We help our customers tackle new technologies.

We also help them make the most of their technology investments.

We do this by equipping our customers with knowledge and skills, improving networks and empowering their businesses along the way.

We are the fun and motivating friends you always wanted as a study buddy.

We are the keen minds that invest in technology research, engineering, and labs.

We are also tech-savvy planners that look to the future and prepare for what’s ahead. We sharpen our skills constantly for our customers.

Creating exceptional training is in our DNA.

Our Values

**Integrity**: We are a trusted, independent training provider to over 255 corporate clients worldwide

**Expertise**: Our SMEs have depth and breadth of knowledge across all wireless and IP technologies

**Quality**: 98% of participants taking Award’s classes would recommend them to others

**Flexibility**: We offer a variety of training options including onsite, virtual, self-paced eLearning, and public training events

**Excellent return on investment**: Our training solutions are not only highly valued in the industry, but they are also available when you need them most
CURRICULUM
Curriculum

**SELF-PACED**
Self-study, on-demand courses
100% online and available 24/7

Curriculums include:

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

- **Automation and Insights**
  - Welcome to AI

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

- **IP and Ethernet**
  - 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**
  - API Overview
  - Big Data Overview
  - Cloud RAN Overview
  - NFV Overview
  - OpenStack IaaS Overview
  - SDN Overview
  - Virtualization and Cloud Overview
  - Welcome to SDN and NFV Introductions
  - Welcome to SDN and NFV Foundations
  - Welcome to SDN and NFV Technologies
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

Welcome to 5G
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
- Sketch the flexible frame and slot structure of 5G NR

Prerequisites
- None

Required Equipment
- None

Course Outline
1. 5G Scenarios and 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
5. Protocol Stack Enhancements
6. 5G Operating Bandwidth
7. 5G NR Frame and Slot Structure
   7.1 Flexible sub-carrier spacing
   7.2 Flexible frame and slot structure
   7.3 Carrier bandwidth part
   7.4 Numerology
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:

- Identify key channels and their usage in the downlink and uplink
- Step through the life of a 5G UE at a high level in non-standalone architecture
- Step through the life of a 5G UE at a high level in standalone architecture
- Identify ways in which 5G NR meets the performance goals of 5G

Prerequisites

- None

Required Equipment

- None

Course Outline

1. Key Signals and Channels of 5G NR
   1.1 Downlink signals and channels
   1.2 Uplink signals and channels

2. Life of a 5G UE
   2.1 NSA vs. SA operations
   2.2 Non-Standalone operations
   2.3 Network acquisition
   2.4 Attach
   2.5 Data transfer
   2.6 Standalone Operations
   2.7 Network acquisition
   2.8 Registration
   2.9 PDU session setup
   2.10 Data transfer

3. Meeting 5G Performance Goals
   3.1 Ways to achieve higher data rates
   3.2 Ways to achieve lower latency
   3.3 Ways to achieve higher connection density
   3.4 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 the QoS framework of 5G and compare it with 4G
- Step through the network operations of registration and PDU session establishment
- Describe network slicing and how it is used in 5G
- Describe MEC and how it can be used in 5G

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

View Curriculum
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?
   1.1 Types of AI
   1.2 Define in nine
2. AI concepts
   2.1 AI terms and concepts
3. Neural Networks
   3.1 What is Neural Networks?
   3.2 Neural Networks in action
4. AI and Automation lifecycle
   4.1 Lifecycle overview
   4.2 Model creation
   4.3 Model Deployment
   4.4 Automation and Human Intervention
   4.5 AI and Automation Lifecycle in the Telecom Industry
5. Impact of AI on Telecom
   5.1 AI, Analytics and Automation
   5.2 Strategic goals
   5.3 Priority areas for CSP AI, ML activities
6. AI focus areas
   6.1 Interaction focus, Complex communication
   6.2 Pattern detection, Process automation, Decisioning
7. AI Use Cases in Telecom
8. AI Use Cases that impact a Telecom Network
   8.1 Streaming Service, IoT
   8.2 VR/AR
   8.3 Autonomous cars
9. Course Summary
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 POC
   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

View Curriculum
Exploring LTE: Signaling and Operations – Part I

The Long Term Evolution (LTE) network is designed to deliver services and content to mobile subscribers quickly and with high quality. To do this, the various elements within the network communicate with each other and with the mobile device using well-defined protocols and procedures to accomplish the tasks and operations required. This 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

View Curriculum
Exploring LTE: Signaling and Operations – Part II

The Long Term Evolution (LTE) network is designed to deliver services and content to mobile subscribers quickly and with high quality. To do this, the various elements within the network communicate with each other and with the mobile device using well-defined protocols and procedures to accomplish the tasks and operations required. This 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

View Curriculum
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 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: 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.

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

Prerequisites

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

Required Equipment

- None

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
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

View Curriculum
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
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

Prerequisites

None

Required Equipment

None

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
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 multiple antenna techniques work. This includes those in a 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. Antenna Basics
   1.1 Antenna Characteristics
   1.2 Antennas in commercial deployments
   1.3 Motivation for MIMO

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

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

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

Putting It All Together
Overview of 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

Prerequisites
- None

Required Equipment
- None

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

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

4.4 Inter Carrier Interference (ICI)
4.5 Cyclic prefix and pilots

View Curriculum
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, 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

Prerequisites
- None

Required Equipment
- None

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
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.

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

View Curriculum
Welcome to LTE

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

Prerequisites
- None

Required Equipment
- None

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

Putting It All Together

View Curriculum
Ethernet VLANs

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

2. VLAN Application and Benefits
   2.1 VLAN Applications
   2.2 VLAN Benefits

3. Single Switch VLANs
   3.1 Port based VLAN

4. Multi-Switch VLANs: Trunks and Tagging
   4.1 Multi-Switch VLANs
   4.2 VLAN tags
   4.3 VLAN Trunks

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

Putting It All Together

View Curriculum
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

View Curriculum
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.

**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

**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
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**
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
   1.1 Functions of the Transport Layer
2. User Datagram Protocol (UDP)
   2.1 Defining the UDP
   2.2 UDP header details
3. Transmission Control Protocol (TCP)
   3.1 TCP functionality
   3.2 TCP connection setup
4. Stream Control Transport Protocol (SCTP)
   4.1 Role of SCTP
   4.2 Capabilities of SCTP
   4.3 Unique features of SCTP
5. Summary
Putting It All together
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
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 Programming 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**
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
1. What is Big Data?
   1.1 Traditional Business Intelligence
   1.2 Big Data Drivers
2. Big Data Technology
   2.1 Commercial and Open Source
3. Hadoop Procedure
   3.1 Why use Hadoop
   3.2 Sample Hadoop Suite
   3.3 How does Hadoop work?
4. Hadoop Modules
   4.1 Hadoop Distributed File System (HDFS)
   4.2 MapReduce
   4.3 Hadoop Plugins
5. Big Data Insights
   5.1 Insights form data sources
6. Data Visualization
   6.1 Data Visualization Basics
7. Data Visualization Examples
   7.1 Word cloud
   7.2 Tree Maps
   7.3 Heat Map
8. Big Data Examples
   8.1 Big Data in Social Media
   8.2 Big Data in Healthcare
Putting It All Together
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

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.
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**

View Curriculum
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

End of Course Assessment

1 HOUR | SELF-PACED, NWV_115
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**

1. SDN Overview
   1.1 SDN: Centralized control, distributed traffic
   1.2 SDN defined

2. SDN Motivations and Benefits
   2.1 Motivation for SDN
   2.2 Potential SDN benefits

3. Routing and Forwarding
   3.1 Routing and forwarding
   3.2 Routing in action
   3.3 Forwarding in action
   3.4 Control plane and forwarding plane inside a router

4. SDN Principles
   4.1 The SDN way
   4.2 The Hybrid way

5. SDN Architecture
   5.1 SDN architecture
   5.2 SDN controller for flow rules
   5.3 SDN switch for forwarding

6. SDN in Action
   6.1 SDN flow rules in action
   6.2 SDN forwarding in action

7. Using SDN
   7.1 SDN: Hybrid approach
   7.2 SDN: Bandwidth on demand service

8. SDN Challenges

9. End of Course Assessment

View Curriculum
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 Orchestrator
   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
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

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

Required Equipment
- None

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

View Curriculum
Welcome to SDN and NFV - Technologies

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

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

Objectives
After completing this course, the 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

View Curriculum
Thank You