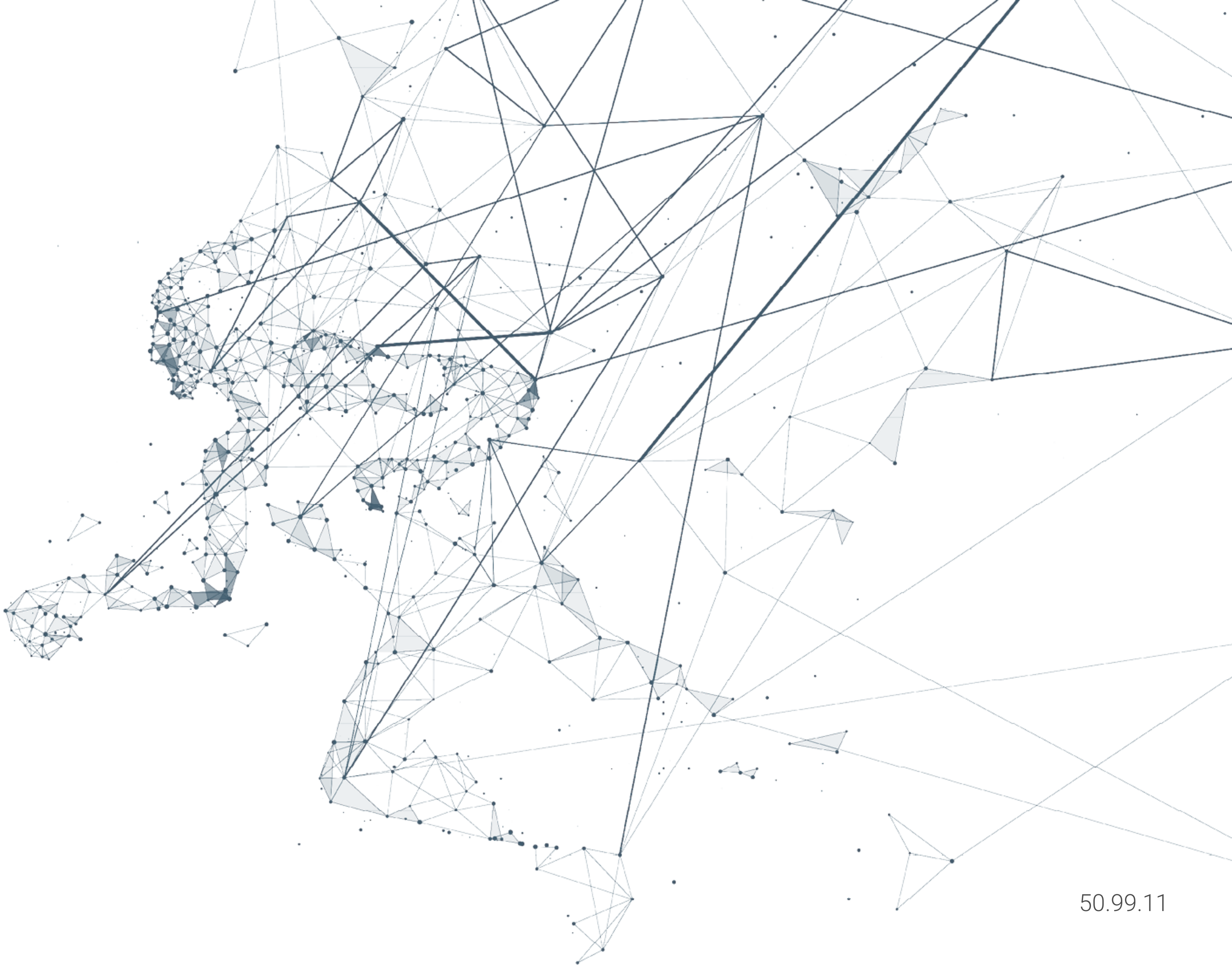
Course Catalog



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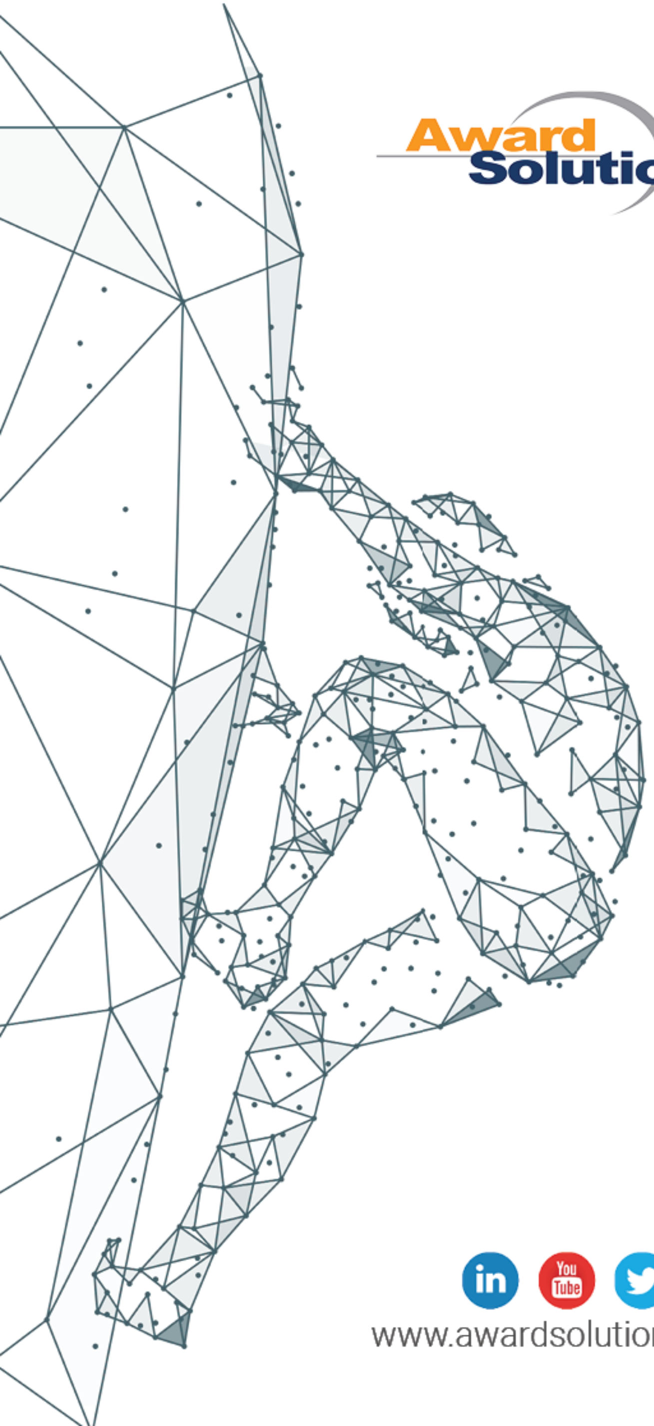

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ON-DEMAND - EXPRESS

RF and Radio Network Fundamentals
Welcome to MIMO and Beamforming in 5G
Welcome to 5G RAN Evolution
5G NR Air Interface Overview - Part I
5G NR Air Interface Overview - Part II
Welcome to O-RAN Part 1: Open RAN and O-RAN in 5G
Welcome to O-RAN Part 2: Disaggregation of the 5G RAN
Welcome to O-RAN Part 3: SMO and O-Cloud
Welcome to O-RAN Part 4: RIC and Apps in O-RAN
Welcome to RF Planning and Design

ON-DEMAND - EXPANDED

Wireless Technologies and Network Operations
LTE-M and NB-IoT
5G Radio Technologies and Deployments
VRAN and Open RAN Overview
O-RAN Architecture Overview
Overview of CBRS
5G (SA) RAN Signaling and Operations Part 1: 5G RAN Essentials
5G (SA) RAN Signaling and Operations Part 2: Network Acquisition
5G (SA) RAN Signaling and Operations Part 3: Registration and PDU Session Setup
5G (SA) RAN Signaling and Operations Part 4: Downlink Data Transfer
5G (SA) RAN Signaling and Operations Part 5: Uplink Data Transfer
5G (SA) RAN Signaling and Operations Part 6: Handover and Idle Mode
5G RF Planning and Design Part 1: 5G NR Air Interface Features
5G RF Planning and Design Part 2: Throughput and Capacity in 5G
5G RF Planning and Design Part 3: 5G Link Budget
5G RF Planning and Design Part 4: Design Process and Tools
5G NR Air Interface

EXPERT-LED

5G Radio Technologies and Deployments
VRAN and Open RAN Overview
Integrated Access and Backhaul (IAB) Overview
O-RAN Architecture Overview
Overview of CBRS
5G Enhancements in R16
5G Enhancements in R17
O-RAN Architecture and Operations
5G RAN Capacity Planning
5G NR Air Interface
LTE-M and NB-IoT Networks and Operations
5G RF Planning and Design
5G (NSA) RAN Signaling and Operations
5G (SA) RAN Signaling and Operations
5G RF Performance Workshop (UE Based)

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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
   - 2.3 Radio network evolution
   - 2.4 Cell site components
   - 2.5 Radio Units and Baseband Units
   - 2.6 C-RAN and V-RAN
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

Final Assessment

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

Welcome to 5G RAN Evolution

This course provides a technical introduction to evolution of the Radio Access Network (RAN) to 5G RAN. You will learn the key RAN components and their connectivity, the architecture of centralized / distributed RAN. The 5G deployment steps through Non-Stand-Alone and Standalone configurations are illustrated. The short-comings of the 4G RAN architecture are described, and shows how the 5G RAN evolution to split architecture, enhanced transport and evolution to virtualized and Open RAN are used to overcoming these issues.

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:

- Show the evolution of wireless networks from 3G to 5G
- What do we mean by Radio Access Network (RAN)?
- Define Distributed and Centralized RAN
- 5G Deployment steps from Non-Stand-Alone to Stand-Alone
- Describe the gNB Functions
- Identify the need for split architecture in 5G RAN
- Identify the three transport networks in 5G RAN
- Define the role for Virtualized and Open RAN in 5G

What You Can Expect

- Self-Paced Duration: 1 HOUR

Outline

1. Introduction to RAN
- 1.1 Wireless Networks Evolution
- 1.2 What is the RAN?
- 1.3 Centralized RAN and CPRI
- 1.4 Limitations of 4G RAN
- 1.5 5G RAN Deployments
- 1.6 RAN Deployment Infographic

2. 5G Split RAN and Fronthaul Upgrade
- 2.1 5G RAN Evolution
- 2.2 gNB Functions
- 2.3 Split Architecture of 5G RAN
- 2.4 Transport connectivity in the Split 5G RAN

3. Virtual and Open RAN
- 3.1 Virtualized and Open RAN
- 3.2 O-RAN architecture overview

Putting It All Together

Final Assessment

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

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 O-RAN Part 1: Open RAN and O-RAN in 5G

This course provides a technical introduction to Open RAN in the 5G radio network and describes the role of the O-RAN Alliance in defining the open 5G RAN architecture. You will identify key drivers and benefits of virtualized and Open RAN initiatives supported by O-RAN Alliance.

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:

- Identify key drivers for virtualized and open RAN
- Show examples of virtualized gNB components like vCU, vDU
- Sketch O-RAN architecture and identify O-RAN components
- Identify the role of SMO, RIC and their interfaces to RAN components
- Identify role of artificial intelligence and external apps for RAN analytics

What You Can Expect

- Self-Paced Duration: 1 HOUR

Outline

Welcome to O-RAN Part 2: Disaggregation of the 5G RAN

This training, part of a multi-part Welcome to O-RAN series, provides insights into how aspects of 5G RAN disaggregation contribute to an open, O-RAN architecture. In this course, you will learn how RAN disaggregation lends itself to an open, virtual, multi-vendor RAN. You will explore open fronthaul (Option 7-2x) for O-RAN and how O-RAN nodes are implemented in the O-RAN reference architecture.

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 key drivers for 5G RAN disaggregation (RAN latency, fronthaul bandwidth, resource pooling)
- Explain the 5G split RAN architecture
- Identify different RAN components and interfaces (CU, DU, RU and Fronthaul, Midhaul, Backhaul)
- Describe the implementation of the 5G RAN in an O-RAN architecture (O-CU, O-DU, O-RU, O-Cloud)
- Explain O-RAN operational interfaces and the need for open fronthaul
- Describe O-RAN management interfaces (O1, O2, E2 and A1) and their operations

What You Can Expect

- Self-Paced Duration: 1 HOUR

Outline

1. Requirements for the 5G RAN
- 1.1 History of RAN Evolution
- 1.2 5G RAN Requirements
- 1.3 5G RAN Standards

2. Building Blocks of Open RAN
- 2.1 Disaggregating the Protocol Stack (Split RAN)
- 2.2 Split RAN and Location Flexibility
- 2.3 Disaggregating the Software Stack (Cloud RAN)

3. Migrating to Open RAN
- 3.1 Distributing RAN Intelligence
- 3.2 Multi-Vendor RAN Management
- 3.3 Extending the Vendor Ecosystem

4. Benefits and Challenges of Open RAN
- 4.1 Summarizing RAN Evolution to O-RAN
- 4.2 Migrating to Open RAN

Putting It All Together

Final Assessment

Welcome to O-RAN Part 3: SMO and O-Cloud

The O-RAN alliance specifies Service Management and Orchestration, along with O-RAN-compliant RAN functions and an Open-Cloud or O-Cloud infrastructure. This gives wireless network operators the automation, intelligence, and open architecture they need to meet the demands of Industry 4.0, including use cases like Augmented Reality and Virtual Reality. In this training, you will learn about both the Service Management and Orchestration (SMO) and the O-Cloud described and specified by the O-RAN Alliance. You will gain an understanding of how these technologies work together to create open and intelligent mobile networks. You will also learn about the benefits of O-RAN, including increased flexibility, reduced costs, and improved scalability.

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 role of SMO and O-Cloud in O-RAN
- Outline the SMO architecture and specify the interfaces
- Explain the SMO key functions
- List the SMO deployment models
- Sketch the O-Cloud architecture
- Outline the services provided by O-Cloud
- Illustrate options to synchronize O-Cloud
- List the O-Cloud deployment options for use cases

What You Can Expect

- Self-Paced Duration: 1 HOUR

Outline

1. Service Management and Orchestration (SMO)
- 1.1 SMO Business Benefits
- 1.2 SMO Architecture and Interfaces
- 1.3 SMO Key Functions
- 1.4 SMO Deployment Models

2. O-Cloud
- 2.1 O-Cloud Architecture
- 2.2 O-Cloud Interactions with the SMO
- 2.3 O-Cloud Service
- 2.4 O-Cloud Synchronization
- 2.5 O-Cloud Deployment Scenarios

Putting It All Together

Final Assessment

View Curriculum

Welcome to O-RAN Part 4: RIC xApps and rApps

This course provides a technology introduction to RAN Intelligence Controller (RIC) Apps and external enrichment in O-RAN operations. You will learn the role of xApps and rApps in O-RAN and the benefits and use of external enrichment data in O-RAN operations. You will also explore how O-RAN can use AI/ML to improve the performance of the RAN.

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 benefits and role of apps in O-RAN operations in Non-RT RIC and Near-RT RIC
- List role and operations of rApps and xApps in O-RAN management
- Explain RIC operations for O-RAN performance improvement
- Describe O-RAN operational use cases

What You Can Expect

- Self-Paced Duration: 1 HOUR

Outline

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

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
- 3.2 Idle mode and paging
- 3.3 Handover and roaming
- **Exercise:** 4G UE Attach
- **Exercise:** Knowledge check

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

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 celluar 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 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:** 5G downlink and uplink 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 uses 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

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 uses 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.

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 functions
- 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

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

View Curriculum

Overview of CBRS

Exponentially rising data traffic, scarcity of spectrum, and expectations of enhanced user experience including 1 Gbps data rates are driving operators to explore the use of shared spectrums such as CBRS – Citizens Broadband Radio Service. Operators can deploy LTE or 5G networks in the 3.5 GHz CBRS spectrum using Licensed Assisted Access. 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 roles of CBSD, Domain Proxy, SAS, and ESC
- Step through key operations of CBRS

What You Can Expect

- Self-Paced Duration: 4 HOUR

Outline

1. CBRS Essentials
- 1.1 Types of radio spectrum
- 1.2 Definition of CBRS
- 1.3 Three-tier structure (IA, PAL, GAA)
- 1.4 Sharing of CBRS Band 48
- 1.5 CBRS Standards - OnGo, WInnForum, FCC
- 1.6 CBRS Use Case Summary

2. CBRS System Architecture
- 2.1 End-to-end architecture
- 2.2 CBSD categories A and B
- 2.3 End user devices
- 2.4 SAS, ESC, Domain Proxy

Exercise: Building a CBRS Network

3. CBRS Operations
- 3.1 Overview of CBSD operations
- 3.2 Registration
- 3.3 Grant Request
- 3.4 Heartbeat Exchanges between CBSD and SAS
- 3.5 Inter-SAS communications
- 3.6 Security Mechanisms

Exercise: CBSD-SAS Procedures

4. CBRS Deployment
- 4.1 CBRS for Wireless Service Providers
- 4.2 CBRS for Enterprise Applications
- 4.3 CBRS for Neutral Host Applications

Exercise: CBRS Coverage

Putting It All Together

Final Assessment

5G SA RAN Signaling and Operations Part 1: 5G RAN Essentials

This is the first course in a six-course set of self-paced courses encompassing 5G SA RAN Signaling and Operations. In this course, you will learn about the 5G SA RAN architecture and interfaces as well as the life of a 5G device in a 5G SA deployment from a RAN signaling and operations perspective. This course includes a review of key 5G New Radio (NR) air interface capabilities needed to put RAN architecture and operations into context. Each course in this six-course set can stand on its own or can be combined with other courses as necessary to meet your learning objectives.

Intended Audience

5G RAN and device engineering, operations, and performance related job functions

Objectives

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

- Describe the interfaces and protocols related to 5G NR RAN signaling
- Step through the life of a 5G UE in SA (Option 2) deployment
- Review key functionalities of 5G NR such as flexible numerology, beamforming

What You Can Expect

- Prerequisite: 5G NR Air Interface
- Self-Paced Duration: 4 HOUR

Outline

1. **5G Standalone (SA) RAN Overview: RAN Essentials**
   - 1.1 5G SA RAN split architecture - gNB-CU, gNB-DU
   - 1.2 Use of interfaces: NR, N1, N2, N3
   - 1.3 Role of protocols like PHY, MAC, RRC, PDCP, NAS
   - 1.4 gNB related interfaces - F1, Xn
   - 1.5 5G RAN performance targets and solutions
   - 1.6 NR Numerology and Frame Structure
   - 1.7 Role of beamforming and MIMO
   - 1.8 Bandwidth adaptation (BWP)

   Exercise: 5G SA RAN architecture and interfaces
2. **5G SA RAN Overview: UE Operations in 5G SA Overview**
   - 2.1 5G NR air interface overview
   - 2.2 Life of a UE in 5G SA network

   Exercise: 5G SA operations
3. **5G NR Air Interface Overview**
   - 3.1 Key features of 5G NR air interface
   - 3.2 NR Numerology and Frame Structure
   - 3.3 Synchronization Signals and Broadcast Channel (SS/PBCH)

Assessment

5G SA RAN Signaling and Operations Part 2: Network Acquisition

This is the second course in a six-course set of self-paced courses encompassing 5G SA RAN Signaling and Operations. In this course, you will learn about network acquisition for a device in a 5G standalone RAN. You will explore how a device finds and downlink synchronizes with a 5G New Radio cell, reads system information needed for cell selection and uplink synchronization, and establishes dedicated communications with the cell. Each course in this six-course set can stand on its own or can be combined with other courses as necessary to meet your learning objectives.

Intended Audience

5G RAN and device engineering, operations, and performance related job functions

Objectives

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

- Describe the steps of preparing to monitor 5G SA cell and 5G network acquisition
- Summarize the Random Access (RACH) operation
- Explain the details of RRC connection setup with the gNB

What You Can Expect

- Prerequisite: 5G NR Air Interface
- Self-Paced Duration: 4 HOUR

Outline

1. Downlink Sync and System Information
    - 1.1 Cell acquisition and RACH operation
    - 1.2 Power on sequence for a device in 5G SA
    - 1.3 SSB and beam sweeping
    - 1.4 Beam association on network acquisition
    - 1.5 Cell search operation using SS/PBCH
    - 1.6 SSB measurements
    - 1.7 System Information: MIB and SIB1
    - 1.8 Cell selection criteria
    - **Exercise:** Network acquisition
2. Uplink Synchronization and RRC Setup
    - 2.1 Uplink synchronization using RACH
    - **Exercise:** RACH configuration
    - **Exercise:** Preamble power control parameters
    - **Exercise:** Preamble power calculations
    - 2.2 RRC connection setup

Assessment

5G SA RAN Signaling and Operations Part 3: Registration and PDU Session Setup

This is the third course in a six-course set of self-paced courses encompassing 5G SA RAN Signaling and Operations! In this course, you will learn key operations for a device to gain access to the 5G SA network and establish sessions with services networks. You will explore registration including authentication of the user as well as PDU session establishment with a data network. Each course in this six-course set can stand on its own or can be combined with other courses as necessary to meet your learning objectives.

Intended Audience

5G RAN and device engineering, operations, and performance related job functions

Objectives

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

- Identify key steps of registering and authenticating a 5G device in SA network
- Esplain the key steps of setting up PDU session in SA
- List 5G identifiers for device and network and radio states of a 5G device
- Illustrate Quality of Service (QoS) parameters in 5G network

What You Can Expect

- Prerequisite: 5G NR Air Interface
- Self-Paced Duration: 4 HOUR

Outline

1. UE Registration

- 1.1 5G Identifiers
- 1.2 Radio states of a UE
- 1.3 UE registration in 5G
- 1.4 Authentication and security
- 1.5 AS and NAS security
- **Exercise:** Registration and authentication signaling flow
- **Exercise:** Registration and AMF selection

2. PDU Session Setup

- 2.1 5G Quality of Service (QoS)
- 2.2 PDU Session Setup
- **Exercise:** PDU session establishment signaling flow
- **Exercise:** PDU session setup and SMF selection
- **Exercise:** PDU session setup - DNN, Network Slice, SSC mode

Assessment

5G SA RAN Signaling and Operations Part 4: Downlink Data Transfer

This is the fourth course in a six-course set of self-paced courses encompassing 5G SA RAN Signaling and Operations! In this course, you will learn about downlink data transfer from a gNodeB to a device. You will explore the necessary signals and feedback the gNodeB needs from the device, how the gNodeB does resource allocation for downlink data, and the use of incremental redundancy for efficient and reliable communications. Each course in this six-course set can stand on its own or can be combined with other courses as necessary to meet your learning objectives.

Intended Audience

5G RAN and device engineering, operations, and performance related job functions

Objectives

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

- Explore the role of beamforming in DL traffic operations
- Identify 5G NR signals and UE measurements related to downlink operation
- Highlight downlink resource allocation and Hybrid ARQ procedures
- Explore RRC signaling messages and parameters for the uplink operation

What You Can Expect

- Prerequisite: 5G NR Air Interface
- Self-Paced Duration: 4 HOUR

Outline

1. Downlink Data Parameters

1.1 Overview of Downlink data transfer in 5G
1.2 Downlink signals and UE measurements
1.3 UE measurement reporting
1.4 SRS and CSI-RS configuration
1.5 CSI metrics
Exercise: CSI-RS configurations
Exercise: CSI Report configurations
Exercise: PDCCH and PDSCH configurations

2. Downlink Data Transfer Operations

2.1 Downlink resource allocation
2.2 Downlink data transfer
2.3 Downlink data transmission with Hybrid ARQ
2.4 Carrier Aggregation (CA) operation
Exercise: Traffic operations in downlink

Assessment

5G SA RAN Signaling and Operations Part 5: Uplink Data Transfer

This is the fifth course in a six-course set of self-paced courses encompassing 5G SA RAN Signaling and Operations. In this course, you will learn about uplink data transfer from a device to a gNodeB. You will explore how the device requests to be scheduled for uplink resources, how the gNodeB does resource allocation for uplink data, and how power control is used to meet uplink signal quality requirements. Each course in this six-course set can stand on its own or can be combined with other courses as necessary to meet your learning objectives.

Intended Audience

5G RAN and device engineering, operations, and performance related job functions

Objectives

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

- Explore the role of beamforming in UL traffic operations
- Step through the procedures of Scheduling Request and Buffer Status Report
- Step through the resource allocation and power control for the uplink
- Explore RRC signaling messages and parameters for the uplink operation

What You Can Expect

- Prerequisite: 5G NR Air Interface
- Self-Paced Duration: 4 HOUR

Outline

1. Uplink Data Parameters

- 1.1 Overview of Uplink data transfer in 5G
- 1.2 Scheduling Request and Buffer Status Report
- 1.3 Scheduling Request (SR) configuration
- 1.4 Buffer Status Report and Power headroom reports
- **Exercise:** PUCCH configuration
- **Exercise:** Scheduling Request configuration
- **Exercise:** PUSCH configuration

2. Uplink Data Transfer Operations

- 2.1 Uplink resource allocation and data transfer
- 2.2 Uplink data transmission and Hybrid ARQ
- 2.3 Uplink power control operation
- **Exercise:** Traffic operations in uplink
- **Exercise:** Uplink power control

Assessment

View Curriculum

5G SA RAN Signaling and Operations Part 6: Handover and Idle Mode

This is the sixth course in a six-course set of self-paced courses encompassing 5G SA RAN Signaling and Operations! In this course, you will learn about mobility in a 5G standalone network. You will explore beam switching and handover for connected devices as well as cell reselection for devices with an idle or inactive cell connection. Each course in this six-course set can stand on its own or can be combined with other courses as necessary to meet your learning objectives.

Intended Audience

5G RAN and device engineering, operations, and performance related job functions

Objectives

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

- Step through the connected mode handovers based on Xn interface
- Identify various handover events and related measurement parameters and reports
- Step through the Idle and Inactive mode mobility and related procedure
- Explore RRC signaling messages and parameters for connected and Idle mode handovers

What You Can Expect

- Prerequisite: 5G NR Air Interface
- Self-Paced Duration: 4 HOUR

Outline

1. Connected Mobility Operations
   - 1.1 Beam Management - Switching, Failures, Recovery
   - 1.2 Xn based handovers
   - **Exercise:** Xn handover messaging flow
   - **Exercise:** Measurement configuration
   - **Exercise:** Measurement reports
   - **Exercise:** Handover execution and completion
2. Idle and Inactive Mode Operations
   - 2.1 Idle mode in 5G
   - 2.2 RRC Idle and Inactive mode operations
   - 2.3 Systems Information and Cell reselection criteria
   - **Exercise:** Idle mode messaging flow
   - **Exercise:** Inactivity operation flow

Assessment

5G RF Planning and Design Part 1: 5G NR Air Interface Features

This is the first course in a four-course set of self-paced courses encompassing 5G RF Planning and Design. In this course, you will learn about the 5G NR air interface features that impact RF design including frequency bands and numerologies. You will also learn about beamforming and MIMO in 5G and the RF propagation considerations for 5G RF design. Each course in this four-course set can stand on its own or can be combined with other courses as necessary to meet your learning objectives.

Intended Audience

RF planning and design and performance optimization engineers

Objectives

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

- Identify 5G NR features important to RF design, e.g., NR numerology, FR1, FR2
- Explain beamforming and massive MIMO and list propagation models suitable for low, mid, and mmW

What You Can Expect

- Prerequisite: 5G NR Air Interface
- Self-Paced Duration: 4 HOUR

Outline

1. 5G NR Essentials
- 1.1 5G Use Cases and Performance Targets
- 1.2 Evolution from 4G to 5G
- 1.3 NSA and Dual-Connectivity

2. 5G NR Features
- 2.1 5G Air Interface Features
- 2.2 Frequencies for 5G
- 2.3 Numerology
- **Exercise:** Numerology Impact on RF Design

3. Beamforming
- 3.1 Beamforming
- 3.2 Beams and Phased Arrays
- 3.3 Analog and Digital Beamforming
- 3.4 Hybrid and Full-Dimension Beamforming
- 3.5 Beamforming and MIMO
- **Exercise:** Beamforming

4. Beam Management
- 4.1 Coverage and Traffic Beams
- 4.2 Beam Operations
- 4.3 Active Antenna Systems (AAS) and MIMO

Final Assessment

5G RF Planning and Design Part 2: Throughput and Capacity in 5G

This is the second course in a four-course set of self-paced courses encompassing 5G RF Planning and Design. In this course, you will learn about downlink and uplink throughput and capacity of a 5G cell and how it is influenced by the 5G NR air interface capacity. You will also learn about device capabilities and how they can affect user throughputs and how to develop a call model to calculate capacity of a cell. Each course in this four-course set can stand on its own or can be combined with other courses as necessary to meet your learning objectives.

Intended Audience

RF planning and design and performance optimization engineers

Objectives

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

- Identify key 5G RF design inputs
- Calculate the downlink and uplink cell capacity and throughput
- Describe the influence of the 5G NR air interface on capacity
- Explore user throughput relative to device capabilities and bandwidths

What You Can Expect

- Prerequisite: 5G NR Air Interface
- Self-Paced Duration: 4 HOUR

Outline

1. **Capacity Planning**
   - 1.1 Capacity Planning Process
   - 1.2 Capacity Planning Inputs and Assumptions
   - 1.3 Capacity Considerations - Band, CA, DC
2. **Network and Device Capacity**
   - 2.1 CORESET Configurations
   - 2.2 5G Device Capabilities and Parameters
   - 2.3 Capacity Estimation
3. **Downlink and Uplink Cell Capacity**
   - 3.1 Downlink Cell Capacity
   - 3.2 Uplink Cell Capacity
   - **Exercise:** Capacity Calculation Exercise
4. **Throughput Calculations**
   - 4.1 Estimating User Throughputs
   - 4.2 Mid-band Throughput Calculations
   - **Exercise:** Throughput Calculation Exercise

Final Assessment

5G RF Planning and Design Part 3: 5G Link Budget

This is the third course in a four-course set of self-paced courses encompassing 5G RF Planning and Design. In this course, you will learn about the components of a 5G link budget. You will also learn the impacts of mid-band frequencies and different types of 5G use cases on the link budget. Each course in this four-course set can stand on its own or can be combined with other courses as necessary to meet your learning objectives.

Intended Audience

RF planning and design and performance optimization engineers

Objectives

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

- Identify components of 5G link budget for different services in low, mid, high bands
- Describe the uplink and downlink channels and signals in 5G
- Calculate 5G link budgets for eMBB and URLLC

What You Can Expect

- Prerequisite: 5G NR Air Interface
- Self-Paced Duration: 4 HOUR

Outline

1. 5G Link Budget Principles
- 1.1 Link Budget Principles
- 1.2 Approach for Developing a Link Budget
- 1.3 Link Budget and Cell Size

2. Propagation Models
- 2.1 Propagation for 5G Spectrum
- 2.2 Propagation Model and Scenarios

3. Channels and Signals for RF Design
- 3.1 Downlink Channels and Signals
- 3.2 Uplink Channels and Signals

4. Link Budget Considerations
- 4.1 Uplink Link Budget for eMBB
- 4.2 Downlink Link Budget for eMBB
- 4.3 URLLC and mMTC Link Budgets
- 4.4 Mid-band Link Budget

Exercise: Link Budget Calculations for DL and UL

View Curriculum

5G RF Planning and Design Part 4: Design Process and Tools

This is the fourth course in a four-course set of self-paced courses encompassing 5G RF Planning and Design. In this course, you will learn about 5G RF parameter planning and the impacts of NSA to the RF design. You will also learn about using RF planning tools for 5G RF design including KPIs and 5G site selection. Each course in this four-course set can stand on its own or can be combined with other courses as necessary to meet your learning objectives.

Intended Audience

RF planning and design and performance optimization engineers

Objectives

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

- Step through the planning process for different RF configuration and operational parameters
- Illustrate the steps of 5G RF design process, including traffic mapping and propagation modeling
- List the steps for 5G RF design with an RF planning tool

What You Can Expect

- Prerequisite: 5G NR Air Interface
- Self-Paced Duration: 4 HOUR

Outline

1. gNB and Cell Configuration Parameters
   - 1.1 5G Network Planning Factors
   - 1.2 5G PCI planning
   - 1.3 RSI Planning
2. NSA and SA Planning Considerations
   - 2.1 5G NSA - Carrier Add/Modify
   - 2.2 5G SA - TA and RNA Planning
3. 5G RF Planning and Design Process
   - 3.1 5G RF Design Goals and Strategies
   - 3.2 5G RF Design Inputs and Outputs
   - 3.3 5G RF Design Preparing the Planning Tool
   - 3.4 5G RF Design Site Selection
4. RF Planning Tool Primer
   - 4.1 RF Planning Tool Introduction
   - 4.2 RF Project Configuration
   - 4.3 Site Configuration
   - 4.4 5G Analysis

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

Design, Development, and Performance Engineers of Radio Network, Device, and Tools.

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: Welcome 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

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: Familiarity with 5G
- 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

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 uses 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

View Curriculum

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

- Prerequisite: Welcome to 5G
- Expert-Led Live Duration: 4 HOUR

Outline

1. IAB: What and Why?
- 1.1 Transport bandwidth
- 1.2 Coverage fill
- 1.3 First mile access
- 1.4 Space limitations
- **Exercise:** Knowledge check

2. IAB Architecture
- 2.1 gNB BBU split
- 2.2 Donors DUs and IAB DUs
- 2.3 Relay
- 2.4 F1 and Backhaul Adaptation Protocol (BAP)
- **Exercise:** Build IAB-based 5G network
- **Exercise:** Knowledge check

3. IAB Operations
- 3.1 Multiplexing access and backhaul
- 3.2 Route management
- 3.3 IAB resource management
- 3.4 Backhaul bearer setup
- **Exercise:** Knowledge check

4. IAB Deployment Scenarios
- 4.1 Cell densification
- 4.2 Coverage fill
- 4.3 Coverage extension
- **Exercise:** Knowledge check

Putting it all together

Final Assessment

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 uses cases of mobile broadband, edge computing, and IoT. This training presents an overview of O-RAN architecture, components of 5G RAN and its intererfaces and likely deployment scenarios.

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 functions
- 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
- Expert-Led Live Duration: 4 HOUR

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
Exercise: Knowledge check

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

View Curriculum

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 Exchance 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

View Curriculum

5G Enhancements in 3GPP R16

5G R16 features augment the existing 5G R15 features to accomplish improved system performance and also address new verticals and deployment scenarios. This course explores 5G R16 enhancements for improved New Radio mobility performance, extended device battery life, reduced latency, enhanced reliability, and security. In addition, this course provides an overview of new features that enrich 5G system performance such as cellular IoT, private 5G networks, 5G SRVCC, and others.

Intended Audience

This course is intended for planning, engineering, and system integration teams.

Objectives

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

- Sketch the 3GPP roadmap for 5G
- Illustrate device power saving features of 5G R16
- Explain 5G R16 mobility performance enhancements
- Describe reliability improvement enhancements in 5G R16
- Describe latency improvement enhancements in 5G R16
- Describe 5G R16 enhancements for cellular IoT, NTN, IAB

What You Can Expect

- Prerequisite: Good understanding of 5G NR R15
- Expert-Led Live Duration: 4 HOUR

Outline

1. 5G Rel 16 Enhancements - What and Why?
- 1.1 5G use case requirements
- 1.2 UE-focused 5G 3GPP roadmap
- 1.3 Network-focused 5G 3GPP roadmap

2. Device Battery Life Enhancement for IoT
- 2.1 C-DRX adaptation/Wake-Up Signaling (WUS)
- 2.2 Enhanced cross-slot scheduling
- 2.3 Maximum MIMO layers adaptation
- 2.4 Relaxed RRM for idle/inactive UEs
- 2.5 Scell dormancy

3. Mobility Enhancement for URLLC
- 3.1 Dual Active Protocol Stack (DAPS) handover
- 3.2 Conditional Handover (CHO)
- 3.3 T312-based fast RLF recovery

4. Reliability Improvement Features
- 4.1 End-to-end dual connectivity
- 4.2 Redundant transmission in Core network tunnel
- 4.3 Enhanced configured grant configurations

5. Latency Improvement Features
- 5.1 2-Step RACH operation
- 5.2 Enhanced PDCCH monitoring
- 5.3 Sub-slot-based HARQ ACK Feedback
- 5.4 Inter-UE Uplink Preemption

6. 5G System Enhancement Features
- 6.1 Network Slice Specific Authentication and Authorization (NSSAA)
- 6.2 Control plane cellular IoT optimization
- 6.3 Non-Public Networks (NPN)
- 6.4 5G SRVCC (from 5GS to 3G)
- 6.5 Integrated Access and Backhaul (IAB)

Putting It All Together

View Curriculum

5G Enhancements in 3GPP R17

5G Release 17 features augment the existing 5G R15 and R16 features to achieve improved system performance and address new verticals and deployment scenarios. This training explores 5G R17 enhancements as well as new features for devices, radio networks, and core networks of 5G. Improved coverage, enhanced mobility performance, extended device battery life, support for Reduced Capability (RedCap) devices, and Non-Terrestrial Networks (NTN) are among the notable improvements.

Intended Audience

This course is intended for planning, engineering, and system integration teams.

Objectives

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

- Identify the driving factors for 5G R17 enhancements
- Describe 5G R17 coverage improvement features
- Explain 5G R17 UE battery power-saving features
- Describe 5G R17 RedCap and Multi-USIM devices
- Describe 5G R17 network-focused enhancements
- Explain 5G R17 network capabilities - NTN and MBS

What You Can Expect

- Prerequisite: Good understanding of 5G NR R15 and R16
- Expert-Led Live Duration: 4 HOUR

Outline

1. 5G R17 Enhancements - What and Why?
- 1.1 Drivers for 5G R17 enhancements
- 1.2 Device-focused features in 5G roadmap
- 1.3 Network-focused features in 5G roadmap

2. Uplink Coverage Improvement Features
- 2.1 Enhanced PUSCH Repetition Type A
- 2.2 PUSCH Repetition Type A for Msg 3
- 2.3 Dynamic PUCCH repetition indication
- 2.4 PUSCH process over Multiple Slots (TBoMS)

Exercise: Knowledge check

3. RedCap (NR-Light) and Multi-USIM devices
- 3.1 5G R17 - RedCap device - What and Why?
- 3.2 UE complexity reduction features
- 3.3 5G network support for RedCap devices
- 3.4 5G R17 Multi-USIM UE - What and Why?
- 3.5 Paging enhancements for MUSIM devices
- 3.6 Network switching for MUSIM devices

Exercise: Knowledge check

4. 5G R17 UE Battey Power Saving Features
- 4.1 Power-efficient paging reception
- 4.2 Small data transmission in inactive mode
- 4.3 Relaxed RLM/BFD measurements
- 4.4 Reduced PDCCH monitoring for active UE

Exercise: Knowledge check

5. 5G R17 Network Performance Enhancements
- 5.1 Network slicing enhancements
- 5.2 MEC network enhancements
- 5.3 Private 5G network enhancements

Exercise: Knowledge check

6. Non-Terrestrial Network (NTN)
- 6.1 NTN - what and why?
- 6.2 Platforms for Non-Terrestrial Network
- 6.3 Satellite-based 5G network architecture
- 6.4 Opportunities and challenges for 5G NTN
- 6.5 NTN 5G NR air interface capabilities
- 6.6 NTN use cases

Exercise: Knowledge check

7. 5G Multicast Broadcast Service (5G MBS)
- 7.1 5G MBS - what and why?
- 7.2 5G MBS architecture
- 7.3 5G MBS use cases

Exercise: Knowledge check

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:

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

What You Can Expect

- Prerequisite: Welcome to 5G
- 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
- 2.8 O-RAN Split Option 7-2x Interface
- 2.9 APIs in O-RAN

Exercise: O-RAN architecture

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

View Curriculum

5G RAN Capacity Planning

This hands-on training takes an in-depth look at the 5G RAN capacity in the context of use of low, mid, and mmW frequency spectrums, FDD and TDD modes of operations, and EN-DC, NR-DC, and Carrier Aggregation. This training provides essential foundation of 5G NR Air Interface and its DL and UL channels, signals, flexible numerologies, use of massive MIMO for beamforming and MU-MIMO for capacity calculations. Training provides introduction to Supervised Learning approach to capacity planning and compare benefits with current time series analysis approach. Participants use capacity planning calculators for both DL and UL cell capacity for traffic and control channels.

Intended Audience

RAN Capacity engineers

Objectives

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

- Identify 5G NR features important to RAN Capacity, e.g., NR numerology, FR1, FR2
- Explain beamforming and massive MIMO and impact to capacity in low, mid, and mmW
- Identify key planning inputs and calculate the downlink and uplink cell capacity and throughput
- Identify key planning inputs and calculate control channel capacity needs
- List RAN capacity KPIs for control and traffic channels
- Describe role of PRB utilization, capacity headroom, and spectral efficiency in RAN capacity
- Discuss planning guidelines for control and traffic channel resources
- Explore the concept of Supervised Learning for Capacity Planning and compare with Time Series analysis

What You Can Expect

- Prerequisite: 5G NR Air Interface
- Expert-Led Live Duration: 7 HOUR

Outline

1. 5G NR for RAN Capacity Considerations
   - 1.1 5G NR features and support for FR1 and FR2
   - 1.2 5G NR numerology and bandwidth adaptation
   - 1.3 TDD formats for capacity considerations
   - **Exercise:** Numerology impact on RF design
2. Massive MIMO and Beamforming
   - 2.1 AAS and beamforming techniques
   - 2.2 MIMO schemes in low, mid, and mmW spectrum
   - 2.3 Cell capacity considerations using MU-MIMO
   - **Exercise:** MU-MIMO and beamforming impact on Capacity
3. Control Channel Capacity Considerations
   - 3.1 Control channel capacity KPI
   - 3.2 Control Resource Set (CORESET) Configurations
   - 3.3 Impact of CCE on RF coverage and Cell capacity
   - **Exercise:** PDCCH capacity calculation
4. 5G Throughput and Capacity
   - 4.1 User and Cell Capacity KPIs
   - 4.2 PRB utilization analysis
   - 4.3 Spectral efficiency analysis
   - 4.4 5G NR DL and UL throughput and cell capacity
   - 4.5 Influence of TDD operation on user experience and cell capacity
   - **Exercise:** Throughput and capacity calculations for DL/UL
5. 5G RAN Capacity Analysis and Forecasting
   - 5.1 Cell and user capacity guidelines
   - 5.2 Capacity Planning, using time series analysis
   - 5.3 Capacity forecasting, influencing factors
   - 5.4 Introduction to Supervised Learning Models
   - 5.5 Highlights, SL models vs Time Series Analysis
   - **Exercise:** Forecasting, cell capacity for Data services

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

Design, Development, and Performance Engineers of Radio Network, Device, and Tools.

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: Welcome to 5G
- Expert-Led Live Duration: 14 HOUR

Outline

1. 5G NR Essentials
   - 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

LTE-M and NB-IoT Networks 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 Non-IP Data Delivery (NIDD) and Service Capability Exposure Function (SCEF). The fundamental operations such as network acquisition, random access, RRC connection setup, data transfer, and mobility are covered.

Intended Audience

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

Objectives

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

- Sketch the end-to-end network architecture of LTE for LTE-M and NB-IoT
- List roles of new network elements of IoT network in LTE
- List and describe categories of IoT devices supported in LTE networks
- Categorize LTE features to enhance coverage for IoT devices
- Categorize LTE features to enhance capacity and network performance
- Categorize LTE features to extend battery life of IoT devices
- Step through life of a Cat-M and NB-IoT devices and explore various network operations

What You Can Expect

- Prerequisite: LTE Overview
- Expert-Led Live Duration: 14 HOUR

Outline

1. LTE-M and NB-IoT Network Architecture

1.1 IoT essentials
1.2 IoT support in 3GPP specifications
1.3 Need for network enhancements for IoT
1.4 LTE-M and NB-IoT network architecture
1.5 End-to-end operation of IoT devices
1.6 LTE IoT devices
Exercise: IP-based IoT architecture
Exercise: Non-IP-based IoT architecture

2. LTE Enhancements for IoT

2.1 Wireless optimizations for IoT
2.2 Coverage enhancements for IoT
2.3 IoT load management
2.4 Power saving enhancements
2.5 IoT network features

3. LTE-M Operations

3.1 Device and network enhancements for LTE-M
3.2 Network Attach and UE-AS link setup
3.3 Network acquisition in LTE-M
3.4 Air interface for LTE-M
3.5 RRC Connection Setup for LTE-M
3.6 DL and UL traffic operations
Exercise: Life of a Cat-M device in LTE Networks

4. NB-IoT Operations

4.1 Characteristics of NB-IoT
4.2 NB-IoT channels and signals
4.3 System acquisition and SIBs
4.4 Random Access in NB-IoT
4.5 Initial Attach Non-IP Data Delivery (NIDD)
4.6 Air interface for NB-IoT
Exercise: Life of a NB-IoT device in LTE networks

5G RF Planning and Design

This hands-on training takes an in-depth look at the unique aspects of 5G RF planning and design, especially in FR1 Mid-band and FR2 mmW. Impact of AAS, beamforming, and MU-MIMO using massive MIMO in mid- and high-band on RF design is explained. The 5G link budgets for different frequency bands and services like eMBB, UR-LLC and mMTC are calculated and can be used for coverage predictions. The use of an RF planning tool to carry out the RF design is illustrated.

Intended Audience

RF planning and design and performance optimization engineers

Objectives

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

- Identify 5G NR features important to RF design, e.g., NR numerology, FR1, FR2
- Explain beamforming and massive MIMO and list propagation models suitable for low, mid, and mmW
- Identify key 5G RF design inputs and calculate the downlink and uplink cell capacity and throughput
- Identify components of 5G link budget for different services, applicable in low, mid, high bands
- Step through the planning process for different RF configuration and operational parameters
- Illustrate the 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 NR for RF Planning and Design
- 1.1 Use cases and performance targets of 5G
- 1.2 5G NR features and support for FR1 and FR2
- 1.3 5G NR numerology and bandwidth adaptation
- 1.4 DL and UL channels and signals
- 1.5 5G devices and power classes

Exercise: Numerology impact on RF design

2. Massive MIMO, Beamforming and Propagation Models
- 2.1 AAS and beamforming techniques
- 2.2 SSB and CSI-RS beam management
- 2.3 Massive MIMO for SU-MIMO and MU-MIMO
- 2.4 Propagation models for FR1 and FR2
- 2.5 Additional learning - Beam management

Exercise: MU-MIMO and beamforming impact on RF design

3. 5G Throughput and Capacity
- 3.1 Traffic analysis and capacity planning in 5G
- 3.2 5G NR DL throughput and cell capacity
- 3.3 5G NR UL throughput and cell capacity
- 3.4 Cell and user capacity calculations for DL/UL

Exercise: Throughput and capacity calculations for DL/UL

4. Link Budget for 5G NR
- 4.1 Components of link budget and role of MAPL
- 4.2 Link budget approaches: Per Carrier, per PRB
- 4.3 UL LB for FR1 and FR2
- 4.4 DL LB for FR1 and FR2
- 4.5 Link budget for UR-LLC and mMTC
- 4.6 Additional learning - Mid-band link budget

Exercise: Link budget calculations for DL and UL

5. 5G RF Parameter Planning
- 5.1 5G PCI planning
- 5.2 5G RACH and RSI planning
- 5.3 5G NSA - Carrier add/modify planning
- 5.4 5G SA - TA and RNA planning

Exercise: RACH parameter planning

6. 5G RF Design Process
- 6.1 5G RF design consideration for FR1 and FR2
- 6.2 5G RF planning tool components and process
- 6.3 5G Site selection - macro and small cells

Exercise: Specifics of 5G RF design process

7. 5G RF Design Using RF Planning Tool
- 7.1 Key parameters in RF planning tool
- 7.2 Project configuration
- 7.3 Site configuration
- 7.4 5G analysis

Exercise: Coverage prediction for RF cluster

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 5G 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
- Expert-Led Live Duration: 21 HOUR

Outline

View Curriculum

5G (SA) RAN Signaling and Operations

Learn about the life of a 5G device and related operations in a 5G Standalone (SA) network such as network acquisition, Radio Resource Control connection setup, registration and data session setup from a RAN signaling perspective. Explore downlink and uplink data transfer using 5G new radio, as well as handover and idle mode operations. Discover these key operations through signaling flows and learn details relating to key signaling messages and their parameters. This training is created to be both practical and engaging with exercises using log messages from a commercially deployed 5G SA network.

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 steps of RRC connection setup with the gNB
- 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
- Expert-Led Live Duration: 21 HOUR

Outline

1. 5G Standalone (SA) 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
   - **Exercise:** Registration and 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) and 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

View Curriculum

EXPERT-LED LIVE

5G RF Performance Workshop (UE Based)

This workshop helps RAN and UE engineers analyze 5G SA and NSA based RAN operations using actual UE logs. Learners use the post processing tools to analyze 5G NR and LTE 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 this hands-on workshop are reinforced. Finally, learners present one of their log analysis to reinforce the learning of this workshop.

Intended Audience

RAN and UE Performance engineers

Objectives

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

- List the 5G RAN KPIs that impacts network performance
- Identify the factors and events that impact 5G 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 (SA) RAN Signaling and Operations
- Prerequisite: 5G (NSA) RAN Signaling and Operations
- Required Equipment: Access to the UE log post processing tool
- Expert-Led Live Duration: 21 HOUR

Outline

1. RF Performance Essentials
    - 1.1 5G RAN KPIs - SA and NSA
    - 1.2 Accessibility, Retainability, Integrity, Handovers
    - 1.3 Mapping Call flow events and RAN KPIs
    - 1.4 Split bearer and PDCP Aggregation in EN-DC based NSA network
    - **Exercise:** UE log analysis
2. Accessibility Analysis
    - 2.1 RACH success in SA network
    - 2.2 SgNB Cell add success in NSA network
    - 2.3 Call flow and event triggers
    - 2.4 Impact of coverage of FR1 and FR2 and in FDD and TDD bands
    - **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
    - 3.4 Beam management
    - **Exercise:** Retainability problem analysis
    - **Exercise:** Student Exercises
4. Throughput and Latency Analysis
    - 4.1 UE and cell throughput and latency analysis
    - 4.2 Impact of Carrier Aggregation (CA), EN-DC, and NR-DC
    - 4.3 Split bearer and PDCP Aggregation
    - 4.4 UL on 5G NR or LTE
    - 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

5G Core
Curriculum

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ON-DEMAND - EXPRESS

Welcome to 5G
Bienvenidos a 5G (Spanish)
5G Core Network Overview
Welcome to Multi-Access Edge Computing (MEC)
Welcome to Voice Solutions in 5G
Welcome to Private 5G Networks
Welcome to Rich Communication Services (RCS)
Welcome to Security in 5G
Welcome to 5G NR-Unlicensed (NR-U)
Welcome to embedded SIM (eSIM)
Welcome to Network Slicing in 5G
Welcome to Non-Terrestrial Networks (NTN) in 5G
Welcome to Roaming in 5G Networks
Welcome to SDN and NFV Introductions
Welcome to SDN and NFV Foundations
Welcome to SDN and NFV Technologies
API Overview
Welcome to Telco Cloud Part 1: Virtualization and Orchestration
Welcome to Telco Cloud Part 2: Cloud-Native Apps
Welcome to Telco Cloud Part 3: Containers
Welcome to Telco Cloud Part 4: Kubernetes
Welcome to Telco Cloud Part 5: Deployment and Operations

ON-DEMAND - EXPANDED

5G Services and Network Architecture
Containers and Microservices in Telecom
Multi-Access-Edge Computing (MEC)
Network Slicing in 5G
5G Core Network (SA) Overview
5G Core Network Signaling and Operations Part 1: 5G Core Network Essentials
5G Core Network Signaling and Operations Part 2: SBA and NFV in 5G
5G Core Network Signaling and Operations Part 3: UE Registration in 5G
5G Core Network Signaling and Operations Part 4: PDU Sessions in 5G
5G Core Network Signaling and Operations Part 5: QoS in 5G
5G Core Network Signaling and Operations Part 6: Mobility and 4G Interworking
5G Voice Solutions - VoNR and EPS Fallback Part 1: Voice Services in 5G
5G Voice Solutions - VoNR and EPS Fallback Part 2: 5G and IMS Registration
5G Voice Solutions - VoNR and EPS Fallback Part 3: EPS Fallback
5G Voice Solutions - VoNR and EPS Fallback Part 4: VoNR Operations and Emergency Calls

EXPERT-LED

5G Services and Network Architecture
Containers and Microservices in Telecom
Multi-Access-Edge Computing (MEC)
Network Slicing in 5G
5G - A Business Perspective
5G Core Network (SA) Overview
5G Voice Solutions - VoNR and EPS Fallback Overview
5G Private Network Overview
Security in 5G Networks
5G Network for Leadership
5G Roaming and Interworking
Policy and Charging in 5G
5G Non-Terrestrial-Network (NTN)
AWS Cloud Practitioner Essentials (AWS)
MEC Architecture and Operations
Network Slicing Architecture and Operations
CNF and Kubernetes Orchestration Essentials
5G Networks and Services
5G Security Architecture and Operations
5G Voice Solutions – VoNR and EPS Fallback
5G Core Network Signaling and Operations
Architecting on AWS (AWS)
Cloud Native NFV Architecture and Operations Workshop
Kubernetes Orchestration Workshop

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

View Curriculum

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.

Intended Audience

Este curso proporciona una visión general de las redes 5G y está dirigido a una amplia gama de profesionistas incluyendo miembros de Ingeniería, Ventas, Operaciones, Implementación, Diseño, Servicios, Mantenimiento, etc.

Objectives

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

- Identificar los objetivos y motivaciones de las redes 5G
- Esbozar la función de la arquitectura de la red 5G en comunicaciones punto a punto
- Describir los tipos de dispositivos que se utilizarán en las redes 5G
- Resumir los conceptos de la interfaz aérea de 5G utilizados en distintas bandas de frecuencia
- Esbozar las múltiples arquitecturas de las redes de acceso 5G así como de la red fija 5G
- Enumerar los tipos de servicios ofrecidos por las redes 5G
- Ilustrar la implementación y soluciones de interconexión de las redes 5G

What You Can Expect

- Self-Paced Duration: 1 Hora

Outline

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.

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

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

Welcome to 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.

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 Multi-Access (or Mobile) Edge Computing (MEC)
- List the benefits of MEC and key use cases for Industry 4.0
- Illustrate end-to-end architecture of MEC in LTE and 5G networks
- List key considerations and challenges of MEC deployment

What You Can Expect

- Self-Paced Duration: 1 HOUR

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
1.4 Deployment use cases
Exercise: Knowledge check

2. MEC Architecture

2.1 End-to-end architecture of LTE and 5G for MEC
2.2 MEC application within operator's network
2.3 MEC application within customer premise
Exercise: Knowledge check

3. MEC Enablers and Deployment Scenarios

3.1 Enablers for MEC - Edge cloud, NFV, SDN
3.2 5G RAN and 5G Core for MEC
3.3 Overview of MEC operations
3.4 MEC deployment scenarios
3.5 Key considerations and challenges
Exercise: Knowledge check

Putting it all together
Final assessment

View Curriculum

Welcome to Voice Solutions in 5G Networks

Voice over New Radio (VoNR) and EPS Fallback are some of the ways to support voice-related services in 5G. This training presents an overview of an end-to-end network architecture of 5G, key network components, and high-level operations of example call scenarios for voice services.

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:

- Identify the various solutions of supporting voice and related services in 5G
- Sketch an end-to-end architecture using the 5G RAN, 5G core and IMS
- Describe VoNR and EPS Fallback and related scenarios in commercial 5G networks

What You Can Expect

- Self-Paced Duration: 1 HOUR

Outline

Welcome to 5G Private Networks

The availability of licensed, unlicensed, and shared frequency spectrums as well as the capabilities of 5G networks enable the deployment of private networks for many verticals, including industrial automation, healthcare, etc. This training provides a technical overview of the private network architecture, key technology enablers, and the role of key players in deploying standalone private networks and operator-supported hybrid private 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 private networks per 3GPP specifications - Non-Public Network (NPN)
- Provide a landscape of use cases for deploying private networks
- Sketch the end-to-end architecture of standalone and operator-assisted private networks
- Identify how 5G enables deployment of private networks
- Identify key players, considerations and challenges of private network deployment

What You Can Expect

- Self-Paced Duration: 1 HOUR

Outline

1. Private Networks: What and Why?
   - 1.1 What are private networks and why do we need them?
   - 1.2 Enterprise needs and use cases
   - 1.3 How does 5G enable private networks?
2. Private Network Architecture
   - 2.1 5G private network architecture options
   - 2.2 Options for operator-managed private networks
3. Private Network Deployment Considerations
   - 3.1 Key enablers of private 5G networks
   - 3.2 Overview of private network operations
   - 3.3 Deployment considerations and challenges

Putting It All Together

Final Assessment

View Curriculum

Welcome to Rich Communication Services (RCS)

This training on Rich Communication Services (RCS) will be valuable for professionals in the wireless industry seeking to stay ahead of the curve in the rapidly evolving landscape of mobile communication. The course covers the fundamental concepts of RCS, including its features and capabilities, as well as its key benefits to network operators and subscribers. Participants will learn how RCS features work and how they can be deployed and implemented in a typical wireless network. Additionally, the course provides an overview of the current outlook for RCS, including emerging trends and future possibilities. By the end of the course, learners will have a solid understanding of RCS technology and its potential to transform the way people communicate using mobile devices.

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 RCS and describe its features and capabilities
- Identify the key benefits of RCS to network operators and subscribers
- Explain how RCS features work such as Chat, Messaging, Chatbot
- Illustrate how RCS can be deployed and implemented in a typical wireless network
- Describe the current outlook for RCS

What You Can Expect

- Self-Paced Duration: 1 HOUR

Outline

1. RCS: What and Why?
- 1.1 The History of RCS
- 1.2 RCS Services
- 1.3 RCS Business Messaging (RBM)

2. RCS Architecture
- 2.1 RCS Network Architecure
- 2.2 RCS Signaling and Operations

3. RCS Deployment Scenarios
- 3.1 Messaging as a Platform (MaaP)
- 3.2 RCS Deployment Considerations

Putting It All Together

Final Assessment

Welcome to Security in 5G

In an all-digital world, 5G wireless is a key enabler for fundamental transformation for many industry segments. Therefore, security is of utmost importance for successful adoption. This training provides a technical overview of vulnerabilities and mitigation mechanisms in 5G networks, end-to-end framework of security in 5G for the device as well as the RAN and core networks in virtualized telco 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:

- List threats and vulnerabilities in 5G networks
- Match various mitigation measures with vulnerabilities
- Sketch the end-to-end 5G security architecture
- Identify unique security features of 5G networks
- Identify roles of 5G network functions related to security procedures
- Describe security mechanisms for infrastructure and network workload

What You Can Expect

- Self-Paced Duration: 1 HOUR

Outline

1. Security in 5G: What and Why?
- 1.1 5G security challenges and mitigation
- 1.2 What's new in 5G security

2. 5G Security Architecture
- 2.1 End-to-end security framework in 5G
- 2.2 A closer look at 5G security - ZTA, microsegmentation, SASE
- 2.3 Key network security functions - AUSF, NRF, NEF, NSSAAF, etc.
- 2.4 Security for interworking and roaming - SEPP

3. 5G Security in a Cloud-Native Environment
- 3.1 Securing containerized 5G network functions
- 3.2 Threats in a container lifecycle

Putting It All Together

Final Assessment

Welcome to 5G NR-Unlicensed (NR-U)

In this training, you will explore the world of using unlicensed frequencies for 5G NR-based networks. The large amount of unlicensed spectrum at 6 GHz, mmWave, as well as 5 GHz, provides ample resources to deliver high data rates and low latency for 5G networks. This opens up many opportunities to bring 5G to enterprise customers for private 5G network deployment. The training covers both standalone and anchor mode NR-U network architecture, operations, and deployment considerations.

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 5G NR-Unlicensed (NR-U) and identify use cases of NR-U deployment
- List capabilities, design considerations, and limitations of NR-U
- Sketch an end-to-end architecture of anchor and standalone NR-U
- Step through an end-to-end operation of NR-U
- Identify the band combinations for NR-U deployment

What You Can Expect

- Self-Paced Duration: 1 HOUR

Outline

1. What and Why 5G NR-Unlicensed (NR-U)?
- 1.1 What is NR-U?
- 1.2 Why NR-U?
- 1.3 NR-U vs. Wi-Fi - Usage comparison
- 1.4 Usage scenarios

2. NR-U Architecture Overview
- 2.1 Anchored NR-U
- 2.2 NR-U Standalone

3. NR-U Operations
- 3.1 Anchored NR-U operations
- 3.2 Standalone NR-U operations
- 3.3 NR-U Operations in the 5-6 GHz Band
- 3.4 Transmit Power Limits for the 6 GHz Band

4. NR-U Deployment Scenarios
- 4.1 Deployment scenarios
- 4.2 Band combinations for NR-U

Putting it all together

Final assessment

View Curriculum

Welcome to Embedded SIM (eSIM)

Subscriber Identity Modules (SIM) have evolved a long way and embedded SIM (eSIM) has become an essential component of 5G device enablement, especially with proliferation of massive IoT (massive Machine Type Communication - mMTC) devices. This training provides an evolution from SIM to USIM to eSIM, an architecture of eSIM/eUICC, and describes a few use cases for both consumer and M2M devices.

Intended Audience

This training 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 eSIM and sketch evolution path from SIM to eSIM
- Sketch eSIM architecture framework for Remote Service Provisioning (RSP)
- Describe eSIM solution for Consumer and M2M
- Walk through the role of eSIM in use cases such as dual subscription, roaming, etc.

What You Can Expect

- Self-Paced Duration: 1 HOUR

Outline

View Curriculum

Welcome to Network Slicing in 5G

Network slicing is one of the key components that provides logical virtual network slices to support diversified services such as mobile broadband, massive IoT, and ultra-reliable low-latency services by leveraging the technologies of 5G, virtualization, automation, and data analytics. This training provides an overview of network slicing across an end-to-end 5G network, including the 5G Core, 5G RAN, and Transport networks, along with its operational and deployment use cases.

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 network slicing and identify key benefits
- Explore various use cases of network slicing
- Sketch the framework of network slicing
- Step through the operation of network slicing in 5G

What You Can Expect

- Self-Paced Duration: 1 HOUR

Outline

1. Network Slicing: What and Why?
- 1.1 Defining network slicing
- 1.2 Benefits of network slicing
- 1.3 Key enablers of network slicing

2. Network Slicing Framework
- 2.1 Terminology of network slicing
- 2.2 5G Core network Functions for network slicing
- 2.3 Network slicing examples

3. Network Slicing Operations
- 3.1 Configuring a network slice
- 3.2 Requesting a network slice
- 3.3 Deployment considerations

Putting it all together

Final assessment

View Curriculum

Welcome to Non-Terrestrial Networks (NTN) in 5G

In this Welcome to Non-Terrestrial Networks (NTN) for 5G course, you will delve into the world of NTN designed to extend 5G services over land and sea where traditional coverage falls short. You will explore how NTN utilizes satellite infrastructure as a crucial component of the comprehensive 5G network and gain insights into the capabilities and hurdles of merging 5G technology with satellites. This course covers essential aspects including air interface implications, services impacts, NTN operations, and aligning specific application requirements with deployment strategies.

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 satellite-based 5G Non-Terrestrial Networks (NTN)
- List capabilities, design considerations, and limitations of NTN
- Sketch an end-to-end architecture of 5G NTN
- Identify use cases for interworking NTN with terrestrial networks

What You Can Expect

- Self-Paced Duration: 1 HOUR

Outline

1. What and Why NTN?
   - 1.1 Defining NTN
   - 1.2 Benefits of NTN and Usage Scenarios
   - 1.3 Requirements for NTN
2. NTN Architecture Overview
   - 2.1 NTN Architecture
   - 2.2 NTN and Terrestrial Network Interworking
3. 5G Air Interface for NTN
   - 3.1 5G Air Interface for NTN
   - 3.2 Key Challenges of Air Interface in NTN
   - 3.3 Beam Management
4. NTN Operations
   - 4.1 Signaling Flow for NTN
   - 4.2 Roaming and Security
5. NTN Deployment Considerations
   - 5.1 Deployment Considerations

Final assessment

View Curriculum

Welcome to Roaming in 5G Networks

Roaming refers to the ability of a mobile device to connect to a visited network and access services while outside its home network coverage area. 5G offers enhanced roaming capabilities, enabling faster and more reliable connections across diverse networks globally. This course provides an overview of 5G Network Roaming including an introduction to key use cases, roaming network elements and how key services are performed while roaming.

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 5G roaming scenarios in 4G/5G networks
- Explain the security procedures in roaming scenarios
- Sketch the most common roaming network architecture
- Step through the 5G roaming operations
- Explain how data and IMS services are delivered while roaming

What You Can Expect

- Prerequisite: Welcome to 5G (OnDemand)
- Self-Paced Duration: 1 HOUR

Outline

1. What and Why Roaming
   - 1.1 Defining Roaming
   - 1.2 Benefits for Operators/Customers
2. 5G Roaming Architecture
   - 2.1 5G-to-5G Roaming Architecture
   - 2.2 5G-to-4G Roaming Architecture
3. 5G Operations in Roaming
   - 3.1 Registration and Security Setup
   - 3.2 Data Session Setup
   - 3.3 Special Scenarios
4. Service Delivery in Roaming
   - 4.1 IMS Service Delivery

Putting It All Together

Final assessment

View Curriculum

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
   - 2.5 Bringing it together to achieve web-scale solutions
   - 2.6 Example: Web server
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 - 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

View Curriculum

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

Welcome to Telco Cloud Part 1: Virtualization and Orchestration

Telecom operators are on the cusp of a multitude of network and business transformation choices. This course (part of multi-part series) provides a high level view of the impact and benefits of the telco cloud infrastructure, the benefits of virtualization, and needs of orchestration. It provides concrete examples of approaches of virtualizations and related orchestrators considered in Telecom networks.

Intended Audience

This course is designed for a broad audience of personnel working in the Telecom industry.

Objectives

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

- Identify the need for Cloud and Virtualization in Telecom networks
- Identify approaches of virtualization and compare Virtual Machines and Containers
- List the needs and benefits of Orchestrators such as OpenStack and Kubernetes

What You Can Expect

- Self-Paced Duration: 1 HOUR

Outline

1. Cloud Computing and Virtualization in Telco
- 1.1 What and why Virtualization?
- 1.2 Needs for Telco Cloud
- 1.3 Private, Public, and Hybrid Clouds in Telco Network

2. Approaches of Virtualization
- 2.1 Compare VMs and Containers
- 2.2 VNFs and CNFs
- 2.3 A real world example – Virtualization

3. Need for Orchestrator
- 3.1 Cloud orchestration
- 3.2 Role of OpenStack for VMs
- 3.3 Role of Kubernetes for Containers

Putting it all together

Final assessment

View Curriculum

Welcome to Telco Cloud Part 2: Cloud Native Apps

Telecom operators are on the cusp of a multitude of network and business transformation choices. This course (part of multi-part series) provides a high-level view of the impact and benefits of Cloud-native Network Functions (CNFs) and applications, microservice architecture, and example implementations of Telco network functions based on cloud-native principles. It provides concrete examples of cloud-native applications and network functions using containers and Kubernetes in telecom networks.

Intended Audience

This course is designed for a broad audience of personnel working in the telecom industry.

Objectives

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

- Identify the need for cloud-native applications for NFs in telecom
- Sketch the architecture framework for CNFs and apps in the Telco cloud
- Explain an implementation of CNFs and apps using containers, Kubernetes

What You Can Expect

- Self-Paced Duration: 1 HOUR

Outline

1. Cloud Native: What and Why?
    - 1.1 Challenges of current Telco applications
    - 1.2 Benefits of cloud-native applications and NFs
    - 1.3 Value of cloud-native NFs for RAN and Core
    - 1.4 Microservices as cloud -native apps for NFs
2. Infrastructure for Cloud Native
    - 2.1 Webscale architecture for cloud-native apps
    - 2.2 Operational framework of Telco clouds (i.e., metrics, tracing, logging)
    - 2.3 Need for cloud-native application management
3. Implementation of Cloud Native Apps in Telco
    - 3.1 Cloud-native apps in RAN and Core
    - 3.2 Role of container runtime and Kubernetes
    - 3.3 Example of end-to-end service in telco network

Putting it all together

Final assessment

Welcome to Telco Cloud Part 3: Container Deployment

Telecom operators are on the cusp of many network and business transformation choices. This course (part of multi-part series) provides a high-level view of containers, container runtimes, container images, and their applicability to network functions and telco clouds. This course outlines the key benefits of adopting and deploying telco network functions in containers vs. VMs, Cloud-native Network Functions (CNFs) and applications, and container lifecycle management. It also introduces Kubernetes for container orchestration in telco clouds.

Intended Audience

This course is designed for a broad audience of personnel working in the telecom industry.

Objectives

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

- Identify the need for containers to deploy cloud-native applications in telecom networks
- Sketch the container framework and identify roles of the container runtime
- Explain the Open Container Initiative (OCI) to unify container images
- Explain the container lifecycle management
- Describe the need for container orchestration and the role of Kubernetes

What You Can Expect

- Self-Paced Duration: 1 HOUR

Outline

1. Containers: What and Why?
- 1.1 Containers for telco network functions
- 1.2 Benefits of containers for telco clouds
- 1.3 Role of containers in telco Cloud-Native NFs
- 1.4 Container deployment options in telco clouds

2. Container Framework
- 2.1 Container Host and container runtime
- 2.2 Open container initiative and standardization
- 2.3 Container runtime options

3. Container Management in Telco Clouds
- 3.1 Container lifecycle management
- 3.2 Container adoption and management challenges
- 3.3 Role of container orchestrators

Putting it all together

Final assessment

View Curriculum

Welcome to Telco Cloud Part 4: Kubernetes in Telco Networks

Telecom operators are on the cusp of a multitude of network and business transformation choices. This course (part of multi-part series) provides a high-level view of the Kubernetes container orchestration framework. This course describes Network Functions (NFs) and services deployment, operations, and maintenance. The role of container runtime and Kubernetes for container management in telco clouds are described. The training steps through the network function packaging, deployment, and operations using Kubernetes (K8s) in telecom networks. In addition, the course discusses how Kubernetes can enhance service availability, resiliency, and performance assurance.

Intended Audience

This course is designed for a broad audience of personnel working in the telecom industry.

Objectives

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

- Describe the need for container management in telco clouds
- Identify the role of Kubernetes orchestration in telco clouds
- Sketch the Kubernetes framework
- Describe the networking and storage options in Kubernetes
- Explain service availability scalability, and resiliency in K8s
- Describe NF performance assurances using K8s
- Explain the role of helm as Kubernetes package manager
- Identify open-source tools for maintenance and operations

What You Can Expect

- Self-Paced Duration: 1 HOUR

Outline

1. Kubernetes: What and Why?
- 1.1 What is Kubernetes and Why
- 1.2 Kubernetes key features
- 1.3 Kubernetes in Telco NFV clouds

2. Kubernetes Framework
- 2.1 What is a Kubernetes cluster?
- 2.2 Container runtime options for Kubernetes
- 2.3 Networking and storage in Kubernetes

3. Kubernetes in Telco Cloud
- 3.1 Network function deployment
- 3.2 Service availability, scalability and resiliency
- 3.3 Packaging Telco network functions
- 3.4 K8s add-on tools for NF operations

Putting it all together

Final assessment

Welcome to Telco Cloud Part 5: Deployment and Operations

Telecom operators are on the cusp of a multitude of network and business transformation choices. This course (part of multi-part series) provides a high-level view of commonly used open-source solutions for packaging, logging, tracing, observability, monitoring of network functions and services in Telco clouds. It provides context of frequently used open-source projects and their relationship to deployment and operations (i.e., log management, infrastructure performance management) in telecom networks and clouds. In addition, the course explains a commonly used visualization solution for items like metrics.

Intended Audience

This course is designed for a broad audience of personnel working in the telecom industry.

Objectives

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

- Describe options for network function deployment automation and orchestration
- Explain configuration management for Day-0 and Day-1 flow
- Identify the need for operational solutions for NFs and services in Telco cloud
- Describe solutions for deployment and NF communication control, security and observability
- Explain solutions for log management, tracing and visualization

What You Can Expect

- Self-Paced Duration: 1 HOUR

Outline

1. **Network Function Deployment and Configuration**
   - 1.1 Network Function Deployment Orchestration
   - 1.2 Day-0 and Day-1 Configuration Management
2. **Tools for Kubernetes Deployment**
   - 2.1 Elasticsearch, Fluentd and Kibana Stack
   - 2.2 EFK Log Visualization
   - 2.3 Communication and Observability using Service Mesh
   - 2.4 Network Function Resiliency using Service Mesh
   - 2.5 Jaeger Distributed Tracing
   - 2.6 Telco Performance Management using Prometheus
   - 2.7 Operational Visualization using Grafana

Putting it all together

Final assessment

View Curriculum

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
- Self-Paced 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

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 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

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

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.

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: Welcome to 5G
- Self-Paced Duration: 4 HOUR

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

Final assessment

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: Welcome to 5G
- 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

View Curriculum

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: 5G Core Network Overview
- 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

View Curriculum

5G Core Network Signaling and Operations Part 1: 5G Core Network Essentials

This is the first course in a six-course set of self-paced courses encompassing 5G Core Network Signaling and Operations. In this course, you will learn about the network functions that make up the 5G Core Network and how they evolve from 4G network functions. This course includes an overview of the key network functions supporting both mobility management and session management as well as functions necessary to support network slicing and charging. Learning is reinforced by participants building a 5G Core network using our learning application as well as both SME-guided and student exercises.

Intended Audience

5G Core Network engineering, operations, and performance related job functions

Objectives

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

- Describe the Network Functions (NF) of the 5G core network and their roles in the 5GC
- Explain Network Slicing in 5G networks
- Identify key functions supporting network slicing and charging

What You Can Expect

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

Outline

1. 5G Core Network Functions

- 1.1 5G Architecture: AMF, AUSF, UDR, UDM
- 1.2 5G Architecture: SMF, UPF, PCF, NEF
- 1.3 Functions that are new to 5G

Exercise: Build a 5G Core network architecture
Exercise: 5G architecture operations overview

2. Network Slicing and the NSSF

- 2.1 Introduction to Network Slicing
- 2.2 Network Slicing Architecture in 5G
- 2.3 Network Slice Selection Function

Exercise: Network Slicing review

3. Charging and the CHF

- 3.1 5G Charging Architecture
- 3.2 Charging Control Function

Assessment

View Curriculum

5G Core Network Signaling and Operations Part 2: SBA and NFV in 5G

This is the second course in a six-course set of self-paced courses encompassing 5G Core Network Signaling and Operations. Fundamental to the 5G Core network is virtualization of the core network functions and employment of a service-based architecture. In this course, you will learn how the functions of the 5G Core network are virtualized to run on shared, off-the-shelf cloud infrastructure equipment as well as the producer/consumer of services approach is used for inter-process communications.

Intended Audience

5G Core Network engineering, operations, and performance related job functions

Objectives

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

- Explain the role of Network Functions Virtualization (NFV) in 5G
- Describe the Service-Based Architecture (SBA) for the 5G Core network
- Explore the use of the HTTP/2 protocol for the service-based architecture

What You Can Expect

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

Outline

1. 5G and Network Functions Virtualization

- 1.1 Virtualization: what and why?
- 1.2 5G and NFV

Exercise: 5G Core Interactive

2. Service-based architecture

- 2.1 5G network reference architecture
- 2.2 Service-based architecture
- 2.3 Network functions in SBA
- 2.4 HTTP/2 Primer

Exercise: Network Function Registration and Discovery

Assessment

5G Core Network Signaling and Operations Part 3: UE Registration in 5G

This is the third course in a six-course set of self-paced courses encompassing 5G Core Network Signaling and Operations! In this course, you will gain an in-depth understanding of the key 5G Core Network operations relating to registration, authentication, and security setup for a UE. You will also learn about UE identifiers used in 5G, UE states relating to registration, PDU connections and radio resource control, and a detailed discussion of the related signaling for registering a UE with the 5G core network.

Intended Audience

5G Core Network engineering, operations, and performance related job functions

Objectives

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

- Describe the procedures for UE registration and authentication in 5G
- Explain the UE states relating to registration, PDU sessions, and RRC connections
- List the UE identifiers used in the 5G network

What You Can Expect

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

Outline

1. UE Identifiers and UE States
   - 1.1 5G Identifiers
   - 1.2 UE States
2. UE Registration and Authentication
   - 2.1 UE Registration in 5G
   - 2.2 Authentication and Security in 5G
   - 2.3 End-to-end registration flow
   - 2.4 Equipment Identity check signaling
   - **Exercise:** UE Registration signaling
   - **Exercise:** Authentication and Security signaling
   - **Exercise:** Authentication and Security signaling
3. Exploring the signaling
   - 3.1 Mastering registration signaling
   - **Exercise:** 5G Registration

Assessment

ON-DEMAND

5G Core Network Signaling and Operations Part 4: PDU Sessions in 5G

This is the fourth course in a six-course set of self-paced courses encompassing 5G Core Network Signaling and Operations. In this course, you will learn about how PDU sessions in 5G are used to connect users to data networks. You will explore the signaling for establishing PDU sessions and how QoS Flows are added or removed from PDU sessions. You will also learn how user data is transferred between a UE and a data network, how usage records are collected for charging, and how 5G provides for service continuity when the IP address anchor changes.

Intended Audience

5G Core Network engineering, operations, and performance related job functions

Objectives

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

- Explain the what and why of PDU sessions
- Sketch the PDU session establishment signaling
- Describe how QoS flows are added and removed from PDU sessions

What You Can Expect

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

Outline

1. Establishing a PDU Session
- 1.1 Introduction to 5G PDU sessions
- 1.2 PDU session overview and establishment
- 1.3 Adding and removing QoS flows
- 1.4 PDU sessions and idle operations

Exercise: PDU session establishement signaling

2. PDU Session related topics
- 2.1 User plane traffic path
- 2.2 PDU sessions and charging
- 2.3 Session and service continuity (SSC) modes

Exercise: PDU sessions and charging flows

3. Exploring the signaling
- 3.1 Mastering PDU Session setup signaling

Exercise: PDU Session establishment

Assessment

View Curriculum

5G Core Network Signaling and Operations Part 5: QoS in 5G

This is the fifth course in a six-course set of self-paced courses encompassing 5G Core Network Signaling and Operations! In this course, you will learn how Quality of Service (QoS) for user data flows is supported by the 5G Core Network. You will explore the signaling for establishing and enforcing QoS and the roles of the Policy Control Function (PCF) and the Network Exposure Function (NEF) in QoS setup and operations.

Intended Audience

5G Core Network engineering, operations, and performance related job functions

Objectives

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

- Describe Quality of Service is in a 5G network
- Explain how QoS flows are established and enforced
- Summarize the key QoS parameters in 5G

What You Can Expect

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

Outline

1. 5G Quality of Service (QoS)
   - 1.1 What is 5G QoS?
   - 1.2 Establishing and enforcing QoS
   - 1.3 5QI QoS characteristics
   - **Exercise:** 5G QoS parameters
2. QoS Signaling Operations
   - 2.1 PDU sessions and network slices
   - 2.2 Reflective QoS
   - 2.3 Policy control, network exposure functions
3. Exploring the Signaling
   - 3.1 Wireshark configuration
   - 3.2 5G QoS HTTP/2 log-based analysis
   - **Exercise:** Evaluating 5G QoS logs

Assessment

View Curriculum

5G Core Network Signaling and Operations Part 6: Mobility and 4G Interworking

ON-DEMAND

This is the sixth course in a six-course set of self-paced courses encompassing 5G Core Network Signaling and Operations! In this course, you will learn about both connected and idle mobility in 5G SA as well as the fundamentals of interworking operations between the 5G core and the LTE EPC. You will explore the signaling for handovers in 5G be they between cells on the same gNB or on different gNBs as well as the signaling for both idle and inactive modes in 5G. Finally, you will gain an understanding of handovers between an LTE network and a 5G network.

Intended Audience

5G Core Network engineering, operations, and performance related job functions

Objectives

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

- Explain both inter-gNB and intra-gNB handovers
- Describe idle mode, inactive mode and paging in 5G
- Summarize interworking between 4G and 5G

What You Can Expect

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

Outline

1. Xn and N2 Handovers
   - 1.1 Xn handover
   - 1.2 Xn handover with UPF insertion
   - 1.3 N2 Handover
   - **Exercise:** Xn and N2 handover signaling
2. Idle Mode and Paging in 5G
   - 2.1 Idle mode in 5G
   - 2.2 Idle mode and paging
   - **Exercise:** RRC idle signaling
3. LTE Interworking
   - 3.1 LTE Interworking
   - 3.2 5G to 4G handover
   - **Exercise:** Interworking handover exercise
4. Exploring the Signaling
   - 4.1 Idle mode and paging
   - 4.2 Xn and N2 handover
   - 4.3 LTE Interworking
   - 4.4 5G to 4G handover signaling

Assessment

5G Voice Solutions - VoNR and EPS Fallback Part 1: Voice Services in 5G

This is the first course in a four-course set of self-paced courses encompassing 5G Voice Services. In this course, you will learn about IMS-based voice solutions for 5G including Voice Over New Radio (VoNR) and EPS Fallback. You will explore at a high level how VoNR works in a 5G Standalone deployment. You will also discover the importance of EPS Fallback and its role in ensuring seamless voice services during the network transition to full VoNR support. Each course in this four-course set can stand on its own or can be combined with other courses as necessary to meet your learning objectives.

Intended Audience

Planning, design, engineering and operations personnel

Objectives

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

- Describe solutions of voice services in 5G networks
- Define Voice over NR (VoNR) and EPS Fallback solutions
- Sketch the architecture for 5G voice services using 5G RAN, 5G Core and IMS networks
- Identify the reasons for EPS Fallback in 5G SA networks
- Identify 5G features for supporting IMS voice services
- List the use of voice codecs in 5G NR

What You Can Expect

- Prerequisite: 5G Networks and Services
- Prerequisite: Working knowledge of VoLTE, LTE and IMS operations
- Self-Paced Duration: 4 HOUR

Outline

1. Voice Services in 5G
- 1.1 Voice in 5G Networks
- 1.2 Review of VoLTE and IMS
- 1.3 Introduction to 5G Voice Services

2. 5G Core Network Overview
- 2.1 5G Architecture: AMF, AUSF, UDR, UDM
- 2.2 5G Architecture: SMF, UPF, PCF, NEF
- **Exercise:** 5G Core Architecture

3. Introduction EPS Fallback and VoNR
- 3.1 Introduction to EPS Fallback
- 3.2 Introduction to VoNR
- 3.3 5G Features for IMS Voice Support

4. 5G and IMS Voice Support
- 4.1 5G Features for IMS Voice Support
- 4.2 IMS Voice over PS Options
- **Exercise:** IMS Voice in 5G
- **Exercise:** Voice Codecs in 5G

Final Assessment

5G Voice Solutions - VoNR and EPS Fallback Part 2: 5G and IMS Registration

This is the second course in a four-course set of self-paced courses encompassing 5G Voice Services. In this course, you will learn 5G Registration and PDU session setup with the IP Multi-media Subsystem (IMS) for voice services. You will also gain an understanding of how 5G voice calls use IMS for voice and an overview of the IMS architecture. Each course in this four-course set can stand on its own or can be combined with other courses as necessary to meet your learning objectives.

Intended Audience

Planning, design, engineering and operations personnel

Objectives

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

- Describe UE registration and PDU session establishment in 5G networks
- Explain pre-call functions in 5G registration and PDU session establishment
- Identify the key components of the IMS network, including CSCFs and application servers
- Analyze the IMS registration call flow
- Describe the integration of 5G Core and IMS architecture and its impact on voice services

What You Can Expect

- Prerequisite: 5G Networks and Services
- Prerequisite: Working knowledge of VoLTE, LTE and IMS operations
- Self-Paced Duration: 4 HOUR

Outline

1. 5G Registration and PDU Session Establishment

1.1 UE Registration in 5G
1.2 PDU Session Overview and Establishment
1.3 Pre-Call Functions in 5G Registration
1.4 Pre-Call Functions in PDU Session Establishment
Exercise: PDU Session Establishment for IMS DNN

2. The IMS Network

2.1 CSCFs and the Gm Interface
2.2 Application Servers and IFC
2.3 Interworking Functions
Exercise: 5G Core and the IMS Architecture
Exercise: IMS Registration Call Flow
Exercise: 5G and IMS Registration

Final Assessment

View Curriculum

5G Voice Solutions - VoNR and EPS Fallback Part 3: EPS Fallback

This is the third course in a four-course set of self-paced courses encompassing 5G Voice Services. In this course, you will learn about 5G Core and EPC coexistence and the role of a combined core network architecture for voice solutions. You will also learn about domain selection for voice services and EPS Fallback operations. You will gain an understanding of SIP signaling for voice calls and moving a user from 5G to LTE during call setup for EPS Fallback. Each course in this four-course set can stand on its own or can be combined with other courses as necessary to meet your learning objectives.

Intended Audience

Planning, design, engineering and operations personnel

Objectives

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

- Explain the rationale for EPS Fallback
- Describe 5G Core and LTE EPC interworking for EPS Fallback in 5G networks
- Identify the operations involved in EPS Fallback
- Summarize the role of Fallback and N26 in voice call scenarios

What You Can Expect

- Prerequisite: 5G Networks and Services
- Prerequisite: Working knowledge of VoLTE, LTE and IMS operations
- Self-Paced Duration: 4 HOUR

Outline

1. Interworking and EPS Fallback Overview
- 1.1 LTE Interworking
- 1.2 Why EPS Fallback?
- 1.3 5GC-EPC Interworking
- 1.4 EPS Fallback High-Level Operation

2. EPS Fallback Operations
- 2.1 Fallback and N26 Summary
- 2.2 Domain Selection for UE Originating Calls
- 2.3 SIP Signaling and Media Flow Summary
- 2.4 Call Origination with EPS Fallback
- 2.5 Call Termination with EPS Fallback
- 2.6 Ending the Call
- **Exercise:** Context Request Signaling with N26
- **Exercise:** EPS Fallback for Voice Call Flow
- **Exercise:** EPS Fallback

Final Assessment

5G Voice Solutions - VoNR and EPS Fallback Part 4: VoNR Operations and Emergency Calls

This is the final course in a four-course set of self-paced courses encompassing 5G Voice Services. In this course, you will explore the IMS call model for VoNR and the necessary signaling for establishing voice calls in a 5G network. Participants will also learn about the process of allocating resources in the 5G network for voice transmission. This course also covers the operations relating to the setup of emergency calls in a 5G network as well as emergency fallback to 4G when the 5G network cannot support emergency calls. Each course in this four-course set can stand on its own or can be combined with other courses as necessary to meet your learning objectives.

Intended Audience

Planning, design, engineering and operations personnel

Objectives

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

- Analyze the VoNR call model and its components
- Step through the process of VoNR call setup and resource establishment
- Highlight key features of 5G to support VoNR
- Sketch the architecture of 5G and IMS to support Emergency calls
- Step through the process of supporting Emergency calls in 5G

What You Can Expect

- Prerequisite: 5G Networks and Services
- Prerequisite: Working knowledge of VoLTE, LTE and IMS operations
- Self-Paced Duration: 4 HOUR

Outline

1. VoNR Operations

- 1.1 VoNR Overview
- 1.2 VoNR Call Model
- 1.3 VoNR Call Setup
- 1.4 Resource Establishment
- 1.5 Paging and Policy Differentiation for Voice

Exercise: 5G VoNR Call Flow
Exercise: VoNR Exercises

2. Emergency Calls

- 2.1 Emergency Services Overview
- 2.2 Emergency Registration and PDU Session
- 2.3 IMS Emergency Registration and Call
- 2.4 Emergency Services Fallback

Exercise: Emergency Calls in 5G
Exercise: Emergency Services Fallback

Final Assessment

View Curriculum

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

View Curriculum

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

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.

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: Welcome to 5G
- Expert-Led Live Duration: 4 HOUR

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

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
- Discuss the management of a network slice in a telco network

What You Can Expect

- Prerequisite: Welcome to 5G
- Expert-Led Live Duration: 4 HOUR

Outline

1. What and Why Network Slicing?
   - 1.1 What and why Network slice?
   - 1.2 Benefits of network slicing
   - 1.3 Network slicing resources
2. Network Slicing in 5G Networks
   - 2.1 Network slice definitions
   - 2.2 Core network functions role in network slicing
   - 2.3 Transport network slicing
   - 2.4 Radio access network slicing
3. Network Slicing Operations
   - 3.1 UE profile and network slice mapping
   - 3.2 Service selection of Network slice
   - 3.3 Registration procedure
   - 3.4 Session establishment procedure
4. Network Slicing Deployment and Management
   - 4.1 Network Slice Management Framework
   - 4.2 Network slice lifecycle
   - 4.3 Network slice management in a telco network

Putting it all together

View Curriculum

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

- Prerequisite: Welcome to 5G
- 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

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
- 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

5G Voice Solutions - VoNR and EPS Fallback Overview

Voice over NR (VoNR) and EPS Fallback are some of the ways to support voice and related services like SMS, video and emergency calls in 5G. This training presents an overview of an end-to-end network architecture, key network components, and high-level operations of various call scenarios, emergency calls, and handovers to VoLTE.

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:

- Describe the various solutions of supporting voice in 5G networks
- Sketch an end-to-end architecture using the 5G RAN, 5G Core, and IMS for voice services
- Describe VoNR and EPS fallback services and the life of a device during a voice call
- Describe key handover scenarios to 4G VoLTE and Wi-Fi, as well as services like video calls and SMS
- Describe support for emergency calls in 5G

What You Can Expect

- Expert-Led Live Duration: 4 HOUR

Outline

1. What are voice solutions in 5G?

1.1 Voice over NR (VoNR) in 5G
1.2 EPS Fallback as an interim solution
1.3 VoLTE in 5G NSA networks

2. VoNR and EPS Fallback Architecture

2.1 5G RAN, 5G Core, and IMS for VoNR
2.2 EPS Fallback architecture
2.3 End-to-end signaling and traffic paths
Exercise: Building VoNR Network

3. VoNR and EPS Fallback Operation

3.1 5G Registration and IMS Registration
3.2 VoNR call setup
Exercise: VoNR call flow
3.3 EPS Fallback call setup
Exercise: EPS Fallback call flow

4. Handover, Interworking, and Emergency Calls

4.1 VoNR to VoLTE and Wi-Fi Handovers
4.2 Support for Video and SMS
4.3 Emergency calls in 5G

Putting it all together

View Curriculum

Private 5G Networks Overview

The availability of licensed, unlicensed, and shared frequency spectrums as well as the capabilities of 5G and 4G networks enable the deployment of private networks for many verticals, including industrial automation, healthcare, etc. This training covers fully private networks and operator-supported hybrid private networks.

Intended Audience

This course is intended for solution architects, planning, engineering, operations, and systems performance teams.

Objectives

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

- List the drivers for deploying Non-Public Networks (NPN) a.k.a. Private Networks
- List and describe private network enablers like spectrum, 5GC, Network Slicing
- Sketch the network architecture for SNPN and PNI-NPN
- Step through the life of a device using private networks
- List deployment scenarios for private networks

What You Can Expect

- Prerequisite: Welcome to 5G
- Expert-Led Live Duration: 4 HOUR

Outline

1. Private Networks: What and Why
   - 1.1 Define Non-Public Networks (NPN)
   - 1.2 Key drivers for Private networks
   - 1.3 Deployment use cases
2. Private Network Architecture
   - 2.1 5G Non-Public Network (NPN) architecture
   - 2.2 Standalone NPN (SNPN) network components
   - 2.3 Public Network Integrated (PNI-NPN) network components
   - 2.4 Deployment configurations e.g. RAN Sharing
   - **Exercise:** Build Private Network
3. Enablers of Private 5G Network
   - 3.1 MEC deployment in Private Networks
   - 3.2 Use of Network Slicing for Private Networks
   - 3.3 Role of Time-Sensitive Networking (TSN) for Industry 4.0
4. Private Network Operations
   - 4.1 Use of PLMN ID, NID, Slice ID for identification
   - 4.2 Device registration and Data session setup in Standalone NPN
   - 4.3 Device registration and Data session setup in PNI based NPN
   - **Exercise:** Life of a UE in Private Networks
5. Private Network Deployment Considerations
   - 5.1 Licensed and Shared frequency spectrums
   - 5.2 Identifying specific needs of enterprise apps
   - 5.3 Stakeholders for Private Networks
   - 5.4 Examples of Real-life Private Networks

Putting it all together

View Curriculum

Security in 5G Networks

5G networks provide connectivity to a massive number of devices, enabling many vertical industries to provide wireless connectivity anytime anywhere. This poses security threats from many sources. 5G network security needs to include wireless, transport and IT network security approaches. This training provides a broad technical overview of 5G network security.

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 various security threats to 5G networks
- Sketch the security framework in 5G RAN, core, transport and interconnect networks
- Identify common security techniques between 5G security and IT networks
- Step through very high-level 5G operations of authentication, encryption, ciphering, etc.
- List key 5G-specific security enhancements

What You Can Expect

- Prerequisite: Welcome to 5G
- Expert-Led Live Duration: 4 HOUR

Outline

1. Security Needs for 5G Network
    - 1.1 5G enhancements over 4G
    - 1.2 Key 5G security challenges
    - 1.3 Types of threat (STRIDE Model)
    - 1.4 Security threats for RAN, Core, Transport
    - **Exercise:** Match threat with its impact
2. Security Framework for 5G Networks
    - 2.1 End-to-end security framework
    - 2.2 Authentication framework
    - 2.3 End-to-end encryption and ciphering
    - 2.4 Security for service-based interfaces
    - **Exercise:** Match security function with its role
3. 5G Security Procedures
    - 3.1 Security life of a UE in 5G network
    - 3.2 Authentication procedure
    - 3.3 Ciphering procedure
    - 3.4 Security for roaming and interconnect
4. Infrastructure Security
    - 4.1 Physical infrastructure security
    - 4.2 Virtual workload security
    - 4.3 RAN and Transport security - an example

Putting it all together

View Curriculum

5G Network for Leadership

Telecom service providers are deploying 5G Non-Standalone (NSA) and Standalone (SA) networks using various frequency spectrum to enable emerging use cases for higher throughput, lower latency, and massive capacity. This leadership session helps network leaders explore the use of low, mid, and mmW spectrum for 5G, the features of 5G RAN and core networks and emerging trends of telco cloud, MEC, and network slicing. This enables leaders to guide their teams for effective network planning, design, engineering, deployment, and monitoring.

Intended Audience

This training is intended for leaders of network planning, engineering, and operations.

Objectives

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

- Identify 5G SA and NSA network components and their connectivity
- Articulate use of various frequency spectrum for 5G networks
- Step through the 5G SA and NSA operations for end-to-end network view
- Effectively communicate technologies within organization and partners
- Guide and inspire your teams towards a 5G strategy
- Identify talent gaps and prioritize planning, engineering and operations tasks
- Identify dependencies and impacts across organization

What You Can Expect

- Prerequisite: Understanding of LTE and 5G Network
- Expert-Led Live Duration: 4 HOUR

Outline

1. 5G Network for SA and NSA
   - 1.1 5G RAN - gNB and its components - CU, DU, RU
   - 1.2 5G Core Network Functions - AMF, SMF, etc.
   - 1.3 Configuration for 5G Standalone (SA) network
   - 1.4 Configuration for 5G Non-Standalone (NSA) network
   - 1.5 Use of Carrier Aggregation and Dual Connectivity
   - **Exercise:** Build your 5G network
2. Spectrum for 5G Deployment
   - 2.1 Low, mid, and high band spectrums for 5G
   - 2.2 FDD and TDD spectrum for 5G
   - 2.3 Beamforming and beam management
   - 2.4 SU-MIMO and MU-MIMO in 5G
   - **Exercise:** Spectrum usage in your network
3. 5G Operations in SA and NSA
   - 3.1 Life of a device in 5G SA network
   - 3.2 Registration and data connectivity
   - 3.3 Life of a device in 5G NSA network
   - 3.4 Getting ready for voice services in 5G
   - **Exercise:** Step through 5G call flows for SA and NSA

Summary and take-aways

View Curriculum

5G Roaming and Interworking

Roaming is an essential feature in wireless networks. It extends home PLMN coverage to other service provider networks nationally or internationally. 5G roaming is implemented as a complement to 4G roaming because the operators will be at different points of implementing 5G networks over the next 5 to 10 years. 5G roaming is different from 4G roaming as it uses Service-Based Architecture. There are several different options for interworking between 5G and 4G networks, and there are differences between IMS network implementations - VoNR versus VoLTE, etc. Further, there are many 5G use cases - Enhanced Mobile Broadband, Massive Machine Type Communications, Ultra-Reliable Low Latency Communications, vehicle apps, etc. This course focuses on the Enhanced Mobile Broadband based on 3GPP specifications Release 16.

Intended Audience

This course is intended for planning, engineering, and operations teams. It assumes existing knowledge of 5GS Core networks.

Objectives

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

- Define various roaming scenarios such as 5G-5G, 5G-4G
- Sketch end-to-end architecture of 5G<-->5G and 5G<-->4G Roaming networks
- Step through end-to-end roaming call flows - Registration and PDU Session
- Walk-through important roaming procedures, e.g., handovers
- Explain service delivery implementations for voice and data services

What You Can Expect

- Prerequisite: 5G Core Network Overview
- Expert-Led Live Duration: 4 HOUR

Outline

1. 5G Roaming Architecture

- 1.1 5G Roaming Scenarios
- 1.2 5G <--> 5G Roaming architecture
- 1.3 5G <--> 4G Roaming architecture
- 1.4 Inter-PLMN secured interconnections

Exercise: Build 5G roaming network

2. Basic 5G Operations for Roaming Ues

- 2.1 Session Registration and Security Setup
- 2.2 Policy Implementation
- 2.3 PDU Session Setup in roaming scenarios

Exercise: End-to-end 5G roaming call flow

3. Special Procedures for Roaming

- 3.1 Network Slice Management
- 3.2 Network Steering
- 3.3 5G <--> 4G Handovers
- 3.4 Idle Mode behavior

4. Service Delivery in Roaming Configurations

- 4.1 Data services
- 4.2 IMS VoNR services
- 4.3 IMS emergency services

Putting It All Together

Policy and Charging in 5G

This training provides a high-level technical overview of the Policy and Charging Control (PCC) role in 5G. The training explains the PCC architecture for roaming and non-roaming and the role of the Policy Control Function (PCF) network function in the PCC rules. In addition, the training describes the interactions of the PCF with other 5G network functions and application functions for PCC and QoS purposes. The training also outlines the role of the Network Data Analytics Function (NWDAF) input to the PCC rules. Finally, the training summarize important 3GPP release 16 and 17 enhancements to the PCC and Quality of Service (QoS).

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:

- Outline the role of the Policy and Charging Control in 5G
- Illustrate the PCC roaming and non-roaming architecture
- Describe the 5G network functions interactions for PCC and QoS
- List and describe the different types of policies in 5G
- Describe the impact of PCC on session- and non-session-related policy
- List PCC and QoS enhancements in 3GPP release 16 and 17

What You Can Expect

- Prerequisite: Welcome to 5G
- Expert-Led Live Duration: 4 HOUR

Outline

1. What is Policy, Charging and QoS?
- 1.1 What is Policy and Charging Control (PCC)?
- 1.2 What are policy rules?
- 1.3 What are charging rules in PCC?

2. Policy Control and Charging Architecture
- 2.1 Non-Roaming Policy and Charging architecture
- 2.2 Roaming Policy and Charging architecture
- 2.3 Types of PCC rules (Dynamic and Pre-Defined)
- 2.4 Example: PCC for PDU session at the UPF
- **Exercise:** Build PCC-Related 5G Network

3. Types of Policy in 5G
- 3.1 Non-session management policy
- 3.2 Session management policy

4. Policy Control Operations
- **Exercise:** PCC Call Flows Signaling

5. 5G PCC and QoS Enhancements 3GPP Rel 16-17
- 5.1 PCC and QoS features in release 16 highlights
- 5.2 PCC and QoS features in release 17 highlights

Putting it all together

5G Non-Terrestrial Network (NTN)

Non-Terrestrial Network (NTN), introduced in 5G Release 17, leverages satellite infrastructure to provide 5G services over sea and land where terrestrial coverage is absent. This training sketches an end-to-end network architecture of NTN of 5G, identifies capabilities and challenges of NTN, steps through life of a 5G device in a 5G NTN and list key deployment use cases.

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:

- Define satellite based 5G Non-Terrestrial Network (NTN)
- List capabilities, design considerations, and limitations of NTN
- Sketch an end-to-end architecture of 5G Non-Terrestrial Network (NTN)
- Step through the life of a 5G device in NTN
- Identify use case scenarios such as NTN-TN interworking, roaming

What You Can Expect

- Expert-Led Live Duration: 4 HOUR

Outline

1. What and Why 5G Non-Terrestrial Network (NTN)
- 1.1 What is 5G NTN and Why?
- 1.2 NTN requirements
- 1.3 Capabilities and challenges of NTN
- 1.4 NTN use cases overview

2. Non Terrestrial Network Architecture
- 2.1 Satellite based 5G NTN architecture
- 2.2 Transparent and Regenerative NTN architecture
- 2.3 Impact of delay and timing on 5G NR air interface
- 2.4 Overview of a link budget for NTN

Exercise: Build Non-Terrestrial Network

3. Non Terrestrial Network Operations
- 3.1 NTN NR air interface and related protocols
- 3.2 Life of 5G UE in NTN
- 3.3 Interworking scenarios of NTN and Terrestrial Network
- 3.4 Roaming scenarios
- 3.5 Beam management

Exercise: NTN call flow

4. Deployment Considerations of NTN
- 4.1 Role of LEO, MEO, and GEO satellites in NTN
- 4.2 NTN NR constraints and Services considerations
- 4.3 Security considerations
- 4.4 Deployment use cases

Putting It All Together

View Curriculum

AWS Cloud Practitioner Essentials (AWS)

This course is for individuals who seek an overall understanding of the Amazon Web Services (AWS) Cloud, independent of specific technical roles. You will learn about AWS Cloud concepts, AWS services, security, architecture, pricing, and support to build your AWS Cloud knowledge. This course also helps you prepare for the AWS Certified Cloud Practitioner exam.

Intended Audience

This course is intended for sales, legal, marketing, business analysts, project managers, AWS Academy students, and other IT-related professionals.

Objectives

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

- Differentiate between on-premises, hybrid-cloud, and all-in cloud
- Describe the basic global infrastructure and the six benefits of the AWS Cloud
- Identify an appropriate solution using AWS Cloud services with various use cases
- Describe the AWS Well-Architected Framework
- Describe the core security services within the AWS Cloud
- Describe the basics of AWS Cloud migration
- Articulate the financial benefits of the AWS Cloud for an organization's cost management
- Explain how to use pricing tools to make cost-effective choices for AWS services

What You Can Expect

- Prerequisite: General IT business knowledge
- Prerequisite: General IT technical knowledge
- Expert-Led Live Duration: 7 HOUR

Outline

1. Introduction to Amazon Web Services
- 1.1 Benefits of AWS
- 1.2 On-demand delivery vs cloud deployments
- 1.3 Pay-as-you-go pricing model

2. Compute in the Cloud
- 2.1 Amazon Elastic Compute Cloud (Amazon EC2)
- 2.2 Amazon EC2 Auto Scaling
- 2.3 Elastic Load Balancing
- 2.4 Amazon Simple Notification Service (Amazon SNS)
- 2.5 Amazon Simple Queue Services (Amazon SQS)

3. Global Infrastructure and Reliability
- 3.1 Availability Zones
- 3.2 Amazon CloudFront and Edge locations
- 3.3 Provisioning AWS services

4. Networking
- 4.1 Public vs private networking resources
- 4.2 Virtual private gateway and virtual private network
- 4.3 AWS Direct Connect
- 4.4 Hybrid Deployments
- 4.5 AWS global network

5. Storage and Databases
- 5.1 Amazon Elastic Block Store (Amazon EBS)
- 5.2 Amazon Simple Storage Service (Amazon S3)
- 5.3 Amazon Elastic File System (Amazon EFS)
- 5.4 Amazon Relational Database Service (Amazon RDS)
- 5.5 Amazon DynamoDB

6. Security
- 6.1 Shared responsibility model
- 6.2 AWS Identity vs Access Management (IAM) security levels
- 6.3 AWS Organizations and compliance
- 6.4 AWS security policies and services

7. Monitoring and Analytics
- 7.1 Monitoring your AWS environment
- 7.2 Amazon CloudWatch, AWS CloudTrail, AWS Trusted Advisor

8. Pricing and Support
- 8.1 AWS pricing and support models
- 8.2 AWS Organizations and consolidated billing
- 8.3 AWS Budget, AWS Cost Explorer, AWS Pricing Calculator
- 8.4 AWS Support Plans
- 8.5 AWS Marketplace

9. Migration and Innovation
- 9.1 AWS Cloud Adoption Framework (AWS CAF)
- 9.2 Six key factors of a cloud migration strategy
- 9.3 AWS data migration solutions, i.e. AWS Snowcone, AWS Snowball, AWS Snowmobile
- 9.4 Five pillars of the AWS Well-Architected Framework

10. AWS Certified Cloud Practitioner Basics
- 10.1 Resources for preparing for the AWS Certified Cloud Practitioner examination
- 10.2 Benefits of becoming AWS Certified

View Curriculum

MEC Architecture and Operations

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 Multi-Access Edge Computing (MEC)
- 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 5GC
   - 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)
   - 2.8 Mobile Edge Services
   - 2.9 Example MEC APIs
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

View Curriculum

Network Slicing Architecture and Operations

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
- Discuss network slice and network slice subnet definition
- Define how network slicing is applied in a 5G network
- Illustrate the relationship between network slices, data networks and QoS
- Describe how slice information is used in 5G operations
- Explain the lifecycle management of network slice
- Discuss the network slice management and orchestration
- List network slice management functions and their roles

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 is 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 Radio Access Network
   - 2.3 Transport network
   - 2.4 Network slice management
3. Defining Network Slices
   - 3.1 Network slicing in subscriber profile
   - 3.2 Network slice policy for user plane
   - 3.3 Network slice NF Registration and Discovery
4. Network Slicing Procedures
   - 4.1 Network slice operations
   - 4.2 Roaming and network slicing
   - 4.3 EPS Interworking
5. Network Slicing Deployment
   - 5.1 Network slice management framework
   - 5.2 Lifecycle management
   - 5.3 Use case

View Curriculum

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 Telco Cloud Part 1: Virtualization and Orchestration
- 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

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: Welcome 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

5G Security Architecture and Operations

In an all-digital world, 5G wireless is a key enabler for fundamental transformation for many industry segments. Therefore, security is of utmost importance for successful adoption. This course is designed to provide a broad technical overview of vulnerabilities in 5G, mitigation measures designed into 5G networks, responsibilities of various components of 5G networks as well as end-to-end security architecture. We show how different security solutions at various layers and components come together to facilitate secure 5G networks to achieve authentication, encryption, data integrity, network availability and secure mobility.

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:

- List threats and vulnerabilities in 5G networks
- Match various mitigation measures with vulnerabilities
- Sketch the end-to-end 5G security architecture
- Detail end-to-end 5G security procedures
- Explain how 5G networks provide authentication, encryption, data integrity, network availability
- Describe security procedures while roaming

What You Can Expect

- Prerequisite: Welcome to 5G
- Expert-Led Live Duration: 7 HOUR

Outline

1. 5G Security Threats and Vulnerabilities
   - 1.1 Security Challenges in 5G
   - 1.2 (STRIDE) Threats Applicability to 5G
   - **Exercise:** Match threats and impact
2. 5G Security Architecture Framework
   - 2.1 End-to-end security architecture
   - 2.2 Roles of AUSF, UDM, NEF, NSSAF and NRF
   - 2.3 Key architectural concepts (Zero Trust, Microsegmentations, etc.)
   - 2.4 Identity and Authentication (SUPI/SUCI, authentication algorithms)
   - 2.5 End-to-end encryption framework
   - 2.6 Security for SBI and non-SBI interfaces (3rd-party services)
   - 2.7 Zero Trust Architecture in 5G networks
   - **Exercise:** Match threats to mitigation framework
3. 5G Security Procedures
   - 3.1 Life of a device in 5G networks
   - 3.2 Air interface and RAN security logs analysis
   - 3.3 Core network security flow
   - 3.4 5G interworking with networks (4G, Wi-Fi)
   - 3.5 Security while roaming
   - **Exercise:** End-to-end 5G connection security flow
4. Network and Infrastructure Security
   - 4.1 gNodeB security
   - 4.2 Infrastructure access security
   - 4.3 Virtual workload security
   - 4.4 PNF, VNF, CNF security evolution
   - 4.5 Network availability and monitoring
   - **Exercise:** Match infrastructure vulnerability with mitigation

View Curriculum

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 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
- Expert-Led Live Duration: 14 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

View Curriculum

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 decomposed 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. Learners 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

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 is it handled for a PDU session

What You Can Expect

- Prerequisite: 5G Core Network Overview
- Prerequisite: 5G Networks and Services
- Expert-Led Live Duration: 21 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, UPF
- 1.3 5GC Network Functions - UDM, AUSF, PSF, CHF..
- 1.4 Network Slicing and Role of NSSF

Exercise: 5GC Network Functions

2. Service-Based Architecture (SBA) and Virtualization
- 2.1 SBA, APIs and NRF
- 2.2 NF Registration and Discovery
- 2.3 Virtualization in 5G - Role of NFV and SDN

Exercise: Service Based Interfaces (SBI)

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

Architecting on AWS (AWS)

In this course, you will learn to identify services and features to build resilient, secure, and highly available IT solutions on the AWS Cloud. Architectural solutions differ depending on industry, types of applications, and business size. AWS Authorized Instructors emphasize best practices using the AWS Well-Architected Framework, and guide you through the process of designing optimal IT solutions based on real-life scenarios. The modules focus on account security, networking, compute, storage, databases, monitoring, automation, containers, serverless architecture, edge services, and backup and recovery. At the end of the course, you will practice building a solution and apply what you have learned.

Intended Audience

Architecting on AWS is for solutions architects, solution-design engineers, and developers seeking an understanding of AWS architecting.

Objectives

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

- Identify AWS architecting basic practices
- Practice building a multi-tier architecture in AWS
- Compare and contrast AWS storage products and database services based on business scenarios
- Identify the role of monitoring, load balancing, and auto scaling responses based on business needs
- Discuss AWS automation tools that will help you build, maintain, and evolve your infrastructure
- Discuss hybrid networking, network peering, and gateway and routing solutions
- Explore AWS container services for an infrastructure-agnostic, portable application environment
- Explore AWS backup, recovery solutions, and best practices to ensure resiliency

What You Can Expect

- Prerequisite: AWS Cloud Practitioner Essentials (AWS)
- Prerequisite: AWS Technical Essentials (AWS)
- Expert-Led Live Duration: 21 HOUR

Outline

1. Architecting Fundamentals
- 1.1 AWS services and infrastructure
- 1.2 AWS Well-Architected Framework

Exercise: Hands-on Lab: Explore the AWS Management Console and AWS Command Line Interface

2. Account Security
- 2.1 Principals and identities
- 2.2 Security policies

3. Networking 1
- 3.1 VPC fundamentals and VPC traffic security

4. Compute
- 4.1 EC2 instances, storage and pricing
- 4.2 AWS Lambda

Exercise: Hands-On Lab: Build your Amazon VPC infrastructure

5. Storage
- 5.1 Amazon S3
- 5.2 Shared file systems

6. Database Services
- 6.1 Amazon RDS
- 6.2 Amazon DynamoDB
- 6.3 Database caching and migration tools

Exercise: Hands-on Lab: Create a database layer in your Amazon VPC infrastructure

7. Monitoring and Scaling
- 7.1 Alarms and events
- 7.2 Load balancing and auto scaling

8. Automation
- 8.1 AWS CloudFormation and Infrastructure management

9. Containers
- 9.1 Microservices, Containers, and Container services

10. Networking 2
- 10.1 VPC endpoints and VPC peering
- 10.2 AWS Transit Gateway

11. Serverless
- 11.1 Amazon API Gateway
- 11.2 Amazon SQS and SNS
- 11.3 Amazon Kinesis
- 11.4 AWS Step Functions

Exercise: Hands-on Lab: Build a serverless architecture

12. Edge Services
- 12.1 Amazon Route 53
- 12.2 Amazon CloudFront
- 12.3 DDoS protection
- 12.4 AWS Outposts

Exercise: Hands-on Lab: Configure an Amazon CloudFront distribution

13. Backup and Recovery
- 13.1 Disaster planning and recovery strategies
- 13.2 AWS Backup

Exercise: Hands-on Lab: Capstone lab – Build an AWS Multi-Tier architecture

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. This training 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 IT networks for a while and 5G networks have 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 lifecycle management
- Hands-on demonstration of some key containerized deployment concepts

What You Can Expect

- 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 Container Overview
   - 1.3 Containerized and Cloud-Native NFs (CNFs)
   - **Exercise:** Lab1.a: Container Basic Operations
   - **Exercise:** Lab1.b: Using docker and podman CLI
   - **Exercise:** Lab1.c: Insecure registries with container runtime
2. Virtualized Infrastructure
   - 2.1 Kubernetes Architecture
   - 2.2 OpenShift for Kubernetes
   - 2.3 Container Runtime Options
   - **Exercise:** Lab2.a: Container CPU limits (Shares and Quota)
   - **Exercise:** Lab2.b: Container memory limits
3. Service Deployment Considerations
   - 3.1 Container Deployment Considerations
   - 3.2 Service Mesh in Kubernetes
   - 3.3 Service-Based Architecture
   - 3.4 Microservices for Network Functions
   - **Exercise:** Lab3.a: Build container image using manifest
   - **Exercise:** Lab3.b: Test App's API from built image
   - **Exercise:** Lab3.c: Copy files to/from containers
   - **Exercise:** Lab3.d: Monitor container logs
   - **Exercise:** Lab3.e: Use persistent storage for containers
4. Networking Considerations
   - 4.1 Container Networking
   - 4.2 Kubernetes Service Routing
   - 4.3 Kubernetes Pod Routing
   - 4.4 SR-IOV and DPDK Considerations
   - **Exercise:** Lab4.a: Use of container network namespace
   - **Exercise:** Lab4.b: Determine containers bridge port
   - **Exercise:** Lab4.c: Test traffic among containers
   - **Exercise:** Lab4.d: MACVLAN for containers networking
5. Orchestration and Deployment
   - 5.1 Kubernetes Orchestration Overview
   - 5.2 Kubernetes Package Manager
   - 5.3 Lifecycle Management
   - **Exercise:** Lab5.a: IP pool for container runtime
   - **Exercise:** Lab5.b: Create K8s deployments and services
   - **Exercise:** Lab6.c: Use K8s dashboard and test self-healing
   - **Exercise:** Lab6.d: Test deployment autoscaling

View Curriculum

Kubernetes Orchestration Workshop

Competitive advantages of business agility drive the need for responsive and flexible IT infrastructure, which can be slow and expensive. The lead time to procure, install, configure and commission new hardware 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 assists 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: Lab1.a: Namespaces and credentials for tenants
Exercise: Lab1.b: RBAC - Assign variable roles for tenants

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: Lab2.a: Create and use private registry
Exercise: Lab2.b: Deploy web server and stateful DB
Exercise: Lab2.c: Tracing pods traffic
Exercise: Lab2.d: Self-healing and manual scaling

3. Networking Services

3.1 Networking capabilities and components
3.2 Network policies and tenant isolation
Exercise: Lab3.a: Apply Calico network plugin for pods
Exercise: Lab3.b: Utilize namespaces and IP pools for pods
Exercise: Lab3.c: Set up pod interworking policy

4. Using Repos and Helm - Lab Only

Exercise: Lab4.a: Practice image pull policy
Exercise: Lab4.b: Deploy Helm charts and customize deployment options
Exercise: Lab4.c: Practice upgrades and rollback with Helm

5. Kubernetes Services

5.1 Deploy Kubernetes applications and services
5.2 Cloud-native service monitoring tools
Exercise: Lab5.a: NodePort and external IPs for services
Exercise: Lab5.b: Pod scheduling using taint and tolerance
Exercise: Lab5.c: Load balancer for services
Exercise: Lab5.d: Deploy services with persistent volumes and claims

6. Sample of Additional Optional Labs

Exercise: Lab6.a: ConfigMaps using env and envFrom
Exercise: Lab6.b: Ingress controller for multiple services
Exercise: Lab6:c: Multi-service pods
Exercise: Lab6:d: Secrets for datastore security
Exercise: Lab6.e: Operations using Startup, Readiness and Liveness probes
Exercise: Lab6.f: Stateful and StatefulSet/Headless deployments
Exercise: Lab6.g: Volumes and claims for stateless and StatefulSet
Exercise: Lab6.h: Use K8s DNS to discover StatefulSet IP address

Note 1: Several types of manifests are used in the lab
Note 2: Different container runtimes are used in the lab

LTE and VoLTE

Curriculum

LTE and VoLTE

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5G Access

5G Core

LTE and VoLTE

Transport

Automation and Insights

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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

Introduction to VoLTE

RF Design Workshop Part 1 - LTE

RF Design Workshop Part 2 - VoLTE and Small Cells

LTE RF Optimization Part 1 - Coverage and Accessibility

LTE RF Optimization Part 2 - DL and UL Throughput

LTE RF Optimization Part 3 - Mobility and Inter-RAT

LTE RF Optimization Part 4 - Carrier Aggregation and Load Balancing

VoLTE Troubleshooting Workshop

VoLTE RAN Performance Workshop

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
- 4.3 OFDM/OFDMA concepts
- 4.4 Multiple antennas in LTE

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

LTE Overview

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.

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

View Curriculum

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.

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

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 DRA
   - 3.4 NAT/PAT
   - 3.5 Firewalls
   - 3.6 MSP
   - 3.7 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

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

Exploring LTE: Signaling and Operations – Part II

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 two 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:

- 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

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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

View Curriculum

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

Outline

1. What is VoLTE?
   - 1.1 IR.92
   - 1.2 VoIP and QoS
   - 1.3 IMS
2. IMS Network Nodes and Functions
   - 2.1 P-CSCF, I-CSCF, and S-CSCF
   - 2.2 ENUM and IMS HSS
   - 2.3 TAS
   - 2.4 SCC-AS and BGCF
   - 2.5 MGCF, MGW, and SGW
   - 2.6 MRFC and MRFP
3. IMS Network Interfaces
   - 3.1 Rx
   - 3.2 Cx and Sh
   - 3.3 ISC
   - 3.4 Media interfaces
4. VoLTE Protocols
   - 4.1 SIP and SDP
   - 4.2 Diameter
   - 4.3 RTP and RTCP
   - 4.4 Megaco (H.248)

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 IPv4v6 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

Outline

1. Setting the Stage
- 1.1 LTE-EPC network architecture
- 1.2 PDN connections
- 1.3 IP address assignment in LTE

2. IPv4 in Wireless Networks
- 2.1 IPv4 address formats
- 2.2 Use of public and private addresses
- 2.3 Mobility support – GTP and mobile IP
- 2.4 Limitations of IPv4

3. IPv6 Essentials
- 3.1 Key aspects of IPv6
- 3.2 Ipv6 header description
- 3.3 IPv6 addressing

4. IPv6 Assignment in LTE Networks
- 4.1 Default bearer setup operation
- 4.2 IPv6 address allocation
- 4.3 Role of NAS signaling
- 4.4 Assignment of dual-stack IPv4/IPv6 addresses

5. IPv4/IPv6 Transition Mechanisms
- 5.1 Dual stack addressing
- 5.2 Tunnels
- 5.3 Translators

6. IPv6 Deployment in LTE Networks
- 6.1 Dual-stack connectivity
- 6.2 IPv6 migration scenarios
- 6.3 Put It All Together
- 6.4 Assess the knowledge of the participant based on the objectives of the course

LTE Air Interface Signaling Overview

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.

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

Outline

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

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 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
- Expert-Led Live Duration: 7 HOUR

Outline

1. The LTE Network
- 1.1 LTE RAN and Core
- 1.2 LTE Attach and PDN Connection Setup
- 1.3 QoS in LTE
- 1.4 IMS Architecture
- 1.5 VoLTE Overview

2. VoLTE Operations
- 2.1 VoLTE Registration
- 2.2 VoLTE Call Origination/Termination
- 2.3 EPS Bearers and DRBs for VoLTE

3. VoLTE Media
- 3.1 Media Path and RTP
- 3.2 Introduction to 5G New Radio
- 3.3 Audio Codecs for VoLTE
- 3.4 RoHC and Other Air Interface Enhancements

4. VoLTE Interworking
- 4.1 VoLTE to 3G/PSTN Call Setup
- 4.2 3G/PSTN to VoLTE Call Setup
- 4.3 Outbound Roaming

5. VoLTE KPIs
- 5.1 VoLTE KPIs and Failures Overview

View Curriculum

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

View Curriculum

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

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
- 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

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
- 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

View Curriculum

LTE RF Optimization: Part 3 – Mobility and Inter-RAT

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 Intra-LTE and IRAT handover operation. 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
- 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
- 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

View Curriculum

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.

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
- Expert-Led Live Duration: 10 HOUR

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

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
- 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

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
Exercise: Case Study: VoLTE Drops

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

Transport
Curriculum

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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

View Curriculum

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

View Curriculum

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

View Curriculum

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.

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

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

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

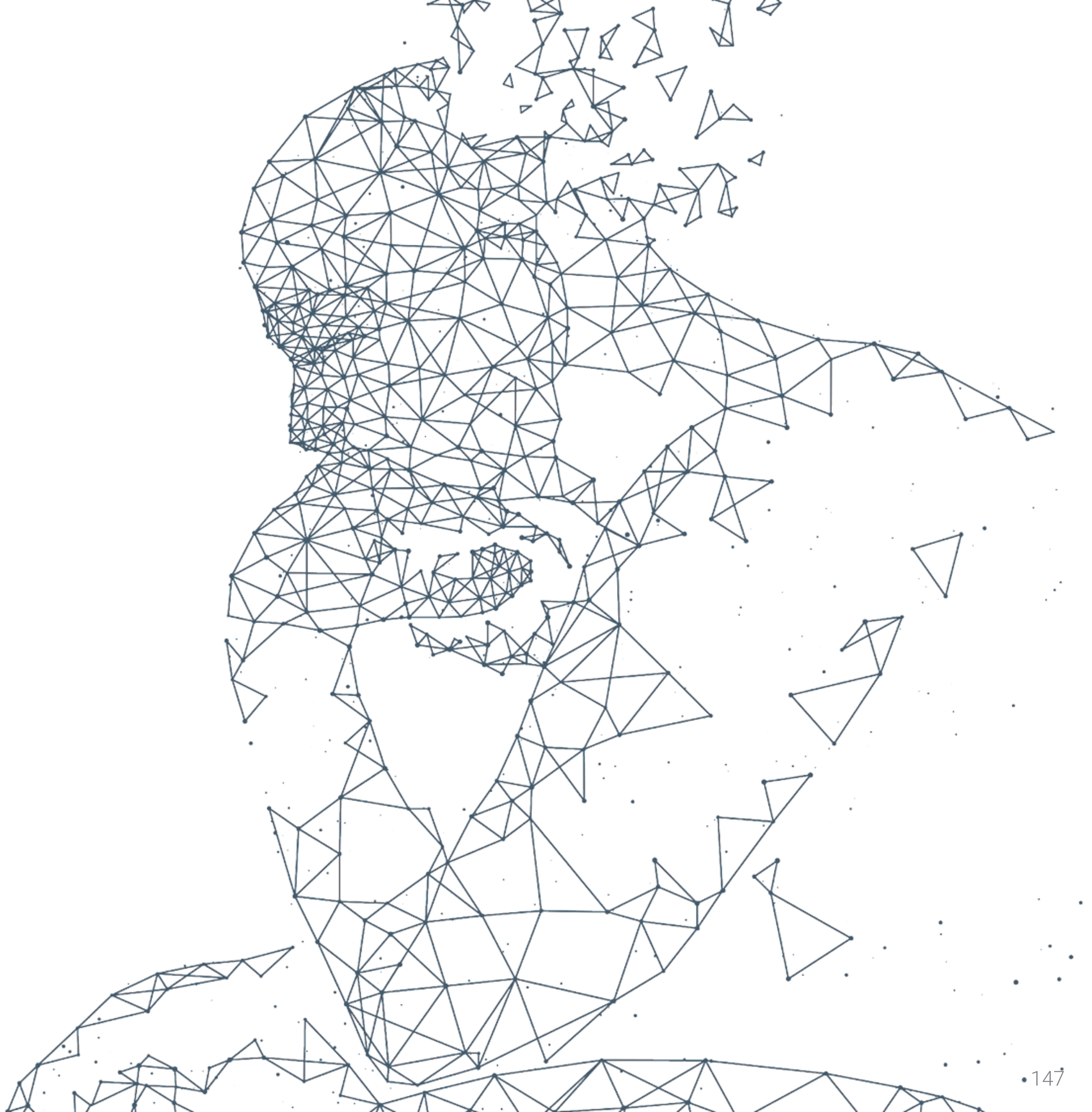
- Self-Paced Duration: 1 HOUR

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

Automation and Insights

Curriculum



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ON-DEMAND - EXPRESS

Welcome to AI

Welcome to Python

Welcome to Machine Learning

Visualizing and Manipulating Data in Python

Python Data Structures

ON-DEMAND - EXPANDED

Artificial Intelligence (AI) Essentials

Analytics Essentials

Award Solutions

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

View Curriculum

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

Visualizing and Manipulating Data in Python

This self-paced eLearning course is a light-hearted introduction to data manipulation and visualization in Python. Students will manipulate data sets and create data visualization using Python libraries.

Intended Audience

Those with some programming experience who are interested in data manipulation and visualization in Python.

Objectives

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

- Describe how to extract data from the CSV format
- Use the matplotlib module to visually represent data
- Use the Python Pandas to manipulate data
- Explain how to use Pandas clean data to eliminate outliers
- Explain how to access APIs
- Describe how to extract data from the JSON format
- Describe commonly used file formats in data science

What You Can Expect

- Self-Paced Duration: 1 HOUR

Outline

1. **Introduction**
2. **Extracting and Visualizing Data**
   - 2.1 Extracting and Visualizing Data
   - 2.2 Code Challenge
3. **Data Manipulation**
   - 3.1 Pandas Overview
   - 3.2 Data Manipulation
   - 3.3 Code Challenge
4. **Data Analysis**
   - 4.1 Data Analysis
   - 4.2 Code Challenge
5. **Working with APIs**
6. **Data Visualization**
   - 6.1 Visualizing Data from JSON

Final Assessment

Python Data Structures

This self-paced on-demand course is a light-hearted introduction to Python data structures. Students will delve a little deeper into data structures and become familiar with ways to organize and access data collections in Python.

Intended Audience

Those with some programming experience who are interested in implementing advanced data structures in Python.

Objectives

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

- Use the dictionary structure to organize information into key value pairs
- Explain the significance of an immutable data type
- Explain the differences between tuples and lists
- Pack and unpack tuples to hold value pairs
- Demonstrate uses for ordered and unordered collections
- Define and perform set operations

What You Can Expect

- Self-Paced Duration: 1 HOUR

Outline

1. Lists Overview
- 1.1 Creating a List

2. Tuples
- 2.1 Tuples Packing
- 2.2 Tuples Unpacking
- 2.3 Nested Tuples
- 2.4 Working with Tuples
- **Exercise:** Code Challenge

3. Dictionaries
- 3.1 Looping through Keys, Values, Key-Value Pairs

4. Set Operations
- 4.1 Union, Intersection, Difference
- 4.2 Symmetric Difference
- 4.3 Set Operations Summary
- 4.4 Working with Set Operations
- 4.5 Organizing with Set Operations

5. Data Structures Overview

6. Common Characteristics
- 6.1 Indexed
- 6.2 Mutable
- 6.3 Duplicates allowed
- 6.4 Heterogenous

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.

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

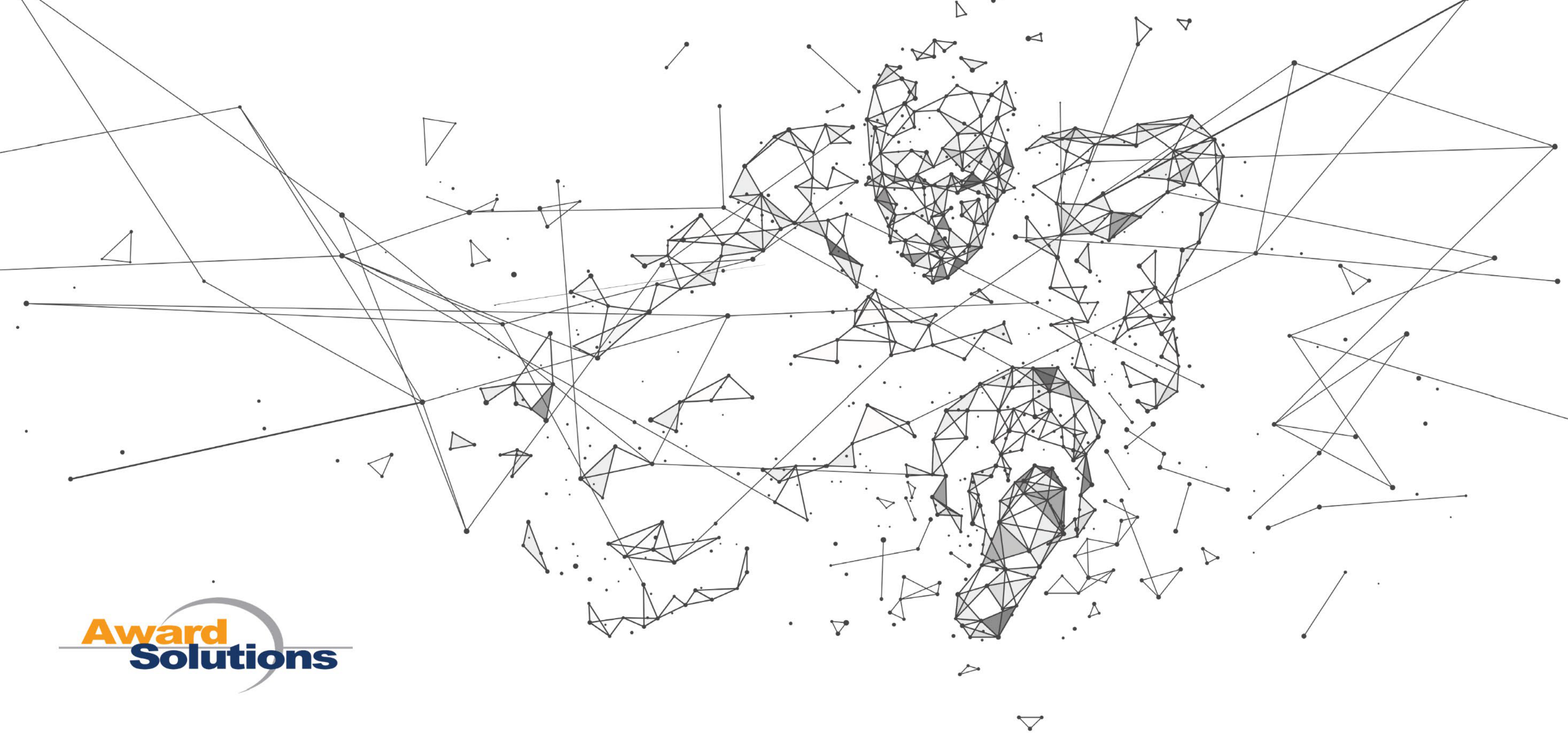
What You Can Expect

- Self-Paced Duration: 4 HOUR

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

Thank You



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