5G and IoT

We help our customers tackle technology, faster.

Curriculums include:

- **eLearning**
  - Welcome to 5G
  - 5G NR Air Interface Overview - Part I
  - 5G NR Air Interface Overview - Part II
  - 5G Core Network Overview

- **Blended Learning**
  - Introduction to 5G
  - 5G (NSA) RAN Signaling and Operations
  - 5G Core Network Signaling and Operations

- **Deep Dives**
  - 5G Essentials for Leadership
  - 5G Networks and Services
  - 5G NR Air Interface
  - 5G (NSA) RAN Signaling and Operations
  - 5G RF Planning and Design
  - 5G Core Network Signaling and Operations
  - Advanced LPWA for IoT
  - LTE-M and NB-IoT Signaling and Operations

- **Tech Primers**
  - 5G Radio Technologies and Deployments
  - 5G Services and Network Architecture
  - LTE-M and NB-IoT
  - Multi-Access Edge Computing (MEC)
  - Network Slicing in 5G
  - 5G RAN Architecture and Transport
  - Dark Fiber and Ethernet Backhaul
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Curriculums include:

- 5G and IoT
- LTE / VoLTE
- IP / Ethernet
- Network Virtualization

**Automation and Insights**

**eLearning**
- Welcome to AI

**Blended Learning**
- AI Tools and Technology

**Tech Primers**
- Artificial Intelligence (AI)
- Blockchains
- Immersive Technologies (AR/VR/MR)

**Deep Dives**
- Data Automation Workshop using Python
- Data Manipulation Workshop
- Data Visualization Workshop using PowerBI
- Data Visualization Workshop
- Deep Learning Concepts Workshop
- Ansible Workshop
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Curriculums include:

| 5G and IoT |
| Automation and Insights |
| LTE / VoLTE |
| IP / Ethernet |
| Network Virtualization |

### eLearning

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

### Deep Dives

| RF Design Workshop |
| Part I - LTE |
| Part II - VoLTE and Small Cells |
| Overview of CBRS |

### Tech Primers

| Licensed-Assisted Access (LAA) |
| Overview of CBRS |
IP/Ethernet

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Curriculums include:

- 5G and IoT
- Automation and Insights
- LTE / VoLTE
- IP / Ethernet
- Network Virtualization

**eLearning**

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

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Curriculums include:
- 5G and IoT
- Automation and Insights
- LTE / VoLTE
- IP / Ethernet
- Network Virtualization

**eLearning**
- API Overview
- Big Data Overview
- Cloud RAN Overview
- NFV Overview
- OpenStack IaaS Overview
- SDN Overview
- Welcome to SDN and NFV Introduction
- Welcome to SDN and NFV Foundations
- Welcome to SDN and NFV Technologies
- Virtualization and Cloud Overview

**Tech Primers**
- Containers and Microservices in Telecom
- Cloud and Virtualization
- Network Functions Virtualization (NFV)
- ONAP
- OpenStack
- Orchestration
- Software-Defined Networking (SDN)

**Deep Dives**
- Foundation Courses
  - OpenStack Workshop for SDN and NFV
  - Scripting Workshop for SDN and NFV
  - SDN and NFV Architecture and Operations

- Advanced Workshops
  - NETCONF/YANG Configuration Workshop
  - Introduction to Software Containers Workshop
  - OpenStack Heat Workshop
5G and IoT
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 student 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

Prerequisites
■ None

Required Equipment
■ None

Course 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
   7.4 Putting It All Together

1 hour | eLearning, 5G_101

View Curriculum | Contact Award
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 self-paced 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. Part II concludes 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 student 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

Course Outline
1. 5G Performance Goals
   1.1 Higher data rates
   1.2 Lower latency
   1.3 Higher connection density

2. 5G NR Air Interface Overview
   2.1 Key features of 5G air interface
   2.2 Flexible numerologies
   2.3 Air interface protocol stack

3. Frequency Spectrum for 5G
   3.1 Spectrum considerations
   3.2 Low, mid, and high bands
   3.3 Channel bandwidths
   3.4 Radio signal propagation

4. MIMO and Beamforming
   4.1 Massive antenna
   4.2 Beamforming and beam tracking
   4.3 FD MIMO

Prerequisites
- None

Required Equipment
- None
## 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 student will be able to:
- Sketch the flexible frame and slot structure of 5G NR
- Identify key channels and their usage in the downlink and uplink
- Step through the life of a 5G UE at a high level
- Identify ways in which 5G NR meets the performance goals of 5G

## Prerequisites
- None

## Required Equipment
- None

## Course Outline

### 1. 5G NR Frame and Slot Structure
   - 1.1 Flexible sub-carrier spacing
   - 1.2 Flexible frame structure
   - 1.3 Flexible slot structure
   - 1.4 Carrier bandwidth part

### 2. Key Signals and Channels of 5G NR
   - 2.1 Downlink signals and channels
   - 2.2 Uplink signals and channels

### 3. Life of a 5G UE
   - 3.1 NSA vs. SA operations
   - 3.2 NSA operations
   - 3.3 Network acquisition
   - 3.4 Attach
   - 3.5 Data transfer
   - 3.6 SA Operations
   - 3.7 Network acquisition
   - 3.8 Registration
   - 3.9 PDU session setup
   - 3.10 Data transfer

### 4. Meeting 5G Performance Goals
   - 4.1 Ways to achieve higher data rates
   - 4.2 Ways to achieve lower latency
   - 4.3 Ways to achieve higher connection density
   - 4.4 Putting It All Together
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.

**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 student 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 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

**Prerequisites**
- None

**Required Equipment**
- None

**Course 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
   8.3 Putting It All Together
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. In order 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 provides an overview of the usage scenarios envisioned by the wireless industry and highlights the changes and enhancements being defined in the 3GPP standards. This course is delivered in a blended format, including two live web sessions along with self-paced multimedia content, allowing students to learn in bite-sized chunks over a three-week interval.

Intended Audience
This blended (self-paced and Instructor-led) course is intended for a technical audience looking for an overview of the drivers for 5G and a basic understanding of the underlying technologies being considered.

Objectives
After completing this course, the student will be able to:
- Describe the 5G usage scenarios defined by the ITU and 3GPP
- Identify the technology building blocks needed for 5G
- Explain the key enhancements to the 5G RAN and core network architectures
- Discuss benefits of enhanced network capabilities, such as MEC, network slicing, and C-RAN
- Identify the new spectrum bands being considered for 5G
- Discuss radio interface enhancements
- Illustrate the key 5G deployment scenarios

Prerequisites
- A basic understanding of LTE and LTE-Advanced

Required Equipment
- None

Course Outline

1. Kickoff Session [Live: Web-based]
   1.1 Getting the most out of the course
   1.2 5G overview

2. Introduction to 5G Services
   2.1 ITU/3GPP usage scenarios
   2.2 5G performance targets
   2.3 5G technology building blocks

3. Introduction to 5G Networks
   3.1 5G RAN and core network architectures
   3.2 Mobile Edge Computing (MEC)
   3.3 Network slicing
   3.4 Cloud RAN (C-RAN)
   3.5 5G deployment options

4. Introduction to 5G New Radio
   4.1 5G spectrum
   4.2 Massive MIMO
   4.3 5G radio enhancements
   4.4 5G channel coding
   4.5 5G transport

5. Checkpoint Session [Live: Web-based]
   5.1 Q&A;
   5.2 5G industry update
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 the students with the 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 student will be able to:

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

### Prerequisites

- 5G NR Air Interface (Instructor-led)

### Required Equipment

- None

### Course Outline

#### 1. 5G NSA Network Architecture

1.1 Performance targets: 4G vs. 5G  
1.2 NSA Option 3x network architecture  
1.3 Signaling and data radio bearers in Option 3x  
1.4 NR air interface & frame structure  
1.5 Overview of EN-DC operations  
1.6 5G UE capability transfer

#### 2. 5G Cell Acquisition

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

#### 3. Connecting to 5G gNB: Random Access

3.1 Overview of random access  
3.2 PRACH configurations and radio resources  
3.3 Uplink synchronization in an NR cell

#### 4. DL Data transfer in 5G

4.1 Overview of DL traffic processing  
4.2 DL signals and UE measurements  
4.3 5G measurements by UE  
4.4 Reporting of UE measurements  
4.5 DL scheduling and resource allocation  
4.6 DL data transmission  
4.7 DL HARQ in 5G

#### 5. UL Data transfer in 5G

5.1 Overview of UL traffic processing  
5.2 Scheduling requests  
5.3 Buffer status reports  
5.4 Resource allocation for UL  
5.5 UL data transmission  
5.6 Uplink power control

#### 6. Mobility and Idle Mode Operations

6.1 Mobility and RRC states  
6.2 Mobility scenarios  
6.3 Measurements and handover signaling  
6.4 5G Connection release  
6.5 Idle mode mobility  
6.6 Putting it all together

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Variable Duration | Blended Learning, 5G_303

[View Curriculum] [Contact Award]
5G Core Network Signaling and Operations

The 5G Core (5GC) network architecture is a significant evolution from 4G LTE EPC. Network functions have been de-composed and re-architected to enable MEC and network slicing and thus supporting many verticals in virtualized network. Students will step through various network operations and related call flows using actual logs where applicable and will be able to highlight key differences of 5G operations from LTE operations.

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

Objectives
After completing this course, the student will be able to:
- Identify the Network Functions (NF) of the 5G core network
- Contrast the roles of the NFs with the 4G LTE EPC
- Sketch the connectivity for the 5G network functions
- Describe the 5G UE registration procedure
- Describe PDU session set up 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

Prerequisites
- 5G Core Network Overview (self-paced eLearning)
- 5G Networks and Signaling (Instructor-led)

Required Equipment
- None

Course Outline

1. 5G Network Architecture
   1.1 End-to-end 5G NG-RAN to 5GC architecture
   1.2 5GC Network Functions (NF) - AMF, SMF, etc.
   1.3 5G Identifiers
   1.4 5G and virtualization technologies
   1.5 SBA, APNs and NRF
   1.6 Network slicing
   **Exercise:** Hands-on build the network

2. 5G UE Registration Procedure
   2.1 System acquisition and registration
   2.2 AMF Selection
   2.3 UE slice assignment and request
   2.4 Authentication
   2.5 Air interface security
   2.6 Dual registration
   2.7 UE states
   2.8 Non-3GPP access

3. PDU Session Establishment
   3.1 User Plane Traffic Path
   3.2 UE Signaling for PDU Session
   3.3 SMF and UPF selection
   3.4 QoS flow and policy rules
   3.5 Traffic flow with DC and split bearers

4. QoS in 5G
   4.1 5G Quality of Service (QoS)
   4.2 PCF and QoS enforcement
   4.3 Use of multiple UPFs
   4.4 Application of SDN
   4.5 IMS Services in 5G and GBR flow establishment
   4.6 External application access and NEF

5. Mobility
   5.1 Connected Mode - Xn HO
   5.2 Idle Mode - TA/Registration Area Update
   5.3 RRC inactive mode
   5.4 HO for EN-DC
   5.5 Session continuity

6. Network slicing and MEC
   6.1 3GPP defined use cases
   6.2 UE slice assignment and requests
   6.3 AMF change
   6.4 SMF and UPF assignment for slices
   6.5 MEC deployment options and traffic flow
Technology Primer: 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. Enhancements to the traditional 4G OFDM/OFDMA such as Universal Filtered Multi Carrier (UFMC), Filter Bank Multi Carrier (FBMC), and Non-Orthogonal Multiple Access (NOMA) are illustrated. Furthermore, enhancements to advanced antenna techniques such as massive MIMO are explained as well as the new frame structure being investigated by 3GPP. Potential deployment scenarios are summarized along with RF design considerations and transport network issues.

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 student will be able to:
- Give examples of spectrum bands for 5G
- List benefits of new multiplexing and multiple access methods
- Explain how massive MIMO facilitates beamforming
- Illustrate potential 5G deployment scenarios
- Describe key design considerations for a transport network
- Give examples of RF design considerations

Prerequisites
- LTE Overview (eLearning)
- Technology Primer: 5G Services and Network Architecture (Instructor Led)

Required Equipment
- None

Course Outline

1. 5G Air Interface
   1.1 Spectrum for 5G
   1.2 Implications of mmW spectrum
   1.3 Multiplexing and multiple access
   1.4 Massive MIMO
   1.5 Beamforming approaches
   1.6 Flexible frame structure
   1.7 5G numerology

2. 5G Deployments
   2.1 Deployment scenarios
   2.2 RF design considerations
   2.3 Signal propagation differences
   2.4 Link budget consideration
   2.5 Antenna for 5G mmW spectrum
   2.6 Transport network considerations

4.4/5 "Efficient delivery of information with a good high level overview."


Technology Primer: 5G Services and Network Architecture

ITU is defining 5G standards as part of IMT2020 with active input from industry groups like the NGMN alliance and 3GPP. This course is an overview of target services and potential technologies of the network architecture in the upcoming 5G standards. Use case families defined by the NGMN alliance are discussed along with the ITU and 3GPP usage scenarios. Key performance goals defined by the ITU for the wireless network to meet requirements of target 5G services are specified. An overview of key components for a 5G wireless network is given and fundamental technologies for a 5G network architecture are discussed. Radio and core technologies in the course include Cloud Radio Access Network (C-RAN), Network Functions Virtualization (NFV), Software-Defined Networking (SDN), Mobile Edge Computing (MEC), and network slicing.

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 student will be able to:
- Give examples of use case families identified by NGMN for 5G
- Specify 5G performance targets defined by the ITU
- Illustrate emerging 5G network architecture
- Explain how NFV and SDN can facilitate deployment of a wireless network
- Summarize benefits of MEC
- Describe how network slicing works

Prerequisites
- LTE Overview (eLearning)

Required Equipment
- None

Course Outline

1. 5G Services
   1.1 Use cases for 5G
   1.2 Performance goals for 5G
   1.3 Key 5G components
   1.4 Evolution to 5G

2. 5G Network Architecture
   2.1 5G End-to-End architecture
   2.2 5G deployment options
   2.3 5G NG-RAN architecture
   2.4 Next Generation Core
   2.5 Interworking with 4G

3. Supporting Technologies
   3.1 NFV and SDN in 5G
   3.2 Network slicing in 5G
   3.3 Mobile Edge Computing (MEC)
   3.4 C-RAN

4.3/5 "Great comprehensive overview with just the right technical depth."
Internet of Things (IoT) is expected to dominate the telecom market where machines exchange data for intelligent applications. Devices and networks supporting IoT pose unique challenges such as low power, low cost, low mobility, and long battery life. This course addresses several low power wide area (LPWA) network technologies defined by 3GPP to meet these requirements. 3GPP-defined LPWA technology options include LTE-M (or enhanced machine type communication) and Narrowband IoT (NB-IoT). This course provides a foundation for MTC, eMTC, NB-LTE, and EC-GSM. 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., Category M1 and Category NB1) 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 student will be able to:
- Give examples of IoT use cases
- Differentiate between 3GPP and non-3GPP IoT
- Explain wireless optimizations for IoT such as Power Save Mode and eDRX
- Distinguish among MTC, LTE-M, and NB-IoT
- Specify IoT-specific characteristics of the network and UE categories

**Prerequisites**
- LTE Overview (eLearning)

**Required Equipment**
- None

**Course Outline**

1. **Introduction to IoT**
   1.1 IoT: what and why
   1.2 Overview of MTC, eMTC, and NB-IoT
   1.3 Non-3GPP IoT solutions (SIGFOX, LoRa, Silver Spring Networks, and Ingenu)
   1.4 Cellular IoT vs. non-cellular IoT

2. **Wireless Optimizations for IoT**
   2.1 IoT requirements on wireless networks
   2.2 Extended Access Barring (EAB)
   2.3 Overload and congestion control
   2.4 Optimized NAS signaling
   2.5 Coverage enhancement (CE) techniques
   2.6 CE Mode A and CE Mode B
   2.7 Power Save Mode (PSM)
   2.8 eDRX for idle and connected modes

3. **Network and UE Characteristics**
   3.1 Network architecture enhancements (e.g., NIDD via SCEF)
   3.2 Overview of UE categories
   3.3 LTE-M and Cat M1: A closer look
   3.4 NB-IoT and Cat NB1: A closer look

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4.4/5 "The course covers a lot of things in only 4 hours. It is very interactive and encourages discussions."
Technology Primer: 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 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. The key components such as Mobile Edge Host (with platform, infrastructure, and applications) and MEC management are described. Technology enablers for MEC such as the cloud infrastructure, NFV, SDN, microservices, and 5G services are discussed. MEC location strategies are summarized. Implementation of MEC in a 5G network is also described. The course concludes with a discussion on challenges faced by MEC.

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 student 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

Prerequisites
- Technology Primer: Cloud and Virtualization (Instructor Led)
- Technology Primer: NFV (Instructor Led)

Required Equipment
- None

Course Outline

1. Edge Computing in Networks
   1.1 MEC: Definition
   1.2 MEC characteristics
   1.3 MEC benefits
   1.4 Business drivers
   1.5 Overview of MEC-facilitated use cases (e.g. video streaming and AR/VR)
   1.6 MEC standardization (e.g., ETSI and 3GPP)

2. MEC Architecture and Functions
   2.1 ETSI reference architecture
   2.2 Mobile Edge Host (platform, infrastructure, applications)
   2.3 MEC management (host-level, system level)
   2.4 Mobile Edge Services
   2.5 Example MEC APIs

3. MEC Technology Enablers
   3.1 Cloud infrastructure
   3.2 Network Functions Virtualization (NFV)
   3.3 Software-Defined Networking
   3.4 Microservices
   3.5 Target 5G services

4. Deployment and Use Cases
   4.1 MEC server location strategies
   4.2 MEC implementation in 5G
   4.3 Challenges and key considerations

0.5 Day | Instructor Led Live Virtual Class, TPR1028
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 student 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

Prerequisites
- Technology Primer: 5G Services and Architecture (Instructor Led)
- Technology Primer: Cloud and Virtualization (Instructor Led)

Required Equipment
- None

Course Outline

1. What and Why
   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 Operation
   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 Life Cycle Management
   4.3 Configuration Management
   4.4 Performance and Assurance

4.4/5 "Great overview with good visual diagrams."
Technology Primer: 5G RAN Architecture and Transport

Radio Access Network of 4G LTE is evolving and operators are getting ready to deploy Next Generation (NG-RAN) of 5G. Cloud and virtualization as well as Open RAN are essential for an agile and flexible access network with RAN vendor inter-operability. 5G NG-RAN introduces split architecture that impacts how operators design and deploy their transport network and related fiber connectivity.

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 student will be able to:
■ Step through the evolution of 4G LTE RAN to C-RAN, Virtualized RAN (V-RAN) and Open RAN (O-RAN)
■ Sketch architecture of 5G NG-RAN and split architecture
■ Discuss the use of CPRI/eCPRI and Ethernet for the fronthaul and backhaul networks
■ Sketch the connectivity of 4G eNB and 5G gNB

Prerequisites
■ LTE Overview (eLearning)
■ Exploring LTE: Architecture and Interfaces (eLearning)

Required Equipment
■ None

Course Outline

1. LTE RAN Evolution
   1.1 Centralized RAN (C-RAN)
   1.2 BBU and RRH
   1.3 CPRI overview
   1.4 CPRI throughput and distance requirements
   1.5 LTE-Advanced and LTE-Advanced Pro features
   1.6 Virtualization in RAN
   1.7 5G service and performance requirements

2. 5G NG-RAN
   2.1 RAN evolution to 5G
   2.2 5G NG-RAN: CU and DU
   2.3 Control and User plane separation
   2.4 Interfaces and Protocols of 5G RAN
   2.5 Interworking with 4G eNB
   2.6 Option 3x deployment

3. Transport in 5G RAN
   3.1 Fronthaul and backhaul
   3.2 Distance and Bandwidth requirements on fronthaul
   3.3 CPRI, eCPRI, and Ethernet in Access Transport Network
   3.4 Transport connectivity for 5G NG-RAN
   3.5 Connectivity between 4G & 5G

4. Industry Update
   4.1 XRAN and ORAN initiatives
   4.2 Virtualization in 5G RAN
**Technology Primer: Dark Fiber and Ethernet Backhaul**

Communication Service Providers around the globe continue to experience rapid growth in data traffic everyday. Deployment of Dark Fiber on the backhaul is a key step in providing the capacity and speeds to support this. This technical primer provides an overview of fiber technology and its use in the transport network.

**Intended Audience**

This course is an introductory course tailored to meet the needs of a wide range of audiences including project managers, real-estate, construction, engineering and operation team members.

**Objectives**

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

- Define backhaul and fronthaul transport networks that use single \( \lambda \), CWDM, and DWDM
- Define dark fiber and explain the benefits of using dark fiber in the transport networks
- Explain ROADMs in the context of optical transmission and optical switching
- List the hardware and optical devices used in the dark fiber networks
- Discuss testing procedures and Fiber Characterization Reports from vendors.

**Prerequisites**

- Knowledge of backhaul architecture

**Required Equipment**

- None

**Course Outline**

1. **Motivation**
   1.1 Define dark fiber
   1.2 Explain the benefits of using dark fiber

2. **Transport Networks**
   2.1 Fronthaul vs. backhaul
   2.2 Fronthaul – Daisy chain, hub and spoke, rings
   2.3 Backhaul rings
   2.4 Single Lambda vs. WDM
   2.5 Wave Division Multiplexing
   2.6 Coarse Wavelength Division Multiplexing (CWDM) vs. Dense WDM (DWDM)

3. **Physical Characteristics of fiber**
   3.1 Optical fiber device components
   3.2 Fiber optic spectrum
   3.3 Best practices for fiber handling

4. **Dark Fiber Topology**
   4.1 ROADMs
   4.2 O-E-O – Changing from WDM to Single \( \lambda \)
   4.3 Capacity
   4.4 Access and aggregation rings
   4.5 Optical devices and hardware

5. **Switching and Redundancy**
   5.1 VLAN steering
   5.2 BFD and switchovers

6. **Testing and Fiber Characterization Reports**
   6.1 OTDR
   6.2 CPRI testing
   6.3 Fiber characterization reports
5G Essentials for Leadership

5G is considered for deployment in various frequency bands with large amounts of bandwidth and massive MIMO – thus completely changing the ways wireless networks are designed, engineered, and deployed. 5G networks support network slicing and thus creates new business opportunities to support new market segments and use cases such as massive IoT, connected cars, smart communities, mission critical applications, industry automation, etc. This course gives an overview of 5G end-to-end network, its capabilities, and deployment scenarios. It helps network leaders prepare for gradual deployment of 5G so they can guide their teams for effective network planning, design and engineering, and deployment.

Intended Audience
This course is intended for leaders of network planning, engineering, and operations.

Objectives
After completing this course, the student will be able to:
- Identify 5G use cases and new opportunities of 5G
- Specify 5G performance targets and identify key enablers
- Sketch evolving 5G NG-RAN architecture
- Identify the role of backhaul, midhaul, and fronthaul transport
- Highlight the key features of 5G NR
- Identify the impact of mmW spectrum and massive MIMO
- Identify the scenarios of Non-Standalone (NSA), dual connectivity and Standalone (SA) deployment
- Sketch 5G core network architecture and describe its capabilities to support network slicing and MEC

Prerequisites
- Understanding of LTE and LTE-Advanced capabilities
- Understanding of core and transport networks

Required Equipment
- None

Course Outline

1. 5G in a Nutshell
   1.1 Defining 5G and its use cases
   1.2 5G performance targets
   1.3 Key enablers of 5G
   1.4 End-to-End 5G architecture

2. 5G NG-RAN Architecture
   2.1 RAN evolution to 5G
   2.2 gNB and Split architecture
   2.3 Backhaul, Midhaul, Fronthaul
   2.4 Role of CPRI and Ethernet
   2.5 Cloud and Virtualization in NG-RAN

3. 5G NR Air Interface
   3.1 5G spectrum and mmW
   3.2 Massive MIMO and beamforming
   3.3 Frame structure flexibility
   3.4 Link budget considerations
   3.5 RF design considerations
   3.6 Capabilities and features of 5G NR

4. 5G NR NSA Deployment
   4.1 Non-standalone (NSA) Deployment
   4.2 Option – 3x with EPC
   4.3 Dual connectivity with LTE & 5G NR
   4.4 Bearer choices in Option 3x

5. 5G Core and SA Deployment
   5.1 5G Core Network architecture
   5.2 Network slicing in 5G
   5.3 Edge computing
   5.4 Migrating from NSA to SA
   5.5 Summary and take-aways

1 Day | Instructor Led, 5G_200

View Curriculum | Contact Award
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 related job functions who need to get an understanding of 5G core and radio network architecture and operations.

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

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

Prerequisites
- Technology Primer: 5G Services and Network Architecture (Instructor-led)
- Technology Primer: 5G Radio Technologies and Deployments (Instructor-led)

Required Equipment
- None

Course 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. NG-RAN Architecture
   2.1 RAN evolution for 5G
   2.2 NG-RAN architecture, interfaces, and protocols
   2.3 Cloud and Open RAN
   2.4 Fronthaul solutions
   2.5 Deployment scenarios

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 5G UE
   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 deployment options
   6.3 Split bearer options
   6.4 NSA call flows
The cellular industry is gearing up for 5G. The industry is planning to support a variety of new and exciting services such as Augmented Reality (AR)/Virtual Reality (VR), hologram videos, and self-driving cars. Such services require a wide range of network capabilities to support a variety of consumer devices and Internet-of-Things (IoT) devices. This course takes an in-depth look at the 5G NG-RAN architecture and major operations that enable a 5G network to support the target 5G services. Various aspects of the NG-RAN are described. Registration and session setup are discussed along with a look at network slicing. The data transfer in both downlink and uplink is described. Mobility in connected, inactive, and idle modes is discussed. Finally, the status of 5G in the industry is summarized.

### Intended Audience

This detailed technical course is intended for engineering and related job functions who need to get an in-depth understanding of 5G NG-RAN architecture and operations.

### Objectives

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

- Illustrate the architecture of the NG-RAN
- Describe the frame structure with numerology of the air interface
- Summarize architecture enhancements such as Cloud-RAN and Dual Connectivity
- Identify key steps of network acquisition, random access, and connection setup
- List main steps of registration, network slice selection, and session setup
- Give examples of QoS parameters in 5G
- Explain how data is transferred in the downlink and uplink
- Differentiate between the connected mode mobility and the idle/inactive mode mobility

### Prerequisites

- Introduction to 5G: (Blended Learning)
- Technology Primers: 5G Services and Network Architecture, 5G Radio Technologies and Deployments

### Required Equipment

- None

### Course Outline

1. **5G in a Nutshell**
   - 1.1 Evolution to 5G
   - 1.2 Services and performance goals
   - 1.3 Key 5G components
   - 1.4 SA and NSA deployments

2. **NG-RAN Architecture**
   - 2.1 5G network architecture
   - 2.2 Multi-RAT dual Connectivity (e.g., EN-DC)
   - 2.3 gNB-CU and gNB-DU
   - 2.4 Protocols for NG-RAN interfaces
   - 2.5 Cloud RAN
   - 2.6 NG-RAN and UE identifiers

3. **New Radio (NR) Air Interface**
   - 3.1 mmW and sub-6 GHz spectrum
   - 3.2 Massive MIMO
   - 3.3 Multiplexing and multiple access
   - 3.4 Numerology and frame structure
   - 3.5 Physical signals and channels
   - 3.6 Dual RRC, RRC states, and state transitions
   - 3.7 Air interface protocol stack

4. **Network Acquisition, Random Access, and Connection Setup**
   - 4.1 DL synchronization
   - 4.2 Minimum SI and Other SI
   - 4.3 Random access procedure
   - 4.4 Connection establishment with gNB-CU

5. **Registration and Session Setup**
   - 5.1 Overview of registration
   - 5.2 Network slicing
   - 5.3 PDU session establishment
   - 5.4 QoS in 5G

6. **DL and UL Data Transfer**
   - 6.1 Overview of data transfer
   - 6.2 Measurements
   - 6.3 Scheduling
   - 6.4 Data transmission
   - 6.5 H-ARQ
   - 6.6 RLF: detection and resolution

7. **Operations in Connected, Inactive, and Idle Modes**
   - 7.1 Cell- and Beam-level mobility
   - 7.2 Handover stages
   - 7.3 Inter-DU/Intra-CU mobility
   - 7.4 LTE mobility with dual connectivity
   - 7.5 Cell reselection
   - 7.6 Paging and RNA
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 the students with the 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.

### Course Outline

#### 1. 5G NSA Network Architecture
   1.1 Performance targets: 4G vs. 5G
   1.2 NSA Option 3x network architecture
   1.3 Signaling and data radio bearers in Option 3x
   1.4 NR air interface & frame structure
   1.5 Overview of EN-DC operations
   1.6 5G UE capability transfer

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

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

#### 4. DL Data transfer in 5G
   4.1 Overview of DL traffic processing
   4.2 DL signals and UE measurements
   4.3 5G measurements by UE
   4.4 Reporting of UE measurements
   4.5 DL scheduling and resource allocation
   4.6 DL data transmission
   4.7 DL HARQ in 5G

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

#### 6. Mobility and Idle Mode Operations
   6.1 Mobility and RRC states
   6.2 Mobility scenarios
   6.3 Measurements and handover signaling
   6.4 5G Connection release
   6.5 Idle mode mobility
   6.6 Putting it all together

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

### Prerequisites
- 5G NR Air Interface (Instructor-led)

### Required Equipment
- None
This course takes an in-depth look at the RF planning and design aspects of 5G. It summarizes the essentials of the 5G air interface. MIMO and beamforming in 5G and suitable propagation models are discussed. The link budgets for 5G for different scenarios are calculated and compared with the LTE link budget. The RF cell configuration and RF operational parameters are discussed. Finally, the overall process of the RF design for 5G is described including traffic mapping and propagation modeling. The use of an RF planning tool to carry out the RF design is illustrated.

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

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

Prerequisites
- 5G NR Air Interface (Instructor-led)

Required Equipment
- Laptop with RF propagation tool supporting 5G NR

Course Outline

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

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

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

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

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

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

7. RF Planning Tool
   7.1 Key Parameters in RF Planning Tool
   7.2 Project Configuration
   7.3 Site Configuration
   7.4 5G Analysis
The 5G Core (5GC) network architecture is a significant evolution from 4G LTE EPC. Network functions have been de-composed and re-architected to enable MEC and network slicing and thus supporting many verticals in virtualized network. Students will step through various network operations and related call flows using actual logs where applicable and will be able to highlight key differences of 5G operations from LTE operations.

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

### Objectives
After completing this course, the student will be able to:
- Identify the Network Functions (NF) of the 5G core network
- Contrast the roles of the NFs with the 4G LTE EPC
- Sketch the connectivity for the 5G network functions
- Describe the 5G UE registration procedure
- Describe PDU session set up 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

### Prerequisites
- 5G Core Network Overview (self-paced eLearning)
- 5G Networks and Signaling (Instructor-led)

### Required Equipment
- None

### Course Outline

#### 1. 5G Network Architecture
- 1.1 End-to-end 5G NG-RAN to 5GC architecture
- 1.2 5GC Network Functions (NF) - AMF, SMF, etc.
- 1.3 5G Identifiers
- 1.4 5G and virtualization technologies
- 1.5 SBA, APIs and NRF
- 1.6 Network slicing

*Exercise: Hands-on build the network*

#### 2. 5G UE Registration Procedure
- 2.1 System acquisition and registration
- 2.2 AMF Selection
- 2.3 UE slice assignment and request
- 2.4 Authentication
- 2.5 Air interface security
- 2.6 Dual registration
- 2.7 UE states
- 2.8 Non-3GPP access

#### 3. PDU Session Establishment
- 3.1 User Plane Traffic Path
- 3.2 UE Signaling for PDU Session
- 3.3 SMF and UPF selection
- 3.4 QoS flow and policy rules
- 3.5 Traffic flow with DC and split bearers

#### 4. QoS in 5G
- 4.1 5G Quality of Service (QoS)
- 4.2 PCF and QoS enforcement
- 4.3 Use of multiple UPFs
- 4.4 Application of SDN
- 4.5 IMS Services in 5G and GBR flow establishment
- 4.6 External application access and NEF

#### 5. Mobility
- 5.1 Connected Mode - Xn HO
- 5.2 Idle Mode - TA/Registration Area Update
- 5.3 RRC inactive mode
- 5.4 HO for EN-DC
- 5.5 Session continuity

#### 6. Network Slicing and MEC
- 6.1 3GPP defined use cases
- 6.2 UE slice assignment and requests
- 6.3 AMF change
- 6.4 SMF and UPF assignment for slices
- 6.5 MEC deployment options and traffic flow
Internet of Things (IoT) is expected to dominate telecom market in the coming years where machines exchange data for intelligent applications. Devices and networks supporting IoT pose unique challenges such as low power, low cost, low mobility, and long battery life. This advanced course on LPWA IoT takes a detailed look at 3GPP’s efficient IoT solutions involving UE Category M1 and UE Category NB1. The network architecture enhancements required for IoT such as NIDD and SCEF are described. The roles played by IoT-specific protocols such as MQTT-SN, FOTA/SOTA, and DoNAS are summarized. A brief overview of the UE module industry is given. The architecture of a UE is discussed. Wireless optimizations customized for IoT are explained. Key technical features of EC-GSM are described.

**Intended Audience**
Technical personnel working for wireless operators, equipment and device manufacturers, who need a detailed look at 3GPP’s IoT solutions.

**Objectives**
After completing this course, the student will be able to:
- Mention roles of IoT-centric protocols such as MQTT-SN and DoNAS
- Explain how of PSM and eDRX help increase UE battery life
- Illustrate the functional architecture of a UE
- Describe key features of UE Categories M1 and NB1
- Compare capacity and battery life of UE categories M1 and NB1
- Explain how EC-GSM enhances performance of IoT devices compared to GSM
- Summarize communications between UE and the network for IoT UEs

**Prerequisites**
- LTE Overview (eLearning)
- Technology Primer: LTE-M and NB-IoT (Instructor Led)

**Required Equipment**
- None

**Course Outline**

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

2. **IoT-centric Features**
   - 2.1 Wireless optimizations for IoT
   - 2.2 Power Save Mode (PSM)
   - 2.3 eDRX in Connected and Idle modes
   - 2.4 High latency communication
   - 2.5 Extended Access Barring (EAB)
   - 2.6 Optimized TAU signaling
   - 2.7 Half Duplex (HD) FDD
   - 2.8 eMBMS for IoT
   - 2.9 Overview of UE location determination methods
   - 2.10 Location services for IoT
   - 2.11 Overview of VoLTE
   - 2.12 Impact of supporting IoT voice services on RAN

3. **eMTC: UE Category M1 and Network Features**
   - 3.1 Characteristics of UE category M1
   - 3.2 Network enhancements

4. **NB-IoT: UE Category NB1 and Network Features**
   - 4.1 Overview of UE category NB1
   - 4.2 Network enhancements
   - 4.3 Deployment scenarios (in-band, guard band, and standalone)
   - 4.4 Downlink and uplink channels
   - 4.5 NB1 UE-Network communications
   - 4.6 Category NB1 battery life
   - 4.7 Category NB1 multicarrier support
   - 4.8 Network capacity for NB1 devices
   - 4.9 Exploiting category NB1 features for enhanced UE design
   - 4.10 FOTA/SOTA for DoNAS

5. **Additional Material**

6. **EC-GSM: A Closer Look**
   - 6.1 IoT enhancements in EC-GSM
   - 6.2 EC-GSM vs. NB-IoT (e.g., coverage)

**2 Days | Instructor Led, 5G_201**

**Contact Award**
LTE-M and NB-IoT Signaling and Operations

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

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

- Describe key features of LTE-M and NB-IoT
- Illustrate the network architecture with LPWA enhancements
- Explain how of PSM and eDRX help increase UE battery life
- Describe how EAB and optimized TAU reduce the signaling load
- Summarize key parameters of System Information messages for LTE-M and NB-IoT
- Discuss Attach enhancements for LTE-M and NB-IoT
- Describe key operational configurations of LTE-M and NB-IoT physical channels
- List main KPIs for LTE-M and NB-IoT

Prerequisites

- LTE Overview (eLearning)
- Technology Primer: LTE-M & NB-IoT

Required Equipment

- None

Course Outline

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

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

3. LTE-M: A Closer Look
   3.1 Characteristics of UE category M1
   3.2 CE Mode A and CE Mode B
   3.3 MIB, SIB1-5, and SIB2
   3.4 LTE-M Random Access
   3.5 RRC Connection Setup for LTE-M
   3.6 LTE-M Attach enhancements
   3.7 MPDCCH configuration
   3.8 Using PDSCH, PUCCH, & PUSCH for LTE-M data transfer
   3.9 LTE-M KPIs

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

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

Internet of Things (IoT) is expected to dominate telecom market in the coming years. Low Power Wide Area (LPWA) IoT has requirements such as low cost, enhanced coverage, high capacity, and long battery life. This course describes network architecture enhancements required for IoT such as NIDD and SCEF. The fundamental operations such as network acquisition, random access, RRC connection setup, data transfer, and mobility are covered. LPWA IoT enhancements related to MIB, System Information, and uplink and downlink channels are discussed using signaling logs (e.g., RRC).
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.

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 student 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

Prerequisites
- None

Required Equipment
- None

Course Outline
1. What is AI?
2. AI and Automation Lifecycle
3. Impact of AI on the Telecom Industry
4. Types of AI
5. What is a Neural Network?
6. Challenges of Automation in Telecom
7. AI Use Cases in Telecom
8. AI Use Cases that impact a Telecom Network
Artificial Intelligence (AI) is revolutionizing all aspects of the computer industry. AI use cases like speech and image recognition have already had an impact on many industries. The telecom industry is different. This course provides a detailed introduction to AI from a telecom perspective. AI is explored from a definition and underlying technology perspective. It starts with an introduction to AI models. The course then moves to an exploration of data selection, then to the details of building Machine Learning models and Deep Learning models based on telecom-specific data. The key concepts are presented using hands-on activities that include analyzing data and using a Machine Learning model in Python.

### Intended Audience
For personnel involved in product management, marketing, planning, design, engineering, and operating wireless (4G, 5G) and wireline access networks who need a technical introduction to AI.

### Objectives
After completing this course, the student will be able to:
- Define key AI terms like neural network, Machine Learning, and Deep Learning
- List key examples of neural networks
- Compare model development and training with model deployment and inference
- Describe types of input data
- List key Machine Learning tools
- Build a basic Machine Learning model

### Prerequisites
- None

### Required Equipment
- None

### Course Outline

1. **Kickoff Session [Live: Web-based]**
   1.1 Getting the most out of the course
   1.2 AI overview

2. **AI Defined**
   2.1 What is AI?
   2.2 What is ML?
   2.3 AI – An End User View
   2.4 Exe: Inference and an AI model

3. **Checkpoint Session - 1 [Live: Web-based]**
   3.1 Question and Answer Session

4. **AI Models Defined**
   4.1 What's an ANN?
   4.2 Basics of AI Model Design
   4.3 Types of Learning
   4.4 AI Models
   4.5 Exe: Types of Supervised Learning and Neural Networks

5. **AI and Automation Lifecycle**
   5.1 Building and Framing the Machine Learning Model
   5.2 Data Gathering and Preparation
   5.3 Model Creation and Training
   5.4 Exe: Build a Simple AI Model and Examine the Results

6. **AI Data Preparation**
   6.1 Types of Data
   6.2 Data Preparation
   6.3 Data Selection and Processing Flow
   6.4 Exe: Process Training Data for AI model creation

7. **Checkpoint Session - 2 [Live: Web-based]**
   7.1 Question and Answer Session

8. **Machine Learning (ML) Lab**
   8.1 Layers Details
   8.2 Neurons and activation functions
   8.3 ML Development Libraries
   8.4 Defining Hyperparameters
   8.5 Exe: Build and Train an AI Model
   8.6 Analyzing Results
Technology Primer: Artificial Intelligence (AI)

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 student 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

Prerequisites
- None

Required Equipment
- None

Course 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
Technology Primer: Blockchains

Blockchains have revolutionized the financial industry with the help of Bitcoins. Blockchains are now moving into other industries like telecommunications to help verify various transactions. This course provides an overview of Blockchains from a telecom perspective. Blockchains are explored from a definition, underlying technology and use-cases perspective. It starts with an introduction to Blockchains. The course then moves to key Blockchains use cases and the Blockchains technologies. The course concludes with a discussion on how a telecom operator will need to enhance their network to support Blockchains.

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 student will be able to:
■ Define the types of Blockchains
■ List the key telecom use cases for Blockchains
■ Compare and contrast Blockchains and Bitcoin
■ List different requirements for supporting Blockchains

Prerequisites
■ None

Required Equipment
■ None

Course Outline

1. Introduction to Blockchains
   1.1 What are Blockchains?
   1.2 Blockchains vs. Bitcoin
   1.3 Types of Blockchains

2. Blockchains Use Cases
   2.1 How is telecom different?
   2.2 Telecom use cases
   2.3 Telecom impacting use cases
   2.4 Impact of Blockchains on telecom architecture

3. Blockchains Overview
   3.1 How Blockchains work
   3.2 Building a Blockchain
   3.3 Verifying a Blockchain

4. Basics of Supporting Blockchains
   4.1 Requirements on the Edge Device and End-User Devices
   4.2 Requirements on the Network Devices
   4.3 Challenges and key considerations
Technology Primer: Immersive Technologies (AR/VR/MR)

Immersive Technologies have revolutionized all aspects of the computer industry. The impacts of Immersive Technologies can be seen in the way users interact with the real world, from augmenting reality to mixing reality with additional objects. The telecom industry is different. This course provides an overview of Immersive Technologies from a telecom perspective. Immersive Technologies is explored from a definition, underlying technology and use-cases perspective. It starts with an introduction to Immersive Technologies. The course then moves to key Immersive Technologies use cases and the Immersive Technologies of Augmented Reality, Mixed Reality, and Virtual Reality. The course concludes with a discussion on how a telecom operator will need to enhance their network to support Immersive Technologies.

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 student will be able to:
- Define the types of Immersive Technologies
- List the key use cases for Immersive Technologies
- Compare and contrast types of Immersive Technologies
- List different requirements for supporting Immersive Technologies

Prerequisites
- None

Required Equipment
- None

Course Outline

1. Introduction to Immersive Technologies
   1.1 Immersive Technologies defined
   1.2 Types of Immersive Technologies
   1.3 Augmented Reality (AR)
   1.4 Mixed Reality (MR)
   1.5 Virtual Reality (VR)

2. Immersive Technologies Use Cases
   2.1 How is telecom different?
   2.2 Telecom use cases
   2.3 Telecom impacting use cases
   2.4 Impact of Immersive Technologies on telecom architecture

3. Immersive Technologies Overview
   3.1 AR defined
   3.2 MR defined
   3.3 VR defined
   3.4 360 vs. Volumetric

4. Basics of Supporting Immersive Technologies
   4.1 Requirements on the Edge Device
   4.2 Requirements on the Network Devices
   4.3 Challenges and key considerations

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

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

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

**Prerequisites**
- Basic knowledge of Excel

**Required Equipment**
- Students will need a laptop with MS-Excel and Python

**Course Outline**

1. **Get started with Python**
   1.1 Create a Python program
   1.2 Run a Python program
   1.3 Import and Modules/Packages
   1.4 Conditional statements
   1.5 For and while loops
   1.6 Functions
   1.7 Lists and Dictionary
   1.8 Dictionary
   1.9 String Operations
   **Exercise:** Create and Run a Program

2. **Processing Data from Text Files**
   2.1 Text File Processing basics
   2.2 Command line arguments in Python
   2.3 Python File Operations
   2.4 File reading and writing
   2.5 Python to walk a directory
   2.6 Counting lines, words
   **Exercise:** Read a file, count lines, words and develop word length vs. frequency data
   **Exercise:** Define a class-specific use-case
   **Exercise:** Develop a Python program to implement the use-case

3. **Processing Data from Excel Workbooks**
   3.1 What is Openpyxl?
   3.2 Installing Openpyxl module
   3.3 Creating a Workbook
   3.4 Reading data from a Workbook
   3.5 Creating and naming Worksheets
   3.6 Deleting a Worksheet
   3.7 Excel Object Structure
   3.8 Reading and writing to/from a cell
   3.9 Inserting Formulas into Excel Sheets from Python Programs
   3.10 Formatting rows and columns
   3.11 Inserting Excel Charts in Python
   3.12 Saving an Excel Workbook
   **Exercise:** Create an Excel file, insert data from text file processing and plot a chart

4. **Data gathering from Websites and Applications**
   4.1 Concept of APIs
   4.2 Using APIs in Python
   4.3 Invoke API on a Web Server
   4.4 Capture the response
   4.5 Save the response to a file
   4.6 Invoke API on an App Server
   4.7 Capture the response
   4.8 Save the response to a file
   **Exercise:** Invoke APIs from Python

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**View Curriculum**  **Contact Award**
Data Manipulation Workshop

4.2/5

Telecom networks are continuing to transform in fundamental ways - cloud platforms are enabling networks to be run as software-based functions. This enables the management of these networks to become software centric and thus requires the use of scripting and software-oriented approaches to automate and manage tasks performed on these networks. Besides the network, all industries are starting to leverage feature-rich tools that analyze massive, varied data sets to complete tasks more productively and effectively. The Data Manipulation Workshop takes one of the most common techniques of storing data—Excel—and shows how to leverage several of its built-in and powerful capabilities to manipulate data. This includes Formulas, Lookups, Pivot Tables, Macros and Visual Basic scripting. This is a hands-on workshop.

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

Course Outline

1. Data Manipulation Basics
   1.1 Data storage (e.g., Workbook)
   1.2 Content types
   1.3 Data validation
   1.4 Managing large data views
   1.5 Sorting large data sets
   1.6 Freeze panes
   1.7 Filtering data and viewing
   1.8 Advanced filters
   1.9 Presenting data
   1.10 Conditional formatting
   1.11 Charts
   Exercise: Assign formats to cells
   Exercise: Filter and sort data
   Exercise: Conditional format cells

2. Simple Manipulation Techniques
   2.1 Using simple functions
   2.2 Calculation and formulas
   2.3 References, Constants and Operators of a formula
   2.4 Manipulating text and numbers
   2.5 Logical functions for decisions
   2.6 Using date and time functions
   2.7 Troubleshooting formulas
   2.8 Synthesizing results
   2.9 Lookup functions
   2.10 HLOOKUP and VLOOKUP
   2.11 INDEX and MATCH
   Exercise: Use of formulas
   Exercise: VLOOKUP Exercise

3. Grouping and Viewing Data
   3.1 Rearrange data using Pivot tables
   3.2 Data analysis using Pivot tables
   3.3 Managing data sources
   3.4 Charts to represent data
   3.5 Create and modify charts
   3.6 Parts of a chart
   3.7 Common types of charts
   3.8 Combine Pivot tables and charts
   Exercise: Analysis using Pivot tables
   Exercise: Chart exercises

4. Data manipulation and automation
   4.1 Using macros to automate tasks
   4.2 Record, create, edit, run macros
   4.3 Macro workbook and shortcuts
   4.4 Macros and security
   4.5 Automation basics
   4.6 Introduction to Visual Basic for Applications
   Exercise: Record and execute Macro

Objectives
After completing this course, the student will be able to:
- Use filters to view data that is relevant in a context
- Sort large data sets to identify useful data
- Write conditions to format cells as per the data
- Use pre-defined functions to manipulate data
- Troubleshoot complex formulas
- Append additional information using Lookup functions
- Group and view data using Pivot tables
- Add a chart in a workbook to represent large amount of data

Prerequisites
- Working knowledge of Excel

Required Equipment
- Students will need a laptop with MS-Excel
Data Visualization Workshop using Power BI

Telecom networks are continuing to transform in fundamental ways - cloud platforms are enabling networks to be run as software-based functions. This enables the management of these networks to become software centric and thus require the use of scripting and software-oriented approaches to automate and manage tasks performed on these networks. Industries are starting to leverage feature-rich tools that analyze massive, varied data sets to complete tasks more productively and effectively. This course teaches data visualization techniques by taking large datasets of network performance data and creating close to 50 visualizations. This includes visualizations like Line Charts, Scatter Maps, Tree Maps, Heat Maps, Box-Whisker Maps, Histograms and covers the use of Joins, Blends, Calculated Columns, Reports and Dashboards to create powerful visualizations.

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

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

Prerequisites
- Basic knowledge of Excel

Required Equipment
- Students will need a laptop with access to Power BI Desktop

Course Outline

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

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

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

4. Visualizations II
   4.1 Key features and differences of Pie Charts and Donut Charts
   4.2 Reinforcing data points using Cards and Multirow Cards
   4.3 Play Axis animation in Scatter Charts
   4.4 Troubleshooting using Tree Maps
   4.5 Visuals with colors and Heat Maps
   4.6 Using Histograms for data distribution
   4.7 Grouping and Binning data
   4.8 Geographical data and Filled Maps
   4.9 Understanding the interaction between Visuals to create a Dashboard
   4.10 Report Drill Through
   4.11 Custom KPI in Data View - New Column vs New Measure
   - Exercise: Create Visualization with Joins and Blends
   - Exercise: Create a Dashboard

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

Telecom networks are continuing to transform in fundamental ways - cloud platforms are enabling networks to be run as software-based functions. This enables the management of these networks to become software centric and thus require the use of scripting and software-oriented approaches to automate tasks performed on these networks. Industries are starting to leverage feature-rich tools that analyze massive, varied data sets to complete tasks more productively and effectively. This course teaches techniques by taking large datasets of network performance data and creating close to 50 visualizations. This includes visualizations like Line Charts, Scatter Maps, Tree Maps, Heat Maps, Box-Whisker Maps, Histograms and covers the use of Joins, Blends, Calculated Fields, Table Calculations, Parameters and Dashboards to create powerful visualizations.

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

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

Prerequisites
- Basic knowledge of Excel

Required Equipment
- Students will need a laptop with access to Tableau Desktop

Course Outline

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

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

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

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

4 Day | Instructor Led, DNP_407

View Curriculum Contact Award
Deep Learning has taken the concepts of Machine Learning and extended them to support more complex data analysis and predictions. This course provides a hands-on introduction to the basic concepts of Deep Learning from a telecom perspective. Deep Learning is explored from a definition and underlying technology perspective. It starts with an introduction to Deep Learning models. The course then moves to an exploration of the data selection and analysis. The course then moves into the details of building a number of Deep Learning models based on telecom specific data. The key concepts are presented using hands on activities that include analyzing data, using a Deep Learning model in python and using a GUI based tool.

Intended Audience
For personnel involved in product management, marketing, planning, design, engineering, and operating wireless (4G, 5G) and wireline access networks who need a technical introduction to AI.

Objectives
After completing this course, the student will be able to:
- List key types of neural networks and compare them
- Define key Data Selection processes like Eigen decomposition
- Prepare Data for training a Deep Learning Model
- Describe a Convolutional Neural Network model and its uses
- Build a CNN model
- Describe a Recurrent Neural Network model and its uses
- Build a RNN model
- Analyze an Unsupervised Learning Model and describe the steps involved

Prerequisites
- AI Tools and Technology

Required Equipment
- None

Course Outline

1. **Overview of Deep Learning Models**
   1.1 Convolutional Neural Networks
   1.2 Recurrent Neural Networks
   1.3 Auto Encoder
   1.4 Generative adversarial networks
   1.5 Model Training vs. Model Deployment
   **Exercise:** Use a number of Deep Learning models

2. **Data Selection**
   2.1 Data Selection and Analysis
   2.2 Intuitive description of n-dimensional vector space
   2.3 Eigen decomposition
   2.4 Eigen values, eigen vectors
   2.5 Decomposition
   2.6 Principle Component Analysis
   **Exercise:** Prepare Data for a Deep Learning Model

3. **Convolutional Neural Network (CNN) Lab**
   3.1 Basic CNN Example
   3.2 CNN Model Details
   3.3 CNN Model Use Cases
   **Exercise:** Build a CNN Model

4. **Recurrent Neural Network (RNN) Lab**
   4.1 Basic RNN Example
   4.2 RNN Model Design
   4.3 RNN Model Use Cases
   **Exercise:** Build a RNN Model

5. **Unsupervised Learning Lab**
   5.1 Basic Unsupervised Learning Example
   5.2 Specific Unsupervised Learning Models
   5.3 Unsupervised Learning Data Analysis
   **Exercise:** Build an Unsupervised Learning Model
Ansible Workshop

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

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

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

Prerequisites
- Basic Linux operating system skills are recommended

Required Equipment
- Laptop/desktop with Internet connectivity

Course Outline

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

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

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

4. Ansible Playbook Extensions
   4.1 Variables, variable arrays, and lookup
   4.2 Facts and custom facts
   4.3 Variable substitutions
   4.4 Host variable extraction
   Exercise: Extend the playbook

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

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

7. Additional Ansible Features
   7.1 Ansible vault
   7.2 Rolling updates
   7.3 Failure percentage
   7.4 Ansible Galaxy
   Exercise: Update playbook to use features of interest
LTE/
VoLTE
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 self-paced eLearning class discusses the overarching goals of LTE networks and then defines the unique network functions needed to achieve those goals. The course then describes the key interfaces between these functions, with particular emphasis on the LTE air interface, as well as the underlying protocols carried over these interfaces. Frequent interactions are used to ensure student comprehension of the essential technologies used in all LTE networks.

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 student 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

Prerequisites

- Welcome to LTE (eLearning)
- LTE-SAE Evolved Packet Core (EPC) Overview (eLearning)

Required Equipment

- None

Course 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
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 eLearning module is part one of the two-module package. Together, these two modules describe each of the key LTE operations, starting with the mobile’s initial access to the system, followed by the steps needed to connect users to their services and content, and continuing with the challenges associated with maintaining the connections as the user moves through the network. The course concludes with a discussion of the mobile’s idle mode activities and the low-level operations needed to maintain the radio link.

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 student 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

Prerequisites
- Exploring LTE: Architecture and Interfaces (eLearning)

Required Equipment
- None

Course 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

1.5 hours | eLearning, LTE_128A | View Curriculum | Contact Award
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 eLearning module is part two of the two-module package. Together, these two modules describe each of the key LTE operations, starting with the mobile’s initial access to the system, followed by the steps needed to connect users to their services and content, and continuing with the challenges associated with maintaining the connections as the user moves through the network. The course concludes with a discussion of the mobile’s idle mode activities and the low-level operations needed to maintain the radio link.

### 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 student 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

### Prerequisites
- Exploring LTE: Architecture and Interfaces (eLearning)
- Exploring LTE: Signaling and Operations – Part I (eLearning)

### Required Equipment
- None

### Course 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

1.5 hours | eLearning, LTE_128B
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 self-paced eLearning course describes the network requirements for VoLTE and describes the IMS network components and interfaces needed to implement VoLTE and other IMS-based services. The course also discusses how IMS and LTE interwork with non-IMS networks in order to support worldwide calling 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 student 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 the 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

### Prerequisites
- Exploring LTE: Architecture and Interfaces (eLearning)
- Exploring LTE: Signaling and Operations (eLearning)

### Required Equipment
- None

### Course 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: 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 self-paced eLearning course defines these KPIs, discusses typical target values for each one, and describes typical failure scenarios for each of the metrics. In addition, the signaling protocols used in VoLTE operations can provide additional insights into certain failures, through the use of error codes and cause codes included in the messages.

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 student 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

Prerequisites
- Exploring LTE: Signaling and Operations (eLearning)
- Exploring VoLTE: Signaling and Operations (eLearning)

Required Equipment
- None

Course 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
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 student 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

Course 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

Prerequisites
- Exploring VoLTE: Architecture and Interfaces (eLearning)
- Exploring LTE: Signaling and Operations (eLearning)

Required Equipment
- None

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 self-paced eLearning 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. The course also looks at the special requirements for emergency calls, discusses how supplementary services are supported, and describes air interface enhancements designed to improve over-the-air performance for VoLTE traffic.
**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 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. By the conclusion of this course, the student will have a deeper understanding of how the UE and the network work together to deliver services to LTE subscribers.

**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 student 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

**Prerequisites**

- LTE Overview (eLearning)

**Required Equipment**

- None

**Course Outline**

1. LTE Network Architecture Overview
   - 1.1 E-UTRAN architecture
   - 1.2 EPC (MME, S-GW, P-GW, HSS)

2. LTE Air Interface Signaling Basics
   - 2.1 LTE physical layer

3. System Acquisition
   - 3.1 Power-up acquisition

4. Network Attachment and Default Bearer
   - 4.1 Attachment steps
   - 4.2 Default bearer setup

5. QoS and Dedicated Bearers
   - 5.1 QoS classes
   - 5.2 Dedicated EPS bearers

6. Uplink and Downlink Traffic
   - 6.1 Downlink traffic operations
   - 6.2 Uplink traffic operations

7. Idle Mode
   - 7.1 Idle mode defined
   - 7.2 Cell reselection
   - 7.3 Tracking and paging

8. Handover
   - 8.1 Handover types
   - 8.2 Measurement
   - 8.3 Handover stages

9. Summary
   - 9.1 Put It All Together
   - 9.2 Assess the knowledge of the participant based on the objectives of the course
Long Term Evolution (LTE) is one of the choices for next generation broadband wireless networks and is defined by the 3GPP standards as an evolution to a variety of 3G wireless networks such as UMTS and 1xEV-DO. Its high data rates enable advanced multimedia applications. This 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. A high-level glimpse into the life of an LTE User Equipment (UE) is provided by walking through stages from power-up all the way to setting up an IP address and exchanging traffic. By the end of this course, the student will understand what LTE offers, its network architecture, how it works, and potential applications and services.

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 student 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

Course 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

Prerequisites
■ None

Required Equipment
■ None
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 course provides fundamental knowledge of numerous multiple antenna techniques that will be an integral part of emerging radio access standards. The antenna basics are explained, along with typical antenna configurations in commercial cellular deployments. Major antenna techniques are covered in the course, providing a strong foundation for advanced antenna technologies.

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

Objectives
After completing this course, the student 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

Prerequisites
■ None

Required Equipment
■ None

Course Outline
1. Introduction to Antenna Techniques
   1.1 Transmit and receive operation, parameters, and gain characteristics
   1.2 Motivation for advanced antenna techniques
   1.3 Example of antenna configurations
   1.4 Summary of multiple antenna techniques

2. Transmit and Receive Diversity Techniques
   2.1 Basic techniques (space, time, and frequency)
   2.2 Advanced transmit diversity techniques
   2.3 Receive diversity

3. Beamforming Techniques
   3.1 Construction of a beam
   3.2 Transmit and receive beamforming
   3.3 Switched-beam system
   3.4 Adaptive beamforming system
   3.5 Benefits and challenges of beamforming

4. MIMO - Spatial Multiplexing
   4.1 Basics of spatial multiplexing
   4.2 Horizontal and vertical encoding, single-code and multi-code word
   4.3 MIMO transmitter and receiver examples
   4.4 Closed-loop MIMO (MIMO + precoding)
   4.5 Collaborative spatial multiplexing
   4.6 Benefits and challenges of MIMO-SM

5. Summary
   5.1 Put It All Together
   5.2 Assess the knowledge of the participant based on the objectives of the course

3 hours | eLearning, TRND104
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. It explains the challenges of radio propagation and describes how OFDM overcomes these challenges to offer high data rates in a spectrally efficient manner, and steps through the key OFDM operations in an end-to-end transmission.

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 student 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

Course 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

Prerequisites
None

Required Equipment
None
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 eLearning course offers a quick, high-level overview of LTE radio and Evolved Packet Core (EPC) networks. The key characteristics of the LTE air interface, access network and core network are defined, along with a review of the capabilities of the LTE user equipment (UE). The services expected to be supported on LTE networks are summarized, with special emphasis on voice solutions. Finally, important considerations for deploying LTE networks are laid out, including the ability to interwork with existing 3G 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 student 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

**Prerequisites**

- None

**Required Equipment**

- None

**Course 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
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 eLearning module provides an overview of supporting voice services using LTE, which is known as Voice over LTE (VoLTE). LTE-EPC, IMS, and the PCC are discussed as the building blocks for VoLTE. The pre-call operations such as connectivity with the IMS network and IMS registration are explained along with VoLTE call setup and configuration. Interworking between LTE and PSTN is discussed.

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 student 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

Prerequisites
■ LTE Overview (eLearning)
■ Overview of IMS (eLearning)

Required Equipment
■ None

Course 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
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 eLearning 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. In conclusion, the student will understand the use of IPv6 addresses and IPv6 operations in LTE networks.

Intended Audience

This course is an overview of IPv6 addressing formats and IPv6 assignment operation in LTE networks, 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 student 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

Course 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

Prerequisites

■ None

Required Equipment

■ None
Exponentially rising data traffic, scarcity of spectrum, and expectations of enhanced user experience are leading operators to explore the use of unlicensed spectrum to carry traffic. 3GPP has defined specific approaches for using the unlicensed spectrum. In one approach, some or all of the traffic is carried by the Wi-Fi network in the unlicensed spectrum. Example mechanisms include Wi-Fi offload and LTE-Wi-Fi Link Aggregation (LWA). In another approach, the traffic is carried by LTE and its evolutionary technologies (e.g., LTE-Advanced) simultaneously on licensed and unlicensed spectrums. Example mechanisms include Licensed Assisted Access (LAA), LTE-Unlicensed (LTE-U), and enhanced LAA (eLAA). This course provides an overview of these mechanisms, a closer look at their key components, and operational similarities and differences between LTE and LAA.

### 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 student will be able to:
- Explain the motivation behind the use of unlicensed spectrum
- Distinguish among Wi-Fi offload, LWA, LTE-U, LAA, and eLAA
- List benefits of using LTE in unlicensed spectrum instead of Wi-Fi
- Identify key technology components for LAA, LTE-U, and eLAA
- Describe mechanisms used by LAA to share the unlicensed spectrum with Wi-Fi networks
- Summarize how downlink data transfer occurs in LAA
- Summarize required changes in the UE and the network to support LAA

### Prerequisites
- LTE Overview (eLearning)

### Required Equipment
- None

### Course Outline

#### 1. LTE in Unlicensed Spectrum
   - **1.1 Motivation for unlicensed spectrum**
   - **1.2 Evolution of unlicensed LTE**
   - **1.3 LTE-Wi-Fi interworking**
   - **1.4.1 Wi-Fi offload**
   - **1.5.3 LWA**
   - **1.6 1.4 Carrier aggregation with unlicensed spectrum**
   - **1.7 1.4.1 LTE-U**
   - **1.8 1.4.2 LAA and eLAA**

#### 2. Key Technology Components
   - **2.1 LTE vs. Wi-Fi**
   - **2.2 Unlicensed spectrum: bands and FCC regulations**
   - **2.3 Small Cells**
   - **2.4 Carrier aggregation**
   - **2.5 Spectrum-sharing mechanisms**
   - **2.6 Dynamic channel selection**
   - **2.7 CSAT**
   - **2.8 Opportunistic SDL**
   - **2.9 Listen before Talk (LBT)**
   - **2.10 Channel access priority classes**
   - **2.11 Hidden node discovery**
   - **2.12 Discovery Reference Signals**

#### 3. LAA Operations
   - **3.1 Bearer setup**
   - **3.2 UE capability exchange**
   - **3.3 SCell configuration and activation**
   - **3.4 DL data transfer**
   - **3.5 UE and network changes for LAA**
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.

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<thead>
<tr>
<th>Intended Audience</th>
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<tr>
<td>A high-level technical overview to personnel involved in product management, marketing, planning, design, engineering, and operations.</td>
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<td>1.1 Types of spectrum</td>
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<td><strong>2. CBRS System Architecture</strong></td>
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<td><strong>3. CBRS Operations</strong></td>
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<td><strong>4. Putting It All Together</strong></td>
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<td>4.1 CBRS deployment examples</td>
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<table>
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<th>Prerequisites</th>
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<tr>
<td>■ Define CBRS</td>
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<tr>
<td>■ Differentiate Tiered licensing structure: IA, PAL and GAA</td>
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<tr>
<td>■ Give examples of business models and use cases for CBRS</td>
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<td>■ Sketch the architecture of a CBRS-based network</td>
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<td>■ Describe the roles of a CBSD, SAS, and ESC</td>
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<td>■ Step through the life of a UE in a CBRS deployment</td>
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<th>Required Equipment</th>
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<td>■ None</td>
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Technology Primer: Overview of CBRS
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. Participants will use coverage prediction tool for exercises to apply their knowledge and skills to real-world scenarios.

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

Objectives
After completing this course, the student 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

Prerequisites
■ Overview of OFDM (eLearning)
■ LTE Overview (eLearning)

Required Equipment
■ PC laptop with administrator privileges

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

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

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

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

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

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

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

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

4.6/5  "This course had an excellent emphasis on design as it relates to Small Cells (VoLTE & data)."

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. In summary, this workshop provides a detailed understanding of RF design enhancements for VoLTE, LTE-Advanced and small cell.

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 student 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

Prerequisites

- Overview of OFDM (eLearning)
- LTE Overview (eLearning)
- PC laptop with administrator privileges

Required Equipment

- PC laptop with administrator privileges

Course 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 RBSs 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

Exercise:

Link budget walk-through
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 student 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

**Prerequisites**

- Exploring LTE (series of self-paced eLearning)

**Required Equipment**

- PC laptop

**Course 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
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 student 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

### Prerequisites
- Exploring LTE (series of self-paced eLearning)
- LTE RF Optimization: Part 1 – Coverage and Accessibility (Instructor Led)

### Required Equipment
- PC laptop

### Course 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

1.5 Days | Instructor Led, LTE_422

[View Curriculum] [Contact Award]
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 student 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

**Prerequisites**
- Exploring LTE (series of self-paced eLearning)
- LTE RF Optimization: Part 1 – Coverage and Accessibility (Instructor Led)

**Required Equipment**
- PC laptop

**Course 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
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 student 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

Prerequisites
- Exploring LTE (series of self-paced eLearning)
- LTE RF Optimization: Part 1 – Coverage and Accessibility (Instructor Led)

Required Equipment
- PC laptop

Course 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 SCell de-activation & typical triggers
   3.6 DL CA traffic operations
   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

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.

View Curriculum  Contact Award
VoLTE Troubleshooting Workshop

This workshop focuses on 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.

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 student 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

Course Outline

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

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

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

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

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

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

7. Putting it all Together

Prerequisites
Exploring VoLTE series (self-paced eLearning)

Required Equipment
Laptop with access to tools used in the course
IP/
Ethernet
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 student 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

Course Outline
1. Ethernet Defined
2. Ethernet Standards
3. Ethernet Addressing and Frame Structure
4. Carrier Ethernet
5. Summary

Prerequisites
- None

Required Equipment
- None
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. It is a modular introductory course only on Ethernet VLAN basics as part of the overall eLearning IP fundamentals curriculum. The course includes a pre-test and a post-test.

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

Objectives
After completing this course, the student 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

Prerequisites
- None

Required Equipment
- None

Course Outline

1. Virtual Local Area Networks (VLANs)
2. VLAN Application and Benefits
3. Default VLAN
4. Multi-Switch VLANs: Trunks and Tagging
5. Summary
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. It is a modular introductory course only on Ethernet Bridging 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 Bridging.

Objectives
After completing this course, the student 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

Prerequisites
- None

Required Equipment
- None

Course 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

1.5 hour | eLearning, IPC_116
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 student 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

Prerequisites
- None

Required Equipment
- None

Course Outline
1. IP Address
2. IP Subnets
3. IP Header
4. Multicast and Broadcast
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. It is a modular introductory course only on MPLS basics as part of the overall eLearning IP fundamentals curriculum.

### 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 student 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

### Prerequisites
- None

### Required Equipment
- None

### Course 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
The Internet is coming to a new age where various applications have their own QoS requirements, and one size definitely 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. This course describes the policy-based QoS architecture which supports the infrastructure for delivering QoS based applications. Finally, emerging trends in IP QoS are introduced.

### Course 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

---

**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 student 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

**Prerequisites**
- None

**Required Equipment**
- None
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. It is a modular introductory course only on IP routing as part of the overall eLearning IP fundamentals curriculum.

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 student 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

Prerequisites
- None

Required Equipment
- None

Course 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

Contact Award
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. 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 IP-based transport layer protocols - TCP, UDP and SCTP.

Objectives
After completing this course, the student 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)

Prerequisites
■ None

Required Equipment
■ None

Course Outline

1. Overview of the Transport Layer
2. User Datagram Protocol
3. Transmission Control Protocol

4. Stream Control Transport Protocol

5. Summary
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. The course concludes with a look at the various approaches to migrating from IPv4 to IPv6 and how these are deployed in LTE networks.

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 student 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

Prerequisites
■ None

Required Equipment
■ None

Course 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 student 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

Prerequisites
- None

Required Equipment
- None

Course 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
Network Virtualization
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 provides a high level view of the impact and benefits of Application Programing Interfaces, the vision and opportunities created by future provider networks, as well as their role in supporting communication across a transformed network.

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 student 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

Prerequisites

- None

Required Equipment

- None

Course 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
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 provides a high level view of the impact and benefits of Big Data, the vision and opportunities created by future provider networks, as well as a number of examples of how Big Data could be used to provide services in a transformed network.

### Intended Audience

The course is intended for all that are interested in understanding what Big Data is and how it will transform the Wireless, Wireline and Cable service provider networks over the next few years.

### Objectives

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

- Describe the concept of Big Data
- Illustrate the Big Data architecture and key protocols
- Describe a possible use case for Big Data

### Prerequisites

- None

### Required Equipment

- None

### Course Outline

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Cloud RAN 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 provides a high level view of the impact and benefits of Cloud RAN, the vision and opportunities created by future provider networks, as well as a number of technology challenges that need to be solved to make Cloud RAN a reality.

Intended Audience

The course is intended for all that are interested in understanding what Cloud RAN is and how it will transform the Wireless, Wireline and Cable service provider networks over the next few years.

Objectives

After completing this course, the student will be able to:
- Describe the concept of Cloud RAN
- Illustrate the Cloud RAN architecture and key protocols
- Describe the operational benefits of Cloud RAN

Prerequisites

- None

Required Equipment

- None

Course Outline

1. Current RAN Architecture
   1.1 RAN architecture
   1.2 Macro cells
   1.3 Small cells
   1.4 RAN connectivity

2. Challenges of Today
   2.1 RAN equipment requirements
   2.2 RAN power requirements

3. Why Cloud RAN?
   3.1 Problems Cloud RAN solves

4. Cloud RAN Architecture
   4.1 Remote radio head
   4.2 Baseband unit
   4.3 Fronthaul

5. Benefits and Challenges
   5.1 OpEx/CAPEX
   5.2 Operational
   5.3 Radio
   5.4 Mobility

6. Baseband Unit Virtualization
   6.1 Virtualization of BBU overview
   6.2 Virtualized BBU-Pool
   6.3 Advantages of Virtualizing BBU

7. Connectivity Topologies
   7.1 Fronthaul technologies
   7.2 Fronthaul protocols

8. Cloud RAN and Virtualization
   8.1 C-RAN interworking with NFV
   8.2 C-RAN interworking with SDN

9. End of Course Assessment
NFV 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 provides a high level view of the impact and benefits of Network Functions Virtualization (NFV), the vision and opportunities created by future Wireless, Wireline and Cable service provider networks, as well as a number of example of how NFV could be used to provide services in a Transformed network.

Intended Audience
The course is intended for all that are interested in understanding what NFV is and how it will transform the Wireless, Wireline and Cable service provider network over the next few years.

Objectives
After completing this course, the student will be able to:
- Describe the concept of Network Functions Virtualization
- List the motivations, challenges and impact of NFV
- List the key components of the NFV architecture

Prerequisites
None

Required Equipment
None

Course Outline

1. NFV Overview
   1.1 Network Functions Virtualization (NFV)
   1.2 NFV defined

2. NFV Motivation and Benefits
   2.1 Motivation for NFV
   2.2 Potential NFV benefits

3. NFV Architectural Framework
   3.1 NFV framework
   3.2 High-level NFV framework

4. NFV Challenges

5. NFV and IMS
   5.1 Simplified IMS functions
   5.2 Virtualized IMS functions

6. NFV and LTE

7. NFV and Content Delivery Networks

8. NFV Examples
   8.1 Hardware failure
   8.2 NFV for elastic capacity

9. End of Course Assessment
OpenStack IaaS 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 provides a high level view of the architecture and operations of OpenStack. The key services families of Keystone, Glance, Nova, Neutron, Cinder, Swift, Ceilometer, and Heat are explored including their architecture, services, and their communication with other services.

Intended Audience

The course is intended for all that are interested in understanding what OpenStack is and how it will transform the Wireless, Wireline and Cable service provider networks over the next few years.

Objectives

After completing this course, the student will be able to:
- Identify the main service families of OpenStack
- List the key resources that are virtualized with OpenStack
- Explain how OpenStack communicates internally with the RabbitMQ and externally with APIs.

Prerequisites

- None

Required Equipment

- None

Course Outline

1. OpenStack IaaS Architecture
   1.1 OpenStack IaaS
   1.2 OpenStack release timeline

2. OpenStack Communication
   2.1 OpenStack APIs
   2.2 RabbitMQ

3. OpenStack Basic Services
   3.1 Keystone and authentication
   3.2 Glance and image store

4. Compute Resources and Nova
   4.1 Nova architecture
   4.2 Nova scheduling

5. Network Resources and Neutron
   5.1 Neutron architecture
   5.2 Neutron services

6. Storage Resources, Cinder and Swift
   6.1 Types of storage
   6.2 Cinder vs. Swift
   6.3 Storage and Glance

7. Ceilometer and Monitoring
   7.1 Telemetry meter types
   7.2 Using Ceilometer

8. Orchestration and Heat
   8.1 What is Orchestration?
   8.2 Heat and Automation
   8.3 Heat templates

9. End of Course Assessment
### SDN 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 provides a high-level view of the impact and benefits of Software Defined Networks, the vision and opportunities created by future provider networks, as well as a number of example of how SDN could be used to provide services in a transformed network.

### Intended Audience

The course is intended for all that are interested in understanding what SDN is and how it will transform the Wireless, Wireline and Cable service provider network over the next few years.

### Objectives

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

- Describe the concept of Software Defined Networks (SDN)
- List the key components of the SDN architecture
- Identify possible uses of SDN

### Prerequisites

- None

### Required Equipment

- None

### Course Outline

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<td>5.3 SDN switch for forwarding</td>
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Welcome to SDN and NFV - Introduction

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

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

Objectives
After completing this course, the student 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

Prerequisites
- None

Required Equipment
- None

Course 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 student 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

Course 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

Prerequisites
- Welcome to SDN and NFV - Introduction (eLearning)

Required Equipment
- None
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 intended for all audiences that are interested in understanding how SDN and NFV provide optimal network solutions that not only provide customers with key benefits (faster time to revenue, reduced costs and increased customer satisfaction), but also improve the ability to respond to customer demands.

Objectives
After completing this course, the student 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

Prerequisites
- Welcome to SDN and NFV - Foundations (eLearning)

Required Equipment
- None

Course Outline
1. Today’s and Tomorrow’s Networks
   1.1 Complexity of today’s service provider’s network
   1.2 Physical and virtual network functions
   1.3 Conceptual model of tomorrow’s network
   1.4 Key concepts of Software-Defined Network

2. NFV and SDN
   2.1 NFV and SDN working together
   2.2 NFV
   2.3 NFV at a glance
   2.4 NFV in action
   2.5 NFV framework
   2.6 Benefits of NFV
   2.7 SDN
   2.8 SDN at a glance
   2.9 SDN framework
   2.10 SDN controller and apps
   2.11 Benefits of SDN

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

4. Walkthroughs: Fine Dining and the Network

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

Mobile Communication Service Providers (CSPs) are on the cusp of a multitude of network and business transformation choices. A good conceptual understanding of the new networking and CSP business paradigms is essential for professionals in the communication industry. This course provides a high level view of the impact and benefits of the cloud infrastructure, the benefits of virtualization, the vision and opportunities created by future CSP networks, as well as an overview of the impact of OpenStack cloud infrastructure on the service provider's network.

Intended Audience
The course is intended for all that are interested in understanding what OpenStack is and how it will transform the CSP network over the next few years.

Objectives
After completing this course, the student will be able to:
- Identify the main elements of virtualization
- List the key components of cloud Infrastructure as a Service (IaaS)
- Describe the role of Orchestration

Prerequisites
- None

Required Equipment
- None

Course Outline
1. Key Attributes of Cloud Computing
2. Virtualization
   2.1 Why Virtualization?
   2.2 A real world example – Virtualization
3. Virtual Machine and Hypervisor
   3.1 Virtual machine
   3.2 The Hypervisor
   3.3 Hypervisor defined
4. Functions of the Hypervisor
   4.1 Functions of the Hypervisor
   4.2 Networking in the virtual world
5. The Cloud
   5.1 Why Cloud?
   5.2 Multi-tenancy (users) in action
6. The Role of the Orchestration
   6.1 Cloud orchestration
   6.2 Cloud Orchestration defined
7. OpenStack IaaS
   7.1 OpenStack IaaS
   7.2 OpenStack release timeline
8. OpenStack Architecture
   8.1 Conceptual architecture
   8.2 OpenStack IaaS at a Service Provider
9. End of Course Assessment

Contact Award
Many forward-looking leaders recognize that the technological functions we use on a daily basis can be virtualized and moved to a cloud computing environment. This class surveys the topic of containers and microservices along with their applications and their implementations used in the industry. The student will learn about the concept of containers and microservices as well as their use cases and landscape.

**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 student will be able to:
- Differentiate between light weight and heavy weight virtualization
- Describe software container
- Describe key use cases for software containers
- Describe key use cases for software micro-services
- Identify the key container life-cycle management concepts
- Step through the examples of uses of micro-services

**Prerequisites**
- Technology Primer: Cloud and Virtualization (Instructor Led)
- Technology Primer: NFV (Instructor Led)

**Required Equipment**
- None

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**Course Outline**

1. **Introduction to Containers**
   - 1.1 Types of virtualization
   - 1.2 Container architecture

2. **Container Landscape**
   - 2.1 Technology landscape
   - 2.2 Use cases

3. **Container and Microservices**
   - 3.1 Microservice architecture
   - 3.2 Microservices use cases

4. **Container Orchestration**
   - 4.1 Container Orchestration landscape
   - 4.2 Container life-cycle management

5. **Putting It All Together**
   - 5.1 Container example
   - 5.2 Microservice example

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**Technology Primer: Containers and Microservices in Telecom**

4.3/5 "The instructor made sure we were engaged through the whole training and he made sure it was always interesting."
Technology Primer: Cloud and Virtualization

4.6/5 "Interactive, real life examples. Very good experience from the instructor."

This half-day Technology Primer introduces the audience to the concepts of Cloud Computing and Virtualization. Cloud Computing is generally characterized by its Service Model types. The course first introduces the audience to the idea of Virtualization, Virtual Machines, Hypervisors and Containers. These are the first building blocks of Cloud Computing. Then the course introduces the audience to second set of building blocks of Cloud Computing - the Cloud Computing Service Models - and presents a high level comparison of the three primary Service Models and where they may fit into a wireless networking environment. The final building block introduces the audience to OpenStack and wraps up the discussion with a simple example of Cloud Computing implemented using OpenStack.

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 student will be able to:
- Describe Virtualization
- Describe Virtual Machines
- List the role and tasks of a Hypervisor
- Describe Containers
- Describe Cloud Computing
- Explain Cloud Computing in the context of a Wireless Network
- Describe OpenStack
- Illustrate an example implementation of the Cloud using OpenStack

Prerequisites
- A working knowledge of wireless networks
- Welcome to SDN and NFV Introductions (eLearning)

Required Equipment
- None

Course Outline

1. Virtualization
   1.1 What is Virtualization?
   1.2 Types of Virtualization
   1.3 Physical Network Functions
   1.4 Virtual Network Functions

2. Virtualization Technology
   2.1 Virtual Machine
   2.2 Hypervisor

3. Cloud Computing
   3.1 What is the Cloud?
   3.2 Cloud Computing
   3.3 Applicability to the wireless domain

4. Cloud Computing Technology
   4.1 What is OpenStack?
   4.2 OpenStack architecture
   4.3 OpenStack as a Cloud enabler

4.6/5 "Interactive, real life examples. Very good experience from the instructor."
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 student will be able to:
- Define NFV and describe its role in the software defined networks
- Sketch the NFV reference architecture
- Identify the components of the NFV Infrastructure (NFVI)
- Define a Network Service (NS) and VNF
- Describe Management and Orchestration (MANO)
- Explain Orchestration and Lifecycle Management
- Illustrate sample implementations of a VNF

Prerequisites
- Welcome to SDN and NFV Foundations (eLearning)
- Technology Primer: Cloud and Virtualization (Instructor Led)

Required Equipment
- None

Course Outline
1. NFV Introduction
   1.1 Define NFV
   1.2 Enabling technologies
   1.3 Benefits of NFV

2. NFV Framework
   2.1 NFV reference architecture
   2.2 Other systems: OSS, PNFS

3. NFV Infrastructure (NFVI)
   3.1 Hardware components of NFVI
   3.2 Software components of NFVI
   3.3 Leaf-Spine for network connectivity

4. Virtualized Network Functions (VNF)
   4.1 Physical and Virtualized Network Functions (PNF to VNF)
   4.2 Definitions of Network Service and VNF
   4.3 Examples of VNFs

5. NFV Management and Orchestration (MANO)
   5.1 MANO components
   5.2 NFV Orchestrator
   5.3 VNF manager
   5.4 VIM – Virtualized Infrastructure Manager
   5.5 Orchestration process

6. Putting It All Together
Cloud computing is transforming telecom service provider networks and ONAP enables the design, creation, and lifecycle management of network services. This course provides a conceptual understanding of the benefits, capabilities, architecture as well as the functionality provided by each of the key ONAP components. Finally, the high-level operations of ONAP and its role in orchestration and service’s telemetry is discussed.

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 student will be able to:
- Explain how ONAP integrates with OpenStack, NFV and SDN
- Explain life cycle management of a service
- Name the components of ONAP and identify their functions
- Identify the functional elements of ONAP Service Design
- Identify the functional elements of ONAP Run-time
- Step through the operation of ONAP in managing services

Prerequisites
- Technology Primer: Cloud and Virtualization (Instructor Led)
- Technology Primer: NFV (Instructor Led)

Required Equipment
- None

Course Outline
1. Introduction to ONAP
   1.1 Overview of ONAP, NFV, and SDN
   1.2 Brief history and ONAP releases
2. ONAP Framework
   2.1 Lifecycle management of resources/services
   2.2 ONAP platform and components
3. ONAP Service Design and Creation
   3.1 SDC architecture
   3.2 Service creation and models
4. ONAP Runtime
   4.1 Service deployment and instantiation
   4.2 Service telemetry and workflow
5. Putting it-all-together
   5.1 ONAP Summary
   5.2 Service Instantiation Examples
Cloud computing is transforming telecom service provider networks and OpenStack is the open source Infrastructure as a Service (IaaS) solution for building and managing cloud infrastructure. This course provides a conceptual understanding of the benefits, capabilities, architecture as well as the high-level operation of the OpenStack. We explain the functionality provided by each of the key services such as Keystone, Nova, Glance, Neutron, Cinder, and Swift as well as Heat orchestration. Finally, we will discuss OpenStack orchestration and telemetry services and how it integrates with NFV and SDN.

### Intended Audience
This course is designed for professionals in the industry who need to develop a high-level understanding of OpenStack.

### Objectives
After completing this course, the student will be able to:
- Define the role of OpenStack as a cloud infrastructure manager
- Identify key services of OpenStack and describe their role
- Step through the operation of OpenStack services in managing cloud resources
- Explain how OpenStack integrates with NFV and SDN
- Identify the benefits and challenges of OpenStack

### Prerequisites
- Technology Primer: Cloud and Virtualization (Instructor Led)
- Technology Primer: NFV (Instructor Led)

### Required Equipment
- None

### Course Outline

1. **Introduction to OpenStack**
   1.1 Physical to Virtualized network
   1.2 NFV reference architecture
   1.3 OpenStack as a cloud manager
   1.4 OpenStack in context of NFV and SDN

2. **OpenStack Framework**
   2.1 Brief history and OpenStack releases
   2.2 OpenStack services
   2.3 Multi-tenancy
   2.4 Role-based authentication
   2.5 Cloud segregation techniques

3. **OpenStack Operations**
   3.1 Roles of services like Keystone, Nova, Neutron

4. **Additional Services of OpenStack**
   4.1 Life cycle management via Heat orchestration
   4.2 Storage services
   4.3 Telemetry service

5. **Putting it-all-together**
   5.1 Features and limitations of OpenStack
   5.2 Integration with NFV and SDN

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**4.6/5  "This course enabled me to grasp a very high level understanding of a complex topic with no prior exposure."**

Cloud computing is transforming telecom service provider networks and OpenStack is the open source Infrastructure as a Service (IaaS) solution for building and managing cloud infrastructure. This course provides a conceptual understanding of the benefits, capabilities, architecture as well as the high-level operation of the OpenStack. We explain the functionality provided by each of the key services such as Keystone, Nova, Glance, Neutron, Cinder, and Swift as well as Heat orchestration. Finally, we will discuss OpenStack orchestration and telemetry services and how it integrates with NFV and SDN.
Orchestration is a requirement to achieve virtualized network automation. The drive towards an automated and virtualized network requires a paradigm shift in the way services are deployed. On demand services can be accomplished by the use of end-to-end orchestration which involves service orchestration, resource orchestration, and network orchestration. In addition, service fulfillment, service assurance, and service billing play a key role in making the automation a system wide end-to-end orchestration. We will present some use cases and scenarios of applying orchestration in a network that has Network Functions Virtualization (NFV), Software Defined Networking (SDN), and OpenStack technologies.

### Intended Audience
This course is designed for professionals in the industry who need to develop a high-level understanding of Orchestration.

### Objectives
After completing this course, the student will be able to:
- Sketch the end-to-end orchestration framework
- Differentiate among the main components of end-to-end orchestration
- Answer the questions of what is orchestration and why orchestration
- Differentiate between the components for resource, service and network orchestration
- Walk-through orchestration use cases
- List the different benefits of orchestration
- Explain how service fulfillment, assurance and billing fit in with end-to-end orchestration
- Sketch end-to-end orchestration in a network with NFV, SDN, and OpenStack technologies

### Prerequisites
- Welcome to SDN and NFV Foundations (eLearning)
- Technology Primer: Cloud and Virtualization (Instructor Led)

### Required Equipment
- None

### Course Outline

1. **Introduction to Orchestration**
   - 1.1 What and why automation and orchestration?
   - 1.2 Role of orchestration in the cloud

2. **Orchestration framework**
   - 2.1 NFV MANO model
   - 2.2 Types of Orchestration
   - 2.3 Orchestrators in the cloud infrastructure

3. **Definition of Network Service and VNF**
   - 3.1 Definition of Network Service
   - 3.2 Definition of VNF
   - 3.3 VNF package components

4. **Service and VNF Onboarding**
   - 4.1 VNF life cycle events
   - 4.2 Onboarding and Service orchestration
   - 4.3 Creating a VNF catalog

5. **Instantiation and Service Assurance**
   - 5.1 VNF instantiation process
   - 5.2 Resource orchestration needs
   - 5.3 Network orchestration needs
   - 5.4 Role of the SDN controller
   - 5.5 Service assurance through orchestration

6. **Putting it-all-together**
   - 6.1 Summary: Benefits of Orchestration
   - 6.2 Summary: Orchestration process
Technology Primer: Software-Defined Networking (SDN)

This half day Technology Primer introduces the audience to the concept of Software-Defined Networking (SDN). SDN proposes to take the traditional implementation of the networking and dis-assemble it. SDN is a collection of technologies that split the data, control and management planes of the network. The course starts off with an introduction to the SDN Architecture. After that it deconstructs the SDN architecture and describes the architecture and function of each of the three key planes. The Forwarding Plane, the Control Plane and the Application Plane are described in relation to current packet routing technologies. We wrap up the course with a simple example of how SDN may be used in a telecom network and how it interworks with NFV to connect Network Services.

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 student will be able to:
- Define and describe Software-Defined Networking
- Sketch the SDN architecture
- Illustrate the SDN Forwarding & Control planes
- Describe the SDN Controller and its interfaces
- Summarize applications of SDN in a service provider’s network

Prerequisites
- Welcome to SDN and NFV Foundations (eLearning)
- Technology Primer: Cloud and Virtualization (Instructor Led)

Required Equipment
- None

Course Outline

1. Introduction to SDN
   1.1 Need for service agility
   1.2 Enabling technologies
   1.3 Role of NFV and SDN

2. SDN Architecture
   2.1 Challenges in networking
   2.2 SDN architecture and principles
   2.3 SDN Controller and SDN Switches
   2.4 Northbound and southbound interfaces

3. SDN Forwarding Plane
   3.1 Legacy routers technology
   3.2 Transition to SDN controller and switches
   3.3 SDN traffic flow

4. SDN Controller and Interfaces
   4.1 Open source SDN controllers
   4.2 Flow and operations management
   4.3 Example protocols e.g. OpenFlow, NETCONF, etc.

5. Applications of SDN
   5.1 SDN and telecom networks
   5.2 Service Function Chaining
   5.3 SDN and OpenStack

6. Putting It All Together

Contact Award
OpenStack Workshop for SDN and NFV

4.7/5  "The entire course/presentation was very well done, with a clean and stable lab environment."

Competitive advantages of business agility drives the need for responsive and flexible IT infrastructure; which can be slow and expensive. The lead time to procure, install, configure, and commission new HW can take weeks. Cloud Computing IaaS brings speed, agility, scalability, and availability with lower CapEx and OpEx. This hands-on workshop is conducted in a Production Communication Service Provider context and the role OpenStack plays in NFV and SDN networks. Hands-on operational exercises are provided with detailed explanations of OpenStack’s component implementation, along with basic troubleshooting. Participants become Tenants and create multi-tiered network topologies and web service applications, enabling the participant to more adeptly deploy and support Cloud applications in an IaaS 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 student will be able to:

- OpenStack’s role in NFV and SDN networks
- Identify the benefits and applications of IaaS and OpenStack
- Diagram OpenStack’s logical and physical architectures
- Provision, manage, and monitor resource pools in a Cloud Computing Center
- Create simple virtual network over OpenStack IaaS
- Explore OpenStack features such Snapshot, etc.
- Contrast the benefits and considerations of cloud deployments
- Cloud partitioning over physical host deployments

Prerequisites

- Technology Primer: Cloud and Virtualization (Instructor Led)
- Technology Primer: NFV (Instructor Led)

Required Equipment

- None

Course Outline

1. Prologue
   1.1 Introduction to cloud computing
   1.2 Role of OpenStack in NFV and SDN Networks
   1.3 OpenStack services highlights

2. Introduction to OpenStack IaaS
   2.1 OpenStack components and architecture, and supporting systems
   2.2 OpenStack services on physical hosts and physical networks
   2.3 Cloud segregation techniques

3. Identity Service (Keystone)
   3.1 Keystone concepts
   3.2 Keystone authentication and authorization policy enforcement.
   3.3 Keystone database and service catalogue

4. Compute Service (Nova)
   4.1 Nova capabilities, components and service daemons
   4.2 Nova under-the-hood VM provisioning trace
   4.3 Scheduler and filter algorithms

5. Image Service (Glance)
   5.1 Glance overview capabilities and concepts
   5.2 Glance services

6. Networking Service (Neutron)
   6.1 Networking capabilities, components and service agents
   6.2 Network use cases
   6.3 Under-the-hood implementation
   6.4 Network frame trace

7. Block Storage Service (Cinder)
   7.1 Cinder overview
   7.2 Cinder architecture
   7.3 Cinder volume management

8. Object Service (Swift)
   8.1 Swift capabilities, architecture and service daemons
   8.2 Account, Container, Object Walk-Through
   8.3 Swift deployment considerations

9. Telemetry and Alarm Services
   9.1 Capabilities, components and services

10. Orchestration (Heat)
    10.1 Capabilities, components and service daemons
    10.2 Heat Stack templates

3 Day | Instructor Led, NWV_405
Scripting Workshop for SDN and NFV

Wireless, Wireline and Cable service providers are deploying Network Functions Virtualization (NFV) and Software-Defined Networking (SDN). This class surveys the popular methodology known as DevOps and introduces software tools which are used to define and orchestrate services. In the world of software defined networks, service providers are moving from configuring networks to programming networks. The participants are introduced to several network programming languages through hands-on exercises. They study how scripting languages interface with SDN Controllers and NFV Virtual Infrastructure Manager (VIM e.g. OpenStack) along with software concepts such as declarative programming which are used in software tools such as TOSCA, YANG, Heat, Ansible and Python.

Intended Audience
This course is intended for those seeking a technical hands-on introduction to scripting in the world of SDN and NFV.

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

- List opportunities for scripting in the SDN, NFV based Networks
- Contrast DevOps with previous project development methodologies
- Develop or modify TOSCA service templates for network service
- Modify simple YANG models for network configuration
- Distinguish between modeling, configuration, and software programming tools
- Differentiate between data formatting languages such as YANG, TOSCA, JSON etc.
- Interpret Ansible playbook for infrastructure configuration
- Write a basic python script to retrieve and modify OpenStack configuration

Prerequisites
- OpenStack Workshop for SDN and NFV (Instructor Led)

Required Equipment
- Students will need a laptop with a web browser and Windows Remote Desktop installed

Course Outline

1. DevOps and Scripting in the SDN and NFV World
   1.1 DevOps in Virtualized Networks
   1.2 Modeling and Scripting
   Exercise: Group discussion of DevOps and changing job roles

2. Orchestration Tools - TOSCA
   2.1 History of TOSCA
   2.2 Overview of TOSCA
   2.3 TOSCA Applications
   Exercise: Examine and execute TOSCA service templates

3. Data Abstraction - YANG
   3.1 History of YANG
   3.2 Overview of Declarative Programming
   3.3 Abstraction Applications
   Exercise: Convert NETCONF YANG to YIN model

4. Orchestration Tools - Heat
   4.1 Orchestration (Heat) Overview
   4.2 Heat Orchestration Template Structure
   4.3 Sample Heat Resources
   Exercise: Launch OpenStack Heat stack

5. Deployment Tools - Ansible
   5.1 History of Ansible
   5.2 Overview of Ansible
   5.3 Ansible Playbook
   Exercise: Examine and execute an Ansible playbook

6. Orchestration Tools - Python
   6.1 History of Python
   6.2 Overview of Python
   6.3 Python Applications
   Exercise: Modify a Python SDN application

Contact Award
Network Functions Virtualization (NFV) standards are still evolving as the telco industry grapples with this significant technology transformation. Software-Defined Networking (SDN) is a relatively new concept within the telco industry and has recently gained traction. NFV proposes to leverage standard IT virtualization technology to consolidate network equipment types onto industry standard high-volume servers, switches and storage. SDN proposes to take the traditional implementation of the networking and disassemble it. SDN is a collection of technologies that split the data, control and management planes of the network. The course provides a technical overview of NFV and SDN - in terms of the architecture, requirements, challenges, operations, and management – and how they relate and complement one another.

**Intended Audience**
This course is intended for personnel in engineering and operations roles who are looking for a technical introduction to Network Functions Virtualization (NFV) and Software-Defined Networking (SDN).

**Objectives**
After completing this course, the student will be able to:
- Sketch the NFV reference architecture and building blocks
- Sketch end-to-end operational scenarios for vEPC, vCPE
- Identify the Key NFV requirements and benefits
- Discuss the role and performance aspects of the virtualization layer
- Define the NFV building blocks: Virtualization of Compute, Network and Storage
- Show how OpenStack can be an NFV VIM
- List and describe performance enhancements techniques
- Sketch the SDN architecture

**Prerequisites**
- Technology Primer: Cloud and Virtualization (Instructor Led)
- Technology Primer: NFV (Instructor Led)

**Required Equipment**
- None

**Course Outline**
1. **SDN and NFV Architecture**
   - 1.1 SDN architecture
   - 1.2 SDN Principles
   - 1.3 NFV components
   - 1.4 NFVI, VNF
   - 1.5 EMS, OSS and BSS
   - 1.6 MANO

2. **NFV Infrastructure**
   - 2.1 NFV infrastructure deployment
   - 2.2 OpenStack components
   - 2.3 Heat and infrastructure Orchestration
   - 2.4 NFVI Domain
   - 2.5 Lab: OpenStack

3. **NFV Application - VNF**
   - 3.1 VNF functional architecture
   - 3.2 VNF composition, VNF states
   - 3.3 Virtual functions software options
   - 3.4 VM live migration

4. **Lab: Management and Orchestration Demo**

5. **NFV Management - MANO**
   - 5.1 Orchestrator, Catalog
   - 5.2 Network service creation
   - 5.3 NFV descriptors
   - 5.4 Onboarding
   - 5.5 Lifecycle management
   - 5.6 VNF forwarding graphs

6. **NFV Deployment Scenarios**
   - 6.1 NFV service models
   - 6.2 Use Case for NFV deployment
   - 6.3 vIMS, vEPC, vPE

7. **Deployment Considerations**
   - 7.1 Life of data packet
   - 7.2 Performance
   - 7.3 DPDK and SR-IOV
   - 7.4 Scheduling and OS enhancements
   - 7.5 Elasticity and scaling in NFV

8. **SDN Controllers**
   - 8.1 SDN Ppanes and functions
   - 8.2 OpenFlow protocol
   - 8.3 SDN controller deployment options

9. **SDN Protocols and Interworking**
   - 9.1 NETCONF and YANG
   - 9.2 SDN for transport and WAN networks
   - 9.3 WAN interworking protocols

10. **Network Orchestration with SDN**
    - 10.1 Intra-Data center
    - 10.2 Integration with VIM
    - 10.3 Inter-Data center
NETCONF/YANG Configuration Workshop

Network configuration tools are increasingly important as more network services move to the cloud. In the past, SNMP has been a standard tool for this task but now it is being superseded by NETCONF (Network Configuration Protocol) and the associated YANG (Yet Another Next Generation) standard. NETCONF has important features which go beyond the capabilities on SNMP. Network operating center workflows will change as we move toward configuration with NETCONF. In this class, the student will update and implement YANG data models and use NETCONF configuration. We will also use YANG modeling for network service and Virtual Network Functions (VNF) models in NFV.

Intended Audience
This hands-on course is designed for network operations, planning, engineering, management or other related functions.

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

- Discuss how does YANG modeling and NETCONF apply to NFV and SDN networks
- Elaborate on YANG modeling
- Discuss NETCONF and its relationship to YANG
- List alternatives to NETCONF
- Describe, update, and build a YANG data model for an NFV network service and VNFs
- Differentiate between NETCONF usage for configuration management and control plane
- Demonstrate Importing data models and running NETCONF configuration
- Utilize the tools used to perform various network functions and device configuration

Prerequisites
- OpenStack Workshop for SDN and NFV (Instructor Led)
- SDN and NFV Architecture and Operations (Instructor Led)

Required Equipment
- It is highly recommended that students use more than one monitor for this workshop

Course Outline

1. NETCONF/YANG for NFV and SDN Networks
   1.1 Why NETCONF and YANG?
   1.2 NETCONF for network management
   1.3 Applicability in NFV and SDN networks
   1.4 TOSCA vs YANG
   Exercise: Lab access and setup

2. YANG Data Models
   2.1 Introduction to data modeling
   2.2 YANG data modeling
   2.3 YANG model components
   Exercise: Create a YANG model

3. YIN XML Introduction
   3.1 YANG-YIN conversion process
   3.2 XML structure highlights
   3.3 YANG to YIN
   Exercise: YANG to YIN, and other YANG model viewing options

4. NETCONF vs. SNMP
   4.1 Introduction to SNMP
   4.2 NETCONF vs SNMP
   4.3 Northbound interface auto rendering
   Exercise: Northbound interface auto rendering and usage

5. NETCONF Introduction
   5.1 Purpose of NETCONF
   5.2 NETCONF features
   5.3 NETCONF layers
   Exercise: NETCONF datastores

6. NETCONF Operations
   6.1 NETCONF protocol handshake
   6.2 NETCONF datastores
   6.3 Main NETCONF operations
   6.4 NETCONF server discovery
   Exercise: NETCONF operations

7. YANG for NFV
   7.1 NFV data modeling
   7.2 YANG modeling for NFV
Many forward-looking leaders recognize that the technology functions used on a daily basis can be virtualized and moved to a cloud computing environment. This course surveys the topic of containers and the applications and implementations used in the industry. The student learns about the concepts of containers as well as their use cases and landscape. Just like virtual machines, containers must be managed. The course explores the networking options for containers. The concepts in the course are solidified through a series of exercises so the students can experience firsthand how containers are used, supported, and orchestrated.

### Intended Audience
This course is designed for professionals in the industry who plan, engineer, and deploy the cloud infrastructure and need to understand Software Containers.

### Objectives
After completing this course, the student will be able to:
- Differentiate between light weight and heavy weight virtualization
- Describe software containers
- Describe networking options for containers
- Describe key use cases for software containers
- List popular Container implementations:
  - Kubernetes, Docker Swarm, Apache Mesos
  - Mesosphere, Flannel, Atomic
  - Calico, CoreOS, Snappy Ubuntu Core
- Cloud Tolerant vs. Cloud Native
  - Exercise: Deploy Containers and examine contents

### Prerequisites
- Introductory knowledge of Linux
- Technology Primer: Cloud and Virtualization (Instructor Led)

### Required Equipment
- None

### Course Outline

#### 1. Overview of Containers
- 1.1 Types of virtualization
- 1.2 Introduction to Containers
- 1.3 Container run-time engine
- 1.4 Container repositories
- 1.5 Cloud Tolerant vs. Cloud Native
  - Exercise: Deploy Containers and examine contents

#### 2. Container Use Cases and Landscape
- 2.1 Use cases
- 2.2 Software distribution
- 2.3 Control plane
- 2.4 Micro-service
- 2.5 Clear Containers
- 2.6 Container layers/images
- 2.7 Container landscape
- 2.8 CNCF – Cloud Native Computing Foundation
- 2.9 OCI – Open Container Initiative
  - Exercise: Show various tools and how they are used to deploy services

#### 3. Containers and Networking
- 3.1 Container Networking Options
- 3.2 Bridge Mode
- 3.3 Networking for Virtualization
  - Exercise: Show IP addresses, ports and network properties of a container
  - Exercise: Launch containers using host and bridge modes

#### 4. Container Orchestration
- 4.1 Container Orchestration
- 4.2 Container Orchestration landscape
- 4.3 Container life-cycle management
  - Exercise: Deployment of Micro-Services using Container Orchestrator
OpenStack Heat Workshop

OpenStack is a very popular open source cloud enablement system for creating private and public clouds. OpenStack software controls large pools of compute, storage, and networking resources in the cloud deployment. Heat is the service for orchestrating resources in an OpenStack deployment. It implements an orchestration engine to launch multiple composite cloud applications based on YAML or JSON templates. This workshop provides a thorough understanding of Heat Orchestration Templates (HOT). Using an OpenStack system, students will develop, enhance and analyze several heat templates of increasing complexity. Students will work together to understand and apply heat templates simulating practical deployments of OpenStack in a Telco environment.

Intended Audience
This course is designed for network planning, engineering, operations, management or other related functions who want to work with OpenStack Heat and create and use Heat Templates (YAML format) for orchestration.

Objectives
After completing this course, the student will be able to:
- Read and interpret Heat Orchestration Templates (HOT)
- Design and develop Heat Orchestration Templates
- Analyze, enhance and validate outcomes of HOT templates
- Create Heat stacks in an OpenStack deployment
- Create nested Heat templates
- Articulate the effects of global environments as they relate to launching Heat stacks
- Practice the scripting of VM actions and configuration at boot time

Prerequisites
- SDN and NFV Architecture and Operations (Instructor Led)
- OpenStack Workshop for SDN and NFV (Instructor Led)

Required Equipment
- Students will need a laptop with a web browser and Windows Remote Desktop installed
- It is recommended for the students to use an additional monitor

Course Outline

1. Prologue
   1.1 OpenStack Heat high level review

2. Introduction to Heat Orchestration
   2.1 HOT versions
   2.2 HOT format
   Exercise: HOT and Heat commands

3. Input and Intrinsic Functions
   3.1 Input parameters
   3.2 Parameter groups
   3.3 Parameter constraints
   3.4 Intrinsic functions
   Exercise: Order and validate input,
   Exercise: Use intrinsic functions

4. Heat Resources
   4.1 Resource section
   4.2 Resource types
   4.3 Properties and attributes
   4.4 Sample resource types
   Exercise: Create servers, volumes, LB pool, VIP to server pool with floating IPs

5. Template Output
   5.1 Output section
   5.2 Use of parameters and attributes
   Exercise: Output resource run-time values

6. Template Composition
   6.1 Nested stacks in templates
   6.2 Build, launch, manage nested HOTs
   6.3 Resource dependencies
   6.4 Information flow in nested stacks
   6.5 Resource_facade
   Exercise: Explore, analyze, launch and manage nested templates
   6.7 Environments
   6.8 Global and effective environments
   6.9 Influencing parameters and parameter defaults
   6.10 Resources registry and override
   Exercise: Resource Groups, Policies, and triggers to scale
   6.12 Virtual Software Configuration
   6.13 Consideration and mechanisms
   6.14 Various configuration tools options