   4.2 Inter Symbol Interference (ISI)
   4.3 Guard Time
4.4 Inter Carrier Interference (ICI)
4.5 Cyclic prefix and pilots
5. Fourier Transform
   5.1 Motivation for using Fourier Transforms in OFDM systems
   5.2 Concept of Fourier Transform
   5.3 Discrete Fourier Transform (DFT)
   5.4 Fast Fourier Transform (FFT)
   5.5 Implementation
6. End-to-End Transmission
   6.1 Transmitter and receiver components
   6.2 OFDM operations
7. Summary
   7.1 Put It All Together
   7.2 Assess the knowledge of the participant based on the objectives of the course
Multiple Antenna Techniques

Advanced multiple antenna technologies enable emerging 4G cellular technologies to achieve superior data rates over the air interface (e.g., in excess of 100 Mbps). While 4G networks utilize an efficient multiple access technique called Orthogonal Frequency Division Multiple Access (OFDMA), OFDMA on its own cannot deliver the expected superior throughput in 4G systems. Multiple antenna techniques play a critical role in increasing spectral efficiency. This on-demand course provides fundamental knowledge of numerous multiple antenna techniques that will be an integral part of emerging radio access standards.

Intended Audience

This course is intended for those seeking a fundamental understanding of how multiple antenna techniques work. This includes those in a systems engineering, sales engineering, network engineering, or verification role.

Objectives

After completing this course, the learner will be able to:

■ Outline key benefits and challenges of multiple antenna techniques
■ Provide examples of various types of multiple antenna techniques
■ Explain transmit and receive diversity techniques such as STC and antenna grouping
■ Contrast a switched-beam system with an adaptive beamforming technique
■ Describe MIMO spatial multiplexing techniques
■ Discuss the implementation of SDMA
■ Give examples of multiple antenna techniques defined in emerging 4G cellular networks

What You Can Expect

■ Self-Paced Duration: 3 HOUR

Outline

1. Antenna Basics
   1.1 Antenna Characteristics
   1.2 Antennas in commercial deployments
   1.3 Motivation for MIMO

2. Transmit and Receive Diversity Techniques
   2.1 Introduction to Diversity
   2.2 Receive Diversity Techniques
   2.3 Transmit Diversity Techniques

3. Beamforming Techniques
   3.1 Basics of Beamforming
   3.2 Receive and Transmit Beamforming
   3.3 Advanced Beamforming techniques

4. MIMO - Spatial Multiplexing
   4.1 Basics of spatial multiplexing
   4.2 MIMO and channel coding
   4.3 Advanced MIMO Techniques

Putting It All Together
Overview of CBRS

Exponentially rising data traffic, scarcity of spectrum, and expectations of enhanced user experience including 1Gbps data rates are driving operators to explore the use of shared spectrums such as CBRS – Citizens Broadband Radio Service. Operators can deploy LTE networks in 3.5 GHz CBRS spectrum using LAA. CBRS can be used in various business models including traditional mobile operators and new operators. CBRS also supports Private LTE networks. The course provides a high-level overview of the CBRS system, motivation for CBRS deployment, network architecture, network operation and deployment use cases.

Intended Audience
A high-level technical overview to personnel involved in product management, marketing, planning, design, engineering, and operations.

Objectives
After completing this course, the learner will be able to:
- Define CBRS
- Differentiate Tiered licensing structure: IA, PAL and GAA
- Give examples of use cases for CBRS
- Sketch the architecture of a CBRS-based network
- Describe the roles of a CBSD, SAS, and ESC
- Step through key operations of CBRS

What You Can Expect
- Prerequisite: LTE Overview
- Expert-Led Live Duration: 4 HOUR

Outline
1. CBRS Essentials
   1.1 Definition of CBRS
   1.2 Three-tier licensing structure (IA, PAL, GAA)
   1.3 Types of spectrum
   1.4 Band 48 for CBRS
   1.5 CBRS Standards bodies - CBRS Alliance, WinnForum
   1.6 CBRS Use cases
2. CBRS System Architecture
   2.1 End-to-end architecture
   2.2 CBSD categories A and B
   2.3 Key nodes: SAS, ESC, Proxy
   2.4 End user devices
   Exercise: CBRS Band characteristics
3. CBRS Operations
   3.1 Overview of CBSD operations
   3.2 Registration
   3.3 Grant Request
   3.4 Exchange between CBSD and SAS
   3.5 Inter-SAS communications
   3.6 Dynamic Protection Area (DPA)
   3.7 Security mechanism
4. CBRS Deployment
   4.1 Use cases: Mobile Offload, Fixed Wireless, Private LTE, Neutral Host
   4.2 CBRS in LAA and eLAA operation

Putting It All Together
Introduction to VoLTE

Since its standardization over a decade ago, VoLTE, or Voice over LTE, has been deployed by operators around the world. Compared to the traditional circuit-based 2G/3G voice solutions, VoLTE provides better voice experiences, enables rich multi-media communications features, and makes the network more efficient for operators. This course provides an overview of the LTE and IMS network architecture supporting VoLTE, and the key technologies used in VoLTE such as IMS and SIP. The course also covers high level information on key scenarios in VoLTE signaling and operations, media support, VoLTE interworking, roaming, and air interface enhancements for VoLTE.

Intended Audience
This blended (self-paced and instructor-led) course is intended for a technical audience looking for an overview of the drivers for VoLTE and a basic understanding of the underlying technologies being considered.

Objectives
After completing this course, the learner will be able to:

■ Describe the architectural elements of the LTE and IMS networks used to support VoLTE
■ Discuss benefits of VoLTE compared to traditional circuit-based 2G/3G voice
■ Explain key VoLTE signaling and operational scenarios including registration and call processing
■ Identify the key technology building blocks needed for VoLTE
■ Describe the network functions involved in VoLTE interworking and roaming
■ Discuss key air interface enhancements for VoLTE
■ List the key KPIs (Key Performance Indicators) used to measure VoLTE performance

What You Can Expect

■ Prerequisite: Welcome to LTE
■ Total Expert-Led Live Duration:  2 HOUR
■ Total Self-Paced Duration:         5 HOUR

Outline
1. Kickoff Session [Live: Web-based]
   1.1 Course Overview
   1.2 VoLTE Overview
2. The LTE Network
   2.1 LTE RAN and Core
   2.2 LTE Attach and PDN Connection Setup
   2.3 QoS in LTE
   2.4 IMS Architecture
3. VoLTE Operations
   3.1 VoLTE Registration
   3.2 VoLTE Call Origination/Termination
   3.3 EPS Bearers and DRBs for VoLTE
4. VoLTE Media
   4.1 Media Path and RTP
   4.2 Introduction to 5G New Radio
   4.3 Audio Codecs for VoLTE
   4.4 RoHC and Other Air Interface Enhancements
5. VoLTE Interworking
   5.1 VoLTE to 3G/PSTN Call Setup
   5.2 3G/PSTN to VoLTE Call Setup
   5.3 Outbound Roaming
6. KPIs
   6.1 KPIs and Failures Overview
7. Review Session [Live: Web-based]
RF Design Workshop: Part 1 - LTE

LTE offers significant improvements over previous mobile wireless systems in terms of data speeds and capacity, through the use of technologies such as OFDMA and multiple antenna techniques. However, these gains are realized only with careful planning and design in the LTE Radio Access Network (RAN), to maximize the efficiency of available RF spectrum. This hands-on workshop guides participants through the theory and practice of RF design for LTE RANs. Participants will apply their understanding of the LTE air interface physical structure and related concepts to calculate the link budgets to support the market coverage and performance requirements.

Intended Audience
This workshop is intended for LTE RF design and system performance engineers.

Objectives
After completing this course, the learner will be able to:
- Apply a consistent process to radio network design
- Assess LTE RAN RF performance with RSRP and RSRQ measurements
- Map network requirements to corresponding system parameters
- Construct uplink/downlink link budgets to meet specific performance requirements
- Use coverage and capacity requirements to determine the optimal radio network design
- Exploit multiple antenna techniques to optimize coverage and performance

What You Can Expect
- Prerequisite: LTE Overview
- Required Equipment: PC laptop with administrator privileges
- Expert-Led Live Duration: 14 HOUR

Outline
1. LTE Air Interface
   1.1 E-UTRAN architecture
   1.2 LTE Physical layer structure
   1.3 Air interface resources
   1.4 UE measurements (RSRP/RSRQ)
   1.5 RSRP/RSRQ exercises

2. Overview of LTE Radio Network Design
   2.1 Radio network design goals
   2.2 Planning inputs and outputs
   2.3 LTE RAN planning process

3. Market and Engineering Requirements
   3.1 Coverage requirements
   3.2 Capacity requirements
   3.3 QoS requirements
   3.4 Engineering requirements

4. LTE Link Budget
   4.1 Cell edge throughput calculations
   4.2 Link budget for UL and DL
   4.3 Role of RRH and TMA
   4.4 UL/DL link budget exercises

5. Antennas in LTE Networks
   5.1 Multiple antenna techniques
   5.2 Downlink feedback (CQI/RI/PMI)
   5.3 Deployment considerations
   5.4 Coverage prediction exercises

6. RF Design and Site Selection
   6.1 RF design process and options
   6.2 Morphology definitions
   6.3 Propagation models
   6.4 RF design tool configuration
   6.5 Coverage prediction

7. RF Configuration Parameters
   7.1 Sync signal and PCI planning
   7.2 Reference signal planning
   7.3 RA preamble planning
   7.4 PCI and RACH planning exercises

8. Advanced Features of LTE
   8.1 Carrier aggregation
   8.2 HetNet and eICIC support
   8.3 SON features
RF Design Workshop: Part 2 – VoLTE and Small Cells

With the introduction of LTE features such as Voice over LTE (VoLTE), multi-frequency, small cell deployment, and LTE-Advanced features, the existing RF design process needs to be enhanced. This workshop offers a foundation for features such as VoLTE, carrier aggregation, Heterogeneous Networks (HetNets), and small cells. The course revisits the data traffic driven link budget to reflect the VoLTE performance requirements and the differences for small cells. The antennas being planned to accommodate multi-band deployments are discussed, as well as the various RF parameters related to cell selection/re-selection and handover for proper load distribution in cases of multi-carrier and small cell deployment.

Intended Audience
This workshop provides practical examples and intertwines the exercises at every stage of the RF design process and is intended for RF designers, RF systems engineers, network engineers, deployment and operations personnel.

Objectives
After completing this course, the learner will be able to:
■ Enumerate design considerations of deploying LTE in various scenarios
■ Identify the key features of LTE-Advanced and their impact on RF design
■ Discuss the link budget and planning for VoLTE, multi-frequency, and small cell deployment
■ Sketch various antenna configurations
■ Calculate the air interface capacity needs for data and VoLTE traffic
■ Explain structure of RF design parameters related to cell selection, re-selection, and handover

What You Can Expect
■ Prerequisite: RF Design Workshop: Part 1 - LTE
■ Required Equipment: PC laptop with administrator privileges
■ Expert-Led Live Duration: 14 HOUR

Outline
1. LTE Radio Network Design Review
   1.1 Radio network design goals, inputs and outputs
   1.2 LTE radio network planning process
2. Antenna Considerations
   2.1 Multi-band antenna considerations
   2.2 4x4 MIMO considerations
   2.3 RRH deployment configurations
   2.4 Integrated antenna considerations
3. LTE Capacity Planning
   3.1 Data and VoLTE traffic modeling
   3.2 Air interface capacity planning
4. Link Budget for Small Cells
   4.1 Review LTE link budget for macro network
   4.2 Small cell considerations
   4.3 Impact of Tx power, frequency, of antennas
   4.4 Pathloss for UL and DL

Exercise: Link budget walk-through
5. Link Budget for VoLTE
   5.1 Link budget differences for VoLTE and data
   5.2 SINR requirement for VoLTE
   5.3 Use of RBs for VoLTE
   5.4 Pathloss for UL and DL
Exercise: Link budget walk-through

6. RF Design Considerations
   6.1 RF design guidelines
   6.2 RF design tool configuration
   6.3 Coverage prediction
   Exercise: Coverage and interference

7. Small Cell Parameter Configuration
   7.1 Cell selection/reselection parameters
   7.2 Handover parameters

View Curriculum
LTE RF Optimization: Part 1 – Coverage and Accessibility

This workshop provides insights into the symptoms and possible causes of field performance issues in LTE radio networks using UE logs. RF measurements related to coverage and interference are discussed to analyze coverage holes and overlapping regions. Students analyze LTE signaling messages through UE logs and map them to success and failure events. Students perform root cause analysis and gain an in-depth understanding of these signaling events to network performance. LTE RF optimization areas such as RRC connection setup, bearer drops, coverage issues. This knowledge transfer is obtained through hands-on experience using UE based diagnostic tools and scanner tools.

Intended Audience
This workshop is primarily intended for RF and systems performance engineers involved in LTE design, performance, and optimization.

Objectives
After completing this course, the learner will be able to:
- Define the LTE RF KPIs and map them to RAN counters
- Identify various LTE signaling events that map to success and failure operational counters
- Identify the RF measurements that are key to coverage and interference
- Analyze the measurements through post processing tools
- Analyze UE logs for root cause analysis of successful and failure events
- Map above events to operational counters and corresponding KPIs
- Accessibility and RRC connection and bearer setup
- Radio link failures and bearer drops

What You Can Expect
- Prerequisite: LTE Overview
- Required Equipment: PC laptop
- Expert-Led Live Duration: 10 HOUR

Outline
1. Workshop Overview
2. LTE RAN KPIs
   2.1 LTE RAN KPIs
   2.2 LTE signaling to KPI mapping
   2.3 Summary
   2.4 Review exercises
3. Coverage Analysis
   3.1 Defining the right coverage
   3.2 RSRP, RSRQ, SINR plot analysis
   3.3 Scanner data analysis
   3.4 Coverage analysis using post processing tool
   3.5 Summary
   3.6 Review exercises
4. Accessibility KPI Analysis
   4.1 PRACH parameter analysis
   4.2 Default bearer setup analysis
   4.3 Radio bearer setup and RRC reconfiguration
   4.4 Call flow to generic counter mapping
   4.5 Summary
   4.6 Review exercises
5. Connection Drop Analysis
   5.1 Radio link failure
   5.2 UE context drops
   5.3 E-RAB drops
   5.4 Drop KPIs and troubleshooting
   5.5 Summary
   5.6 Review exercises

What You Can Expect
- Prerequisite: LTE Overview
- Required Equipment: PC laptop
- Expert-Led Live Duration: 10 HOUR
LTE RF Optimization: Part 2 – Downlink and Uplink Throughput

This workshop provides insights into the symptoms and possible causes of field performance issues in LTE radio networks using UE logs. RF measurements related to coverage and interference are discussed to analyze coverage holes and overlapping regions. Students analyze LTE signaling messages through UE logs and map them to success and failure events. Students perform root cause analysis and gain an in-depth understanding of these signaling events to network performance. LTE RF optimization areas such as downlink and uplink throughput analysis are addressed. This knowledge transfer is obtained through hands-on experience using UE based diagnostic tools and scanner tools.

Intended Audience
This workshop is primarily intended for RF and systems performance engineers involved in LTE design, performance, and optimization.

Objectives
After completing this course, the learner will be able to:
- Define the LTE RF KPIs and map them to RAN counters
- Identify various LTE signaling events that map to success and failure operational counters
- Identify the RF measurements that are key to coverage and interference
- Analyze the RF measurements through post processing tools
- Analyze UE logs for root cause analysis of successful and failure events
- Map above events to operational counters and corresponding KPIs
- Understand LTE KPIs where they are pegged
- Describe DL and UL bandwidth and UE throughput

What You Can Expect
- Prerequisite: LTE RF Optimization: Part 1 – Coverage and Accessibility
- Required Equipment: PC laptop
- Expert-Led Live Duration: 10 HOUR

Outline
1. Workshop Overview
2. LTE RAN KPIs
   - 2.1 LTE RAN KPIs
   - 2.2 LTE signaling to KPI mapping
   - 2.3 Summary
   - 2.4 Review exercise
3. DL Data Traffic Performance
   - 3.1 DL traffic operation walk-through
   - 3.2 DL traffic KPIs
   - 3.3 Analysis of CQI, PMI, RI
   - 3.4 HARQ/ARQ and BLER analysis
   - 3.5 Summary
   - 3.6 Review exercises
4. UL Data Traffic Performance
   - 4.1 UL traffic operation walk-through
   - 4.2 UL traffic KPIs
   - 4.3 UL power control parameters
   - 4.4 HARQ/ARQ and BLER analysis
   - 4.5 Summary
   - 4.6 Review exercises
Intended Audience
This workshop is primarily intended for RF and systems performance engineers involved in LTE design, performance, and optimization.

Objectives
After completing this course, the learner will be able to:
- Define the LTE RF KPIs and map them to RAN counters
- Identify various LTE signaling events that map to success and failure operational counters
- Analyze UE logs for root cause analysis of successful and failure events
- Map above events to operational counters and corresponding KPIs
- Intra LTE handovers and Inter-RAT handovers

What You Can Expect
- Prerequisite: LTE RF Optimization: Part 1 – Coverage and Accessibility
- Required Equipment: PC laptop
- Expert-Led Live Duration: 10 HOUR

Outline
1. Workshop Overview
2. Intra-LTE Handover Analysis
   2.1 Intra and Inter-frequency handover events and trigger parameters
   2.2 Handover KPIs/Counters
   2.3 Handover execution: success and failure scenario
2.4 Summary
2.5 Review exercises
3. Inter-RAT Handover
   3.1 Idle mode system reselection
   3.2 Inter-RAT handover events and related trigger parameters
3.3 Inter-RAT handover message flow and related KPIs/generic counters
3.4 Handover execution: success and failure scenario
3.5 Summary
3.6 Review exercises
4. Idle Mode Performance
   4.1 Bearer inactivity timer
   4.2 Paging procedure optimization
   4.3 TAU procedure optimization
   4.4 Summary
   4.5 Review exercises
LTE RF Optimization: Part 4 – Carrier Aggregation and Load Balancing

This workshop (part 4 of 4 parts series) provides insights into the symptoms and possible causes of field performance issues in LTE radio networks using UE logs. RF measurements related to coverage and interference are discussed to analyze coverage holes and overlapping regions. Students analyze LTE signaling messages through UE logs and map them to success and failure events. Students perform root cause analysis and gain an in-depth understanding of these signaling events to network performance. LTE RF optimization areas such as Intra-LTE and IRAT handover operation. This knowledge transfer is obtained through hands-on experience using UE based diagnostic tools and scanner tools.

Outline

1. Workshop Overview
2. DL Carrier Aggregation Essentials
   2.1 CA operation overview
   2.2 UE category and CA support capability
   Exercise: Analysis of ‘UE Capabilities Response’ message
3. Carrier Aggregation Operations
   3.1 PCell setup signaling
   3.2 SCell configuration & typical criteria
   3.3 SCell configuration signaling
   Exercise: Signaling log showing PCell setup & SCell configuration
   3.4 SCell activation & typical triggers
   3.5 DL CA traffic operations
   3.6 SCell de-activation & typical triggers
   3.7 SCell de-configuration & typical criteria
   3.8 Typical KPIs for DL CA

4. Inter-Frequency Idle Mode Load Balancing
   4.1 Inter-frequency cell re-selection operations
   Exercise: SIB 3, 4, 5 parameter analysis
   4.2 Strategies for inter-frequency idle mode load balancing
   4.3 High priority to largest bandwidth
   4.4 Sticky carrier
   4.5 Dedicated Priorities
5. Inter-Frequency Connected Mode Load Balancing (IFLB)
   5.1 Event A4/A5 for IFLB handovers
   5.2 Measurement gaps and UE capability
   5.3 IFLB behavior with VoLTE
   5.4 Typical KPIs for IFLB

Intended Audience
This workshop is primarily intended for RF and systems performance engineers involved in LTE design, performance, and optimization.

Objectives
After completing this course, the learner will be able to:

| Identify the network and UE capabilities to support Carrier Aggregation |
| Step through the successful operation of Carrier Aggregation using UE logs |
| Identify various LTE signaling events that map to success and failure operational counters |
| Identify the opportunities of load balancing in the idle and connected mode |
| Analyze UE logs for root cause analysis of successful and failure events |
| Map above events to operational counters and corresponding KPIs |

What You Can Expect

| Prerequisite: LTE RF Optimization: Part 1 – Coverage and Accessibility |
| Required Equipment: PC laptop |
| Expert-Led Live Duration: 10 HOUR |
VoLTE Troubleshooting Workshop

This workshop focuses on End-to-End VoLTE troubleshooting techniques by examining specific failure examples throughout the VoLTE network encompassing IMS, EPC, and EUTRAN. The workshop provides practical experience in detecting, analyzing and resolving problems. The workshop emphasizes student participation via hands-on exercises allowing students to practice what they have learned. This workshop requires message traces of success and failure scenarios from the customer.

Intended Audience
This workshop is primarily intended for network performance and optimization engineers involved in monitoring and optimizing VoLTE operations in LTE networks.

Objectives
After completing this course, the learner will be able to:

■ Sketch a troubleshooting plan to tackle specific VoLTE failures,
■ Demonstrate proficiency in VoLTE troubleshooting tasks
■ Analyze VoLTE-related KPIs and identify issues in the network
■ Use network traces and other resources to perform root-cause analysis of specific failures
■ Analyze KPIs for VoLTE interworking scenarios and handovers
■ Explain the QoS implementation for the VoLTE traffic plane
■ Explain and analyze RTP and related traffic plane logs
■ Analyze KPIs for VoLTE Lost Call Scenarios

What You Can Expect

■ Prerequisite: Exploring VoLTE: Architecture and Interfaces
■ Prerequisite: Exploring VoLTE: Signaling and Operations
■ Required Equipment: Laptop with access to tools used in the course
■ Expert-Led Live Duration: 21 HOUR
■ Additional development and customization fees apply

Outline
1. VoLTE Troubleshooting Overview
   1.1 VoLTE environment
   1.2 Failure categories
   1.3 Root causes of failures
   1.4 Failure analysis
   Exercise: Knowledge of tools/probes/protocol

2. VoLTE Call Setup Troubleshooting
   2.1 Categorize call setup outcomes
   2.2 Understanding prioritized cause codes
   2.3 Review call setup statistics
   2.4 VoLTE call failure signatures
   2.5 Analyze the Top Ten failures
   Exercise: Top Ten and EPS specific issues

3. VoLTE Drop Call Troubleshooting
   3.1 Categorize call drops
   3.2 Review VoLTE drop statistics
   3.3 VoLTE drop signatures
   Exercise: Call drop cause code chain

4. RTP-RTCP Timeout Drops
   4.1 What is an RTP timeout?
   Exercise: RTP timeout failure cases

5. Call Drops due to Mobility
   5.1 Non-3GPP handover attempts
   5.2 Intra-LTE handover failures
   Exercise: VoLTE mobility failure cases

6. VoLTE Traffic Quality
   6.1 Measuring quality: MOS, ACQ KPIs
   6.2 RTCP Reports from UEs
   6.3 Impact of high latency, jitter and packet loss
   6.4 Components of the latency budget
   Exercise: Quality KPIs
   6.5 Understanding audio gaps
   6.6 Review gap count and duration statistics
   6.7 Analyze gaps in a specific call
   Exercise: RTP flow information

7. Putting it all Together
VoLTE RAN Performance Workshop

This workshop focuses on radio aspects of VoLTE performance by examining specific examples such as VoLTE setup analysis, Drop call analysis, voice quality analysis, and voice capacity analysis. The workshop provides practical experience in detecting, analyzing and resolving problems. The workshop emphasizes student participation via hands-on exercises allowing students to practice what they have learned. This workshop requires UE and network traces of success and failure scenarios from the customer.

Intended Audience
This workshop is primarily intended for RAN performance and optimization engineers involved in monitoring and optimizing VoLTE operations in LTE networks.

Objectives
After completing this course, the learner will be able to:
■ Sketch a troubleshooting plan to tackle specific VoLTE failures
■ Demonstrate proficiency in VoLTE troubleshooting tasks
■ Analyze VoLTE-related KPIs and identify issues in the network
■ Use UE and network traces to perform root-cause analysis of specific failures
■ Analyze VoLTE Setup, Drops, and voice quality performance issues
■ Explain and analyze RTP and related traffic plane logs

What You Can Expect
■ Prerequisite: Exploring VoLTE: Architecture and Interfaces
■ Prerequisite: Exploring VoLTE: Signaling and Operations
■ Required Equipment: Laptop with access to tools used in the course
■ Expert-Led Live Duration: 21 HOUR
■ Additional development and customization fees apply

Outline
1. VoLTE Troubleshooting Overview
   1.1 Components of VoLTE calls
   1.2 Failure categories
   1.3 RAN KPIs for VoLTE
   Exercise: Knowledge of tools/probes/protocol
2. VoLTE Call Setup Analysis
   2.1 Accessibility KPIs
   2.2 Default and Dedicated bearer setup for VoLTE
   2.3 VoLTE call setup failure signatures
   2.4 Review call setup statistics
   Exercise: Case Study: VoLTE Call Setup failure
3. VoLTE Call Drop Analysis
   3.1 VoLTE Call Drop KPIs
   3.2 Use of TTI Bundling
   3.3 VoLTE call drop failure signatures
   3.4 Review call drop statistics
4. VoLTE Call Quality Analysis
   4.1 Measuring quality: MOS, ACQ KPIs
   4.2 RTCP Reports from UEs
   4.3 Impact of high latency, jitter and packet loss
   4.4 Components of the latency budget
   4.5 Understanding audio gaps
   4.6 Review gap count and duration statistics
   4.7 Analyze gaps in a specific call
   Exercise: Case Study: RTP Flow and Audio Gaps
5. VoLTE Capacity Analysis
   5.1 VoLTE Capacity KPIs
   5.2 PDCCH capacity and Semi-persistent Scheduling
   Exercise: Case Study: Connected User and PDCCH Analysis
Putting it all Together

Exercise: Case Study: VoLTE Drops

View Curriculum
Transport
Curriculum
Learn about the transport network and protocols that form the backbone of telecommunications networks

ON-DEMAND - EXPRESS

Ethernet Basics
Ethernet Bridging
Ethernet VLANs
Welcome to Fiber
IP Basics
IP Routing
IP Quality of Service (QoS)
TCP and Transport Layer Protocols
Interconnecting in IP Networks
Welcome to IPv6
Wireshark Overview
Ethernet Basics

As the communications industry transitions to wireless and wireline converged networks to support voice, video, data and mobile services over IP networks, a solid understanding of Ethernet and its role in networking is essential. Ethernet is native to IP and has been adopted in various forms by the communication industry. A solid foundation in IP and Ethernet has become a basic job requirement in the industry. Starting with a brief history, the course provides a focused basic level introduction to the fundamentals of Ethernet technology. It is a modular introductory course only on Ethernet basics as part of the overall eLearning IP fundamentals curriculum.

Intended Audience
This course is intended for those seeking a basic level introduction to Ethernet technology.

Objectives
After completing this course, the learner will be able to:
- Define Ethernet
- Summarize the key variations of the Ethernet family of standards
- Discuss Ethernet addressing and frame structure
- Discuss Ethernet services offered by carriers

What You Can Expect
- Self-Paced Duration: 1.5 HOUR

Outline
1. Ethernet Defined
   1.1 What is Ethernet?
   1.2 CSMA/CD
2. Ethernet Standards
   2.1 Media and Connectors
   2.2 Auto Negotiation
3. Ethernet Addressing and Frame Structure
   3.1 Details of MAC addresses
   3.2 Ethernet frame structure
4. Carrier Ethernet
   4.1 Definition and Service types
   4.2 SLA and Service Continuity
Putting It All Together
Ethernet Bridging

As the communications industry transitions to wireless and wireline converged networks to support voice, video, data and mobile services over IP networks, a solid understanding of Ethernet and its role in networking is essential. Ethernet is native to IP and has been adopted in various forms by the telecom industry as the Layer 1 and Layer 2 technology of choice. Ethernet bridging and associated capabilities are used extensively in the end-to-end IP network and a solid foundation in IP and Ethernet has become a basic job requirement in the carrier world. Starting with a brief history, the course provides a focused basic level introduction to the fundamentals of Ethernet Bridging as a key capability of Ethernet based nodes.

Intended Audience
This course is intended for those seeking a basic level introduction to Ethernet Bridging.

Objectives
After completing this course, the learner will be able to:
- Introduce Ethernet bridges and explain how they operate
- Introduce Ethernet switches and explain how they differ from Ethernet bridges
- Discuss Spanning Tree Protocol and its variations
- Introduce the concept of multilayer switching
- Discuss the use of link aggregation group in Ethernet networks

What You Can Expect
- Self-Paced Duration: 1.5 HOUR

Outline
1. Ethernet Bridge
   1.1 Definition
   1.2 History
   1.3 Learning bridge
2. Ethernet Switch
   2.1 Definition
   2.2 History
   2.3 Ethernet switching
   2.4 Full duplex operation
3. Spanning Tree Protocol (STP)
   3.1 Function
   3.2 Operation
   3.3 Variants
4. Multilayer Switch (MLS)
   4.1 Definition
   4.2 Function
5. Link Aggregation Group
   5.1 Definition
   5.2 Uses
6. Summary
Ethernet VLANs

As the communications industry transitions to wireless and wireline converged networks to support voice, video, data and mobile services over IP networks, a solid understanding of Ethernet and its role in networking is essential. Ethernet is native to IP and has been adopted in various forms by the telecom industry as the Layer 1 and Layer 2 of choice. VLANs are used extensively in the end-to-end IP network and a solid foundation in IP and Ethernet has become a basic job requirement for the carrier world. Starting with a brief history, the course provides a focused basic level introduction to the fundamentals of Ethernet VLAN technology.

Intended Audience
This course is intended for those seeking a basic level introduction to Ethernet Bridging.

Objectives
After completing this course, the learner will be able to:
- Define Ethernet VLANs
- Identify Ethernet VLAN applications and benefits
- Summarize the key variations of the Ethernet family of standards to support VLANs
- Identify the key types of Ethernet VLANs
- Describe VLAN Trunks and their purpose

What You Can Expect
- Self-Paced Duration: 1.5 HOUR

Outline
1. Virtual Local Area Networks (VLANs)
   1.1 VLAN Definition
   1.2 Characteristics of LAN
   1.3 Packet flow in VLAN
   1.4 Advantages of VLAN
2. VLAN Application and Benefits
   2.1 VLAN Applications
   2.2 VLAN Benefits
3. Single Switch VLANs
   3.1 Port based VLAN
4. Multi-Switch VLANs: Trunks and Tagging
   4.1 Multi-Switch VLANs
   4.2 VLAN tags
   4.3 VLAN Trunks
Putting It All Together
Welcome to Fiber
This course covers the basics you need to handle fiber connections properly. The course introduces the basics of light, the anatomy of a fiber-optic cable, and some basic concepts used when transmitting information over fiber, like Wavelength Division Multiplexing (WDM).

Intended Audience
This course covers the basics of light and fiber optic cables, as well as the operations of a fiber for a broad audience – both technical and non-technical.

Objectives
After completing this course, the learner will be able to:
- Describe basics of light and fiber optic cables
- Describe the operations of a fiber
- Describe the anatomy of optical fiber
- Compare and contrast SMF and MMF
- List factors working with connectors and ferrules
- List best practices working with fiber and SFPs
- Describe key components in WDM systems

What You Can Expect
- Self-Paced Duration: 1 HOUR

Outline
1. Fiber Basics
   1.1 Light Basics
   1.2 All About SFPs
   1.3 Fiber Anatomy
   1.4 SMF vs. MMF
   1.5 Connectors and Ferrules
2. Fiber Operation
   2.1 Power Loss, Dispersion and Attenuation
   2.2 Physical Impairments in Fiber
   2.3 Fiber Cleaning
3. Fiber Troubleshooting
   3.1 What’s wrong with this picture?
4. Wavelength Division Multiplexing
   4.1 Wavelength Division Multiplexing
   4.2 CWDM vs. DWDM
   4.3 WDM Systems
   4.4 CWDM Systems
Final Assessment
IP Basics

As the communications industry transitions to wireless and wireline converged networks to support voice, video, data and mobile services over IP, a solid understanding of IP and its role in networking is essential. IP is to data transfer as what a dial tone is to a wireline telephone. A fundamental knowledge of IPv4 and IPv6 networking along with use of VLANs is a must for all telecom professionals. A solid foundation in IP has become a basic job requirement in the carrier world. Starting with a brief history, the course provides a focused basic level introduction to the fundamentals of IP technology. It is a modular introductory course only on IP basics as part of the overall eLearning IP fundamentals curriculum.

Intended Audience
This course is intended for those seeking a basic level introduction to the Internet Protocol (IP).

Objectives
After completing this course, the learner will be able to:
- Describe the purpose and structure of an IP address
- Describe network prefix
- Explain the purpose of CIDR Prefix
- Explain the purpose of Subnet Mask
- Describe IP Subnets
- Explain the IP header and its key fields
- Describe broadcasting in IP networks
- Describe multicasting in IP networks

What You Can Expect
- Self-Paced Duration: 1 HOUR

Outline
1. IP Address
   1.1 IP address Structure
   1.2 CIDR based IP address
   1.3 IP address examples
2. IP Subnets
   2.1 IP subnet definition
   2.2 Subnet creation principle
   2.3 Subnet creation Example
3. IP Header
   3.1 IP Header fields description
   3.2 Importance of TTL field in IP header
4. Multicast and Broadcast
   4.1 Broadcast Operations
   4.2 Multicast Operations
Putting It All Together
IP Routing

As the communications industry transitions to wireless and wireline converged networks to support voice, video, data and mobile services over IP, an understanding of IP and its role in networking is essential. IP is to data transfer as a dial tone is to a wireline telephone. A fundamental knowledge of IPv4 and IPv6 networking along with use of routing is a must for all telecom professionals. A solid foundation in IP and routing has become a basic job requirement in the carrier world. Understanding of IP routing protocols is an important part of building this foundation. Starting with a basic definition, the course provides a focused base level introduction to the fundamentals of IP routing and associated protocols like OSPF, BGP, and VRRP.

Intended Audience
This course is intended for those seeking a basic level introduction to IP routing and the common associated protocols.

Objectives
After completing this course, the learner will be able to:

■ Define the differences between IP routing and forwarding
■ Distinguish between Interior Gateway Protocols and Exterior Gateway Protocols
■ Explain Open Shortest Path First (OSPF) and how it is used
■ List the main types of Link State Advertisements in OSPF
■ Describe Border Gateway Protocol (BGP) and how it is used
■ Show how route reflectors simplify network configuration and reduce routing overhead
■ Explain how PING can be used to verify end-to-end connectivity in an IP Network
■ Describe how Traceroute can be used to track down routing errors in a network

What You Can Expect
■ Self-Paced Duration: 2 HOUR

Outline
1. What is IP routing?
   1.1 IP routing basics
   1.2 Routing and forwarding
   1.3 Routing protocols
2. Open Shortest Path First (OSPF)
   2.1 OSPF basics
   2.2 A closer look at OSPF
3. Border Gateway Protocol (BGP)
   3.1 BGP basics
   3.2 A closer look at BGP
   3.3 Scaling BGP
4. Redundancy Protocols
   4.1 Introduction
   4.2 VRRP
   4.3 GLBP
5. Debugging Tools and Utilities
   5.1 PING
   5.2 Traceroute
6. Summary
IP Quality of Service (QoS)

The Internet is coming to a new age where various applications have their own QoS requirements, and one size does not fit all. This course introduces the concept of QoS and discusses the current limitations within the Internet. The new services requirements driving QoS in the Internet are presented. The two basic techniques used for QoS - Integrated Services and Differentiated Services - are presented. The discussion includes the benefits and limitations of the Integrated Services and the Differentiated Services approaches to QoS. While IntServ and DiffServ are the approaches, service providers need an infrastructure to deploy QoS-based applications rapidly.

Intended Audience
This course is intended for anyone seeking an overview of the IP Quality of Service architectures in the Internet.

Objectives
After completing this course, the learner will be able to:
- Determine the limitations of the best effort approach to QoS
- Describe the need for QoS with respect to new applications
- Explain how QoS requirements are communicated
- Define policy-based architecture
- Explain the benefits and limitations of the Integrated Services approach to QoS
- Explain the benefits and limitations of the Differentiated Services approach to QoS
- Describe the protocols that are used for each of the QoS approaches
- Identify emerging trends in IP QoS

What You Can Expect
- Self-Paced Duration: 3 HOUR

Outline
1. Motivation for Quality of Service (QoS)
   1.1 Definition of Quality of Service
   1.2 Service examples
   1.3 QoS parameters
2. QoS in today’s Internet
   2.1 Current QoS mechanisms
   2.2 Limitations of the current QoS mechanisms
3. QoS Requirements
   3.1 Requirements of QoS on the Internet
   3.2 Service Level Agreements (SLAs)
   3.3 Challenges for deploying IP QoS
   3.4 Policy based QoS architecture
4. QoS Models
   4.1 Application approach vs. aggregated approach
   4.2 Introduction to IP QoS models
5. Integrated Services Approach (IntServ)
   5.1 Limitations of the Integrated Services approach
5.2 ReSerVation Protocol (RSVP)
6. Differentiated Services Approach (DiffServ)
   6.1 Differentiated services approach
   6.2 DiffServ protocol
   6.3 DiffServ implementation
   6.4 Traffic management functions
   6.5 Issues with DiffServ
7. Emerging Trends in QoS
   7.1 Hybrid architectures
   7.2 Automated QoS management
   7.3 Bandwidth brokers
8. Summary
   8.1 Put It All Together
   8.2 Assess the knowledge of the participant based on the objectives of the course
TCP and Transport Layer Protocols

As the communications industry transitions to wireless and wireline converged networks to support voice, video, data and mobile services over IP, a solid understanding of IP and its role in networking is essential. IP is to data transfer as what a dial tone is to a wireline telephone. A fundamental knowledge of IPv4 and IPv6 networking along with use of IP based transport protocols is a must for all telecom professionals. Understanding of TCP and other IP based transport layer protocols is an important part of building this foundation. Starting with a basic definition, the course provides a focused basic level introduction to the fundamentals of IP based transport layer protocols like TCP, UDP and SCTP.

Intended Audience
This course is intended for those seeking a basic level introduction to the IP-based transport layer protocols - TCP, UDP and SCTP.

Objectives
After completing this course, the learner will be able to:
- Explain the key transport layer functions and the concept of ports
- Describe User Datagram Protocol (UDP) and Transmission Control Protocol (TCP)
- Explain how TCP provides reliable communication over IP and achieves optimal transmission
- Define the special requirements for carrying telecom signaling over IP networks
- List the key functions of Stream Control Transmission Protocol (SCTP)

What You Can Expect
- Self-Paced Duration: 1 HOUR

Outline
1. Overview of the Transport Layer
   1.1 Functions of the Transport Layer
2. User Datagram Protocol (UDP)
   2.1 Defining the UDP
   2.2 UDP header details
3. Transmission Control Protocol (TCP)
   3.1 TCP functionality
   3.2 TCP connection setup
4. Stream Control Transport Protocol (SCTP)
   4.1 Role of SCTP
   4.2 Capabilities of SCTP
   4.3 Unique features of SCTP
5. Summary
Putting It All together
Interconnecting in IP Networks

As the communications industry transitions to wireless and wireline converged networks to support voice, video, data and mobile services over IP networks, a solid understanding of IPv4 and IPv6 networking along with their use for inter-networking is a must for all telecom professionals. As the services and applications of wireless networks continue to expand, the backbone must evolve to support them. Multi-Protocol Label Switching (MPLS) is designed to make the backbone fast, scalable and manageable, and capable of carrying heavy traffic, supporting QoS. This course presents a technical overview including a discussion on the architecture of MPLS, the components of the MPLS network and the supporting protocols required for MPLS.

Intended Audience
This course is intended for anyone seeking a basic level overview of the MPLS and IP interconnecting architectures.

Objectives
After completing this course, the learner will be able to:
- Describe the motivation behind MPLS
- State the role of MPLS in the convergence of networks
- List key applications of MPLS
- Sketch the architecture of MPLS
- Describe the important components and operations of MPLS
- Describe how MPLS is used to set up layer 3 and layer 2 VPNs

What You Can Expect
- Self-Paced Duration: 1.5 HOUR

Outline
1. Why MPLS?
   1.1 Advantages of MPLS
   1.2 New applications
2. MPLS Networks
   2.1 MPLS domain
   2.2 Label edge router
   2.3 Label switch router
3. MPLS Terminology
   3.1 Label Switched Paths (LSP)
   3.2 Forward Equivalence Class (FEC)
   3.3 Structure of a label
4. Packet Forwarding Along LSPs
   4.1 Label Forwarding Information Base (LFIB)
   4.2 Packet forwarding along LSPs
   4.3 Label stacking
5. MPLS and Virtual Private Networks
   5.1 VPNs support in MPLS
   5.2 Layer 3 and Layer 2 VPNs establishment in MPLS
   5.3 Label stacking and VPNs
   5.4 MPLS based L2 VPN solutions
Welcome to IPv6

As the communications industry transitions to wireless, wireline converged networks to support voice, video, data and mobile services over IP networks, a solid understanding of IP and its role in networking is essential. IP is to data transfer as a dial tone is to a wireline telephone. IPv6 was defined in 1998 but saw little adoption for over a decade. With continued IPv4 address depletion and the migration to wireless VoIP in LTE networks, the time for widespread adoption has finally arrived. This course begins with a look at the motivation for migrating to IPv6, followed by an explanation of the IPv6 header and addressing concepts, and the 128-bit address necessitates changes to many of the supporting protocols for IP.

Outline

1. Motivation and Benefits
   1.1 IPv4 address depletion
   1.2 Limitations of NAT
   1.3 Benefits of IPv6

2. IPv6 Header and Addresses
   2.1 Header format
   2.2 Address format
   2.3 Address notation
   2.4 Types of addresses
   2.5 Address assignment

3. Supporting Protocols
   3.1 ICMP
   3.2 DNS
   3.3 DHCP
   3.4 OSPF
   3.5 BGP

4. Transition to IPv6
   4.1 The transition problem
   4.2 Dual stack
   4.3 Configured tunneling
   4.4 Automatic tunneling
   4.5 IPv6 in LTE

Intended Audience

This course is intended for technical personnel with a grounding in IPv4 networks who are seeking a technical overview of IPv6 and related protocols.

Objectives

After completing this course, the learner will be able to:
- Describe why the migration to IPv6 is finally happening
- List the key benefits of IPv6
- Explain key fields in the IPv6 header
- Discuss how IPv6 addresses are formatted and how they are assigned
- Explain how the basic IP supporting protocols are enhanced to support IPv6
- Describe how automatic routing for IPv6 networks is enabled by BGP and OSPF
- Discuss how dual stack devices help ease the transition from IPv4 to IPv6
- Understand the differences between configured and automatic tunnels for IPv6 transition

What You Can Expect

- Self-Paced Duration: 1 HOUR
Wireshark Overview

Wireshark is an open-source protocol capture and analysis tool used by many wireless operators to help evaluate network performance and debug end-to-end operational failures. This self-paced eLearning course provides a high-level look at Wireshark and its key capabilities, taking a step-by-step approach to show the main elements of the user interface, the process of capturing and analyzing traces, and a brief overview of how Wireshark can be used to evaluate typical signaling flows in VoLTE networks. Frequent interactions are used to ensure student comprehension and engagement at every stage.

Intended Audience
This course is suitable for those looking for a high level introduction to Wireshark and how it may be used to evaluate and debug field issues.

Objectives
After completing this course, the learner will be able to:
■ Set up the elements of the user interface and Wireshark to their personal tastes
■ Capture a network trace from their PC and save the packet capture file
■ Search and select protocols and packets.
■ Modify the time display and reference
■ Analyze elements of IMS/VoIP protocols (i.e. SIP) and display a VoIP call graph

What You Can Expect
■ Self-Paced Duration: 1 HOUR

Outline
1. User Interface
   1.1 UI elements
   1.2 Menu items
2. Capturing and Displaying Data
   2.1 Capturing and saving traces
   2.2 File management
   2.3 Capture Filters
3. Wireshark Features
   3.1 Filters and searching
   3.2 Time display, reference, and shift
   3.3 Using host files
4. Analyzing SIP Messages
   4.1 SIP messages
   4.2 VoIP call Flow
   4.3 SIP filters
Remove the daily grind from your workday by learning technologies behind intelligent business

ON-DEMAND - EXPRESS
Welcome to AI
Welcome to Python
Welcome to Machine Learning

ON-DEMAND - EXPANDED
Artificial Intelligence (AI) Essentials
Analytics Essentials

EXPERT-LED
Ansible Workshop
Data Visualization Workshop
Data Visualization Workshop using PowerBI
Analytics Workshop
Data Automation Workshop using Python
Data Automation Mentoring Program

5G
Network Virtualization
LTE and VoLTE
Transport
Automation and Insights

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Welcome to AI

Artificial Intelligence (AI) technologies are reshaping how telecom service providers’ networks operate resulting in more efficient operation that reduces costs and increases savings. Together, these solutions allow networks to operate at web-scale and provide customers with unprecedented levels of agility and flexibility. This course gives an overview of AI, describes the AI and automation lifecycle, and details AI’s impact on the telecom industry. In addition, several AI use cases are explored.

Intended Audience
The course is intended for all audiences that are interested in understanding how Automation and AI are changing the telecommunications industry.

Objectives
After completing this course, the learner will be able to:
- Give examples of AI in action
- Sketch the AI and Automation Lifecycle
- Articulate how AI changes the telecommunications industry
- List some of the AI Use Cases

What You Can Expect
- Self-Paced Duration: 1 HOUR

Outline
1. What is AI?
   1.1 Types of AI
   1.2 Define in nine
2. AI concepts
   2.1 AI terms and concepts
3. Neural Networks
   3.1 What is Neural Networks?
   3.2 Neural Networks in action
4. AI and Automation lifecycle
   4.1 Lifecycle overview
   4.2 Model creation
   4.3 Model Deployment
   4.4 Automation and Human Intervention
   4.5 AI and Automation Lifecycle in the Telecom Industry

5. Impact of AI on Telecom
   5.1 AI, Analytics and Automation
   5.2 Strategic goals
   5.3 Priority areas for CSP AI, ML activities
6. AI focus areas
   6.1 Interaction focus, Complex communication
   6.2 Pattern detection, Process automation, Decisioning
7. AI Use Cases in Telecom
8. AI Use Cases that impact a Telecom Network
   8.1 Streaming Service, IoT
   8.2 VR/AR
   8.3 Autonomous cars
9. Course Summary
Welcome to Python
This self-paced eLearning course is a light-hearted introduction to Python. Students will work with Python data structures and become familiar with some basic programming concepts. The course will provide a basic familiarity with Python and programming for automation.

Intended Audience
Those with little or no experience in programming who are interested in using Python for automation.

Objectives
After completing this course, the learner will be able to:
- Identify and work with Python data types
- Identify and work with key control statements
- Use functions to create code blocks
- Use functions to automate a process

What You Can Expect
- Self-Paced Duration: 1.5 HOUR

Outline
1. Introduction
2. Data Types
   2.1 Strings
   2.2 Numbers and Floating Point Numbers
   2.3 Lists and Boolean
3. Key Control Statements
   3.1 The If Statement
   3.2 The Nested If Statement
   3.3 If ... Else and ELIF
   3.4 For and While Loop
   3.5 Try, Except, Finally
4. Functions
5. Data Workflow and Automation
6. Conclusion
Welcome to Machine Learning

In the age of Automation and Artificial Intelligence, Machine Learning, or ML, has become the dominant AI approach. This course provides an overview of Machine Learning and how it is used within the telecom industry. A high-level description of the training process is also explored.

Intended Audience
This course provides an overview of AI technology with an emphasis on Machine Learning for a broad audience – both technical and non-technical.

Objectives
After completing this course, the learner will be able to:
- Define key AI terms
- Describe basic operations of training an AI model
- Describe the structure of a basic ML model
- Describe the lifecycle of an AI project
- List key steps in ML model development
- Explain common use cases for machine learning

What You Can Expect
- Self-Paced Duration: 1 HOUR

Outline
1. What is Machine Learning?
   1.1 What is Machine Learning?
   1.2 What is an AI Model?
   1.3 An End User View
2. Use Cases
   2.1 Telecom Use Cases
   2.2 Dig Deeper: Other Use Cases
3. Basic AI Model Design
   3.1 Basic AI Model Design
   3.2 Types of Machine Learning
4. AI and Automation Lifecycle
   4.1 AI Models Defined
   4.2 Frame the ML Problem
   4.3 Data Gathering and Preparation
   4.4 Model Creation
   4.5 Training the Model
   4.6 Apply and Deploy
Final Assessment
Artificial Intelligence (AI) Essentials

Artificial Intelligence (AI) is revolutionizing all aspects of the computer industry. The impacts of AI have been seen on a number of areas such as speech and image recognition. The telecom industry is different. This course provides an overview of AI from a telecom perspective. AI is explored from a definition, underlying technology and use-cases perspective. It starts with an introduction to AI. The course then moves to key AI use cases and the AI technologies of Machine Learning and Deep Learning. The course concludes with a discussion on how to build an AI model, some of the common tools, and the key challenges.

Intended Audience
A high-level technical overview to personnel involved in product management, marketing, planning, design, engineering, and operating wireless (4G, 5G) and wireline access networks

Objectives
After completing this course, the learner will be able to:
- Define Artificial Intelligence (AI)
- List the key use cases within telecommunications for AI
- Compare and contrast deep learning and machine learning
- List different AI design models

What You Can Expect
- Self-Paced Duration: 4 HOUR

Outline
1. Introduction to AI
   1.1 AI defined
   1.2 Types of AI
   1.3 Common non-telecom AI use cases
2. Service Provider AI Use Cases
   2.1 How is telecom different?
   2.2 Telecom use cases
   2.3 Customer support
   2.4 Engineering and planning
   2.5 Retail and supply chain
   2.6 Workforce management
   2.7 Telecom impacting use cases
   2.8 Autonomous driving
   2.9 IoT
2.10 Impact of AI on telecom architecture
2.11 MEC
3. AI, Machine Learning, and Deep Learning
   3.1 Machine Learning and Deep Learning defined
   3.2 How to train an AI model
   3.3 Types of Machine Learning
   3.4 Impacts of data on Machine Learning model
4. Basics of Building an AI Model
   4.1 Common AI tools
   4.2 Key AI model structure
   4.3 Types of neurons
   4.4 Challenges and key considerations
Analytics Essentials

In the age of Automation and AI, statistics are critical in developing automation capabilities or just understanding how AI works. This course provides an overview of statistics and analytics that are used within the telecom industry. Statistics principles are explored from a definition, functional and specific uses perspective. It starts with an introduction to Data Science Fundamentals. The course concludes with uses within the telecom industry.

Outline
1. Big picture of Analytics
   1.1 Types of Analytics
   1.2 Landscape of Analytics
2. Descriptive Analytics
   2.1 Concepts of Descriptive Analytics
   2.2 Demonstration Usecase
3. Predictive Analytics
   3.1 Predictive Analytics a subset of AI
   Exercise: Review Questions
4. Getting Started with Data
   4.1 Data Types
   4.2 Measures of Central Tendency
   4.3 Measures of Dispersion
   4.4 Correlation
   4.5 Skew/Symmetry
   4.6 Kurtosis
5. Data Terminology in Predictive Analytics
   5.1 Understand input and output for ML/DL models
   Exercise: Review Questions
6. Process of Predictive Analytics
   6.1 Understand each step of the Process
   Exercise: Review Questions
7. Visit Models
   7.1 Taxonomy of Models
   Exercise: Review Questions
8. Linear Regression
   8.1 Understand How it works
   Exercise: Review Questions
9. Logistic Regression
   9.1 Understand How it works
   Exercise: Review Questions
10. Use Cases

Intended Audience
A high-level technical overview to personnel involved in product management, marketing, planning, design, engineering, and operating wireless (4G, 5G) and wireline access networks

Objectives
After completing this course, the learner will be able to:
- Understand Descriptive Analysis
- Understand Predictive Analytics
- Understand Linear Regression
- Understand Logistic Regression
- Explore Usecases in telecom

What You Can Expect
- Self-Paced Duration: 4 HOUR

Analytics Essentials

In the age of Automation and AI, statistics are critical in developing automation capabilities or just understanding how AI works. This course provides an overview of statistics and analytics that are used within the telecom industry. Statistics principles are explored from a definition, functional and specific uses perspective. It starts with an introduction to Data Science Fundamentals. The course concludes with uses within the telecom industry.

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   Exercise: Review Questions
9. Logistic Regression
   9.1 Understand How it works
   Exercise: Review Questions
10. Use Cases

Intended Audience
A high-level technical overview to personnel involved in product management, marketing, planning, design, engineering, and operating wireless (4G, 5G) and wireline access networks

Objectives
After completing this course, the learner will be able to:
- Understand Descriptive Analysis
- Understand Predictive Analytics
- Understand Linear Regression
- Understand Logistic Regression
- Explore Usecases in telecom

What You Can Expect
- Self-Paced Duration: 4 HOUR
Ansible Workshop

Automation and orchestration are becoming key factors in successful network deployment and operations. Ansible is an important tool that uses a declarative mechanism and often is used as part of DevOps. In this workshop, you will learn the Ansible components and use Ansible to automate the deployment, configuration and updates of Ansible targets such as virtual machines. The workshop provides a hands-on opportunity to build playbooks and their dependencies. In addition, the workshop enables the use of several Ansible features including the use of Ansible vault, rolling updates, variables, redirection, custom modules, and plugins.

**Intended Audience**
A hands-on in-depth technical training to personnel involved in design, engineering, operations and monitoring of networks.

**Objectives**
After completing this course, the learner will be able to:
- List ansible features
- Explain the benefits of the main Ansible component
- Demonstrate building and enhancing playbooks
- Construct Ansible playbooks using various modules
- Perform various Ansible CLI commands
- Apply different features such as vault, plugins, etc.
- Summarize the value of Ansible in DevOps
- Demonstrate playbook re-usability

**What You Can Expect**
- Prerequisite: Basic Linux operating system skills are recommended
- Required Equipment: Laptop/desktop with Internet connectivity
- Expert-Led Live Duration: 21 HOUR

**Outline**

1. Ansible Overview
   1.1 Introduction to Ansible
   1.2 Ansible applications in NFV clouds
   1.3 Ansible and other DevOps tools
   Exercise: Lab setup

2. Ansible Environment
   2.1 Introduction to YAML templates
   2.2 Ansible environment
   2.3 Ansible CLI
   Exercise: Using Ansible CLI

3. Ansible Playbook
   3.1 Playbook structure
   3.2 Ansible modules
   3.3 Inventories, roles, handlers, etc.
   Exercise: Building a playbook

4. Ansible Playbook Extensions
   4.1 Variables, variable arrays, and lookup
   4.2 Facts and custom facts
   4.3 Variable substitutions

4.4 Host variable extraction
   Exercise: Extend the playbook

5. Ansible Interactions
   5.1 Applying scopes and precedence
   5.2 Various Ansible modules
   Exercise: Extend the playbook to use different modules

6. Further Ansible Automation
   6.1 Assertions
   6.2 Redirection
   6.3 Output formatting for readability
   Exercise: Extend playbook with further automation

7. Additional Ansible Features
   7.1 Ansible vault
   7.2 Rolling updates
   7.3 Failure percentage
   7.4 Ansible Galaxy
   Exercise: Update playbook to use features of interest
Data Visualization Workshop

Telecom networks are continuing to transform in fundamental ways - cloud platforms are enabling networks to be run as software-based functions. This enables the management of these networks to become software centric and thus require the use of scripting and software-oriented approaches to automate tasks performed on these networks. Industries are starting to leverage feature-rich tools that analyze massive, varied data sets to complete tasks more productively and effectively. This course teaches techniques by taking large datasets of network performance data and creating close to 50 visualizations.

Outline

1. Tableau Prep for ETL
   1.1 Introduction to the ETL concepts and process
   1.2 Navigation in Prep
   1.3 Understanding the various panes and their functions
   1.4 Extracting data from various sources: Excel, Text/CSV, JSON, Web, Database
   1.5 3 Types of Transformation: Content, Shape, Combine datasets
   1.6 Tall vs Wide Data Sets
   Exercise: Preview Data in Desktop
   Exercise: Load Data Output files
   Exercise: Data Sampling Options in Prep

2. Data Visualization and Tableau
   2.1 Getting started with Tableau
   2.2 Navigation of Tableau
   2.3 Dimensions and Measures
   2.4 Visualizing Time Series
   2.5 Use of Line Charts
   2.6 Filtering Large Data Sets
   2.7 Filtering Techniques
   2.8 Comparing Categorical Data
   2.9 Use of Bar Charts
   Exercise: Connect to data source
   Exercise: Create Tableau Visualizations

3. Data Visualizations
   3.1 Correlating KPIs using Scatter Maps
   3.2 Using granularity for Visualizations
   3.3 Pie Charts
   3.4 Hierarchical data and Tree Maps
   3.5 Visuals with color and Heat Maps
   3.6 Data distribution and Box-Whisker Maps
   3.7 Correlating two KPIs with Dual Axis
   3.8 Using bins and Histograms for comparison
   3.9 Correlating multiple KPIs with Multi-Measure Comparisons
   Exercise: Create Tableau Visualizations

4. Advanced Data Visualizations
   4.1 Joins to visualize two data sources
   4.2 Geographical data and Filled Maps
   4.3 Blends to visualize two data sources
   4.4 Modifying data with calculated fields
   4.5 Table Calculations and aggregated data
   4.6 Parameters for interactive visualizations
   4.7 Using Highlights to draw attention
   4.8 Merging data with Groups
   4.9 Sets
   4.10 Creating a visual narrative with Dashboard and Story
   Exercise: Create Visualizations with Joins and Blends
   Exercise: Create a Dashboard

Intended Audience
This workshop is intended for anyone who wants to build knowledge and skills related to leveraging data tools to be more productive.

Objectives
After completing this course, the learner will be able to:
- Connect to a data source
- Visualize KPIs that change over time
- Visualize large data sets by leveraging power of Filters
- Visualize KPIs using Bar Charts, Scatter Maps and Pie Charts
- Visualize KPIs using Tree Maps, Heat Maps, Box-Whisker Maps
- Correlate/Compare data with Dual Axis and Histograms
- Use Joins and Blends to visualize data from multiple sources
- Visualize geographical data with Filled Maps

What You Can Expect
- Prerequisite: Basic knowledge of Excel
- Required Equipment: Students will need a laptop with access to Tableau Desktop
- Expert-Led Live Duration: 21 HOUR
Data Visualization Workshop using Power BI

Telecom networks are continuing to transform in fundamental ways - cloud platforms are enabling networks to be run as software-based functions. This enables the management of these networks to become software centric and thus require the use of scripting and software-oriented approaches to automate and manage tasks performed on these networks. Industries are starting to leverage feature-rich tools that analyze massive, varied data sets to complete tasks more productively and effectively. This course teaches data visualization techniques by taking large datasets of network performance data and creating close to 50 visualizations.

Outline

1. Getting Started with Power BI
   Exercise: Connect to a Data Source
   Exercise: Navigate Power BI Desktop

2. Data Query in Power BI
   2.1 Introduction to ETL
   2.2 Navigate the Query Editor
   2.3 Import Data vs Direct Query
   2.4 3 Types of Transformation: Content, Shape, Combine datasets
   2.5 Tall vs Wide Data Sets
   2.6 Managing the Query List, Applied Steps
   2.7 Load vs Edit
   2.8 Extract from data sources: Excel, CSV, JSON, Web, API, Database
   Exercise: Extract, Transform, Load

3. Visualizations I
   3.1 Visualization Concepts and Process
   3.2 Dimensions, Measures
   3.3 Relationship View, Data View, Report View
   3.4 Filtering Techniques: Filters, Slicers
   3.5 Tables and Matrices
   3.6 Bar Charts: Simple, Clustered, Stacked
   3.7 Time Series: Discrete vs Continuous
   Exercise: Create Visualizations in Report View

4. Visualizations II
   4.1 Key features and differences of Pie Charts and Donut Charts

5. Data Modeling for Power BI
   5.1 Introduction to the Data Modeling Concept
   5.2 Dim Tables and Fact Tables
   5.3 Star and Snowflake schema
   5.4 Single vs Bidirectional Relations
   5.5 Creating Date/Time Dimension Tables
   5.6 Leveraging the Time Intelligence Functions of Power BI
   Exercise: Creating relationships between Dim Tables and Fact Tables

Intended Audience
This workshop is intended for anyone who wants to build knowledge and skills related to leveraging data tools to be more productive.

Objectives
After completing this course, the learner will be able to:
- Connect to Data Sources using Query Editor
- Extract, Transform using Query Editor
- Visualize different data types and large data sets
- Visualize KPIs using Bar Charts, Scatter Maps and Pie Charts
- Visualize KPIs using Tree Maps, Heat Maps, Box-Whisker Maps
- Join/Blend data to visualize data from multiple sources
- Create Dashboards
- Use PowerBI for Data Modeling

What You Can Expect
- Prerequisite: Basic knowledge of Excel
- Required Equipment: Students will need a laptop with access to Power BI Desktop
- Expert-Led Live Duration: 21 HOUR

View Curriculum
Analytics Workshop

By using hands-on, lab-based programming exercises (using Python, Pandas, Jupyter Notebooks and other Python modules), this workshop provides a practical hands-on starting point by focusing on ONLY the necessary statistical concepts needed without getting into the mathematical details. Once the foundational concepts have been covered the workshop takes a use case based approach to get, clean, analyze, visualize and predict from multiple data sets. The students develop programs to go through the analytics process by using Linear Regression, Time Series Analysis and Logistic Regression. The end goal is to get them ready to take the next step of their journey into Machine Learning.

Intended Audience
This workshop is intended for anyone with Python skills and the desire to build knowledge and skills related to leveraging data tools to start their journey into Data Analytics.

Objectives
After completing this course, the learner will be able to:
- Describe the landscape of Data Analytics
- Describe the role of Pandas in Data Analytics
- Describe the role visualization in Data Analytics
- Use Scikit-learn for Linear Regression and prediction
- Use Scikit-learn for Logistic Regression and prediction
- Use Statsmodels for Time Series forecasting

What You Can Expect
- Prerequisite: Data Automation Workshop using Python
- Prerequisite: Python programming skills
- Required Equipment: Students need a laptop with Python, Jupyter Notebook
- Required Equipment: Students need privileges to install Python modules
- Expert-Led Live Duration: 21 HOUR

Outline
1. Landscape of Analytics and ML
   1.1 What is AI/ML/DL?
   1.2 Why Analytics? Why Now?
   1.3 Common Examples/Use cases of AI
   1.4 What knowledge and skills?

2. Data Concepts and Visualizations
   2.1 Understand Categorical data
   2.2 Treatment of Categorical data
   2.3 Understand Numerical data
   2.4 Treatment of Numerical data
   2.5 Data Visualization role in ML

3. Process for Analytics and ML
   3.1 Data Exploration and Data Wrangling
   3.2 Evaluation: Train, Test and Cross Validation
   3.3 Feature Engineering/Selection/Scaling
   3.4 Spot Check Models
   3.5 Finalize Model
   3.6 Save and Use Model

4. Taxonomy of Algorithms
   4.1 Understand different families of Algorithms
   4.2 Understand Decision Boundary of Linear versus Non Linear Algorithms

5. Linear Regression
   5.1 Why and When of Regression
   Exercise: Simple Linear Regression USECASE
   Exercise: Multivariate Linear Regression USECASE
   5.2 Data Exploration (PANDAS)

5.4 Feature Engineering/Selection/Scaling (SKLEARN)
5.5 Train Model (SKLEARN)
5.6 Understand the metrics
5.7 Save Model (PICTLE/JOBLIB), Use Model to Predict

6. Logistic Regression
   Exercise: Binary Classification USECASE - decision boundary
6.1 Plot Boundaries (MLEXTEND)
   Exercise: Binary Classification USECASE
6.2 Why and When of Classification
6.3 Data Exploration (PANDAS)
6.4 Data Visualization (MATPLOTLIB, SEABORN)
6.5 Feature Engineering/Selection/Scaling (SKLEARN)
6.6 Train Model (SKLEARN)
6.7 Understand the metrics
6.8 Save Model (PICTLE/JOBLIB), Use Model to Predict

7. Time Series Forecasting
   Exercise: Time Series USECASE specification
7.1 Understand SARIMAX
7.2 Understand Hyperparameter Tuning of (P,D,Q)(p,d,q,m) for SARIMAX
7.3 Save Model (PICTLE/JOBLIB), Use Model to Predict
Data Automation Workshop using Python

The Data Automation Workshop using Python is designed for non-programmers who want to create programs in Python to help them automate some of their mundane daily tasks related to gathering and analyzing data. By using hands-on, lab-based programming exercises, it takes the student on a practical guided tour of Python’s capabilities and throughout the session create several practical and useful Python programs. The workshop provides an opportunity to define and develop a Python program based on a practical and relevant use case.

Intended Audience
This workshop is intended for anyone (non-programmers) who wants to build knowledge and skills related to leveraging data tools to be more productive.

Objectives
After completing this course, the learner will be able to:
- Analyze a problem and design step-by-step ways to automate the task at hand
- Learn how to manage data in different forms of data structures to load and manipulate data
- How to use key control structures to manage the process flow
- Implement solutions based on string manipulation, regular expression processing and loops
- Implement a data processing exercise using control and data structures including file operations
- Implement text file and Excel file handling for Input/Output processing
- Learn how to automate data collection through APIs
- Python is used as the programming language for all exercises and lab-work

What You Can Expect
- Prerequisite: Basic knowledge of Excel
- Required Equipment: Students will need a laptop with MS-Excel and Python
- Expert-Led Live Duration: 21 HOUR

Outline
1. Get started with Python
   1.1 Create a Python program
   1.2 Run a Python program
   1.3 Import and Modules/Packages
   1.4 Conditional statements
   1.5 For and while loops
   1.6 Functions
   1.7 Lists
   1.8 Dictionary
   1.9 String Operations
   Exercise: Create and Run a Program
2. Processing Data from Text Files
   2.1 Text File Processing basics
   2.2 Command line arguments in Python
   2.3 Python File Operations
   2.4 File reading and writing
   2.5 Python to walk a directory
   2.6 Counting lines, words
   Exercise: Read a file, count lines, words and develop word length vs. frequency data
   Exercise: Define a class-specific use case
   Exercise: Develop a Python program to implement the use case
3. Processing Data from Excel Workbooks
   3.1 What is Openpyxl?
3.2 Installing Openpyxl module
3.3 Creating a Workbook
3.4 Reading data from a Workbook
3.5 Creating and naming Worksheets
3.6 Deleting a Worksheet
3.7 Excel Object Structure
3.8 Reading and writing to/from a cell
3.9 Inserting Formulas into Excel Sheets from Python Programs
3.10 Formatting rows and columns
3.11 Inserting Excel Charts in Python
3.12 Saving an Excel Workbook
   Exercise: Create an Excel file, insert data from text file processing and plot a chart
4. Data gathering from Websites and Applications
   4.1 Concept of APIs
   4.2 Using APIs in Python
   4.3 Invoke API on a Web Server
   4.4 Capture the response
   4.5 Save the response to a file
   4.6 Invoke API on an App Server
   4.7 Capture the response
   4.8 Save the response to a file
   Exercise: Invoke APIs from Python

View Curriculum
Data Automation Mentoring Program

The Data Automation Mentoring is designed for non-programmers who want to create programs in Python to help them automate some of their mundane daily tasks related to gathering and analyzing data. By using hands-on, lab-based programming exercises and a mix of live sessions and programming assignments, it provides an opportunity to the student to define and develop a Python program based on a practical and relevant use case. [Live Session: 1/2 day every week], [One-on-One Mentoring: 1 hour each week], [Self-Study: Python program development, approximately 6 hours average each week]

Intended Audience
This workshop is intended for anyone (non-programmers) who wants to build knowledge and skills related to leveraging data tools to be more productive.

Objectives
After completing this course, the learner will be able to:
■ Analyze a problem and design step-by-step ways to automate the task at hand
■ Learn how to manage data in different forms of data structures to load and manipulate data
■ How to use key control structures to manage the process flow
■ Implement solutions based on string manipulation, regular expression processing and loops
■ Implement a data processing exercise using control and data structures including file operations
■ Implement text file and Excel file handling for Input/Output processing
■ Learn how to automate data collection through APIs
■ Python is used as the programming language for all exercises and lab-work

What You Can Expect
■ Prerequisite: Basic knowledge of Excel
■ Required Equipment: Students will need a laptop with MS-Excel and Python
■ Total Expert-Led Live Duration: 40 HOUR
■ Total Self-Paced Duration: 32 HOUR

Outline
1. Fundamentals of PYTHON 1
   1.1 Create and run a program
   1.2 int, str, float, print()
   1.3 Import - os, sys
   Exercise: Program Development Assignment

2. Fundamentals of PYTHON 2
   2.1 File operations
   2.2 for, if/elif/else, lists, sys.argv
   2.3 try, except
   Exercise: Program Development Assignment

3. OPENPYXL
   3.1 pip install, while
   3.2 xlsx - open, create, read, write, save
   3.3 chart, sys.argv, tkinter
   Exercise: Program Development Assignment

4. PANDAS
   4.1 pandas dataframe
   4.2 load dataframe, output to xlsx
   4.3 add, drop, columns, rows, analysis
   Exercise: Program Development Assignment

5. Participant USE CASE - PART 1
   5.1 Designing simple, maintainable scripts
   5.2 Writing pseudo-code, functions, logical steps

6. Participant USE CASE - PART 2
   6.1 Types of inputs
   6.2 File-based, URL-based, API-based, SQL-based
   6.3 Example of invoking an API
   Exercise: Program Development Assignment

7. Participant USE CASE - PART 3
   7.1 Analysis using python and/or pandas
   7.2 Package specific implementations
   7.3 Pros and Cons of approaches
   Exercise: Program Development Assignment

8. Participant USE CASE - PART 4
   8.1 Output the analysis from the USE CASE
   8.2 Output format
   8.3 Output visualizations
   Exercise: Program Development Assignment

9. Participant USE CASE - Final Completion
   9.1 Participant USE CASE submission
   9.2 Participant USE CASE presentation
   9.3 Participant USE CASE demonstration
   9.4 Feedback and Wrap-up

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Thank You