

---

# Teracom Training Institute

## Certified Telecommunications Network Specialist CTNS Certification Package

---

CTNS Certification Package Overview.....	2
Detailed Course Descriptions.....	5
2241 Broadband Converged IP Telecommunications .....	5
2206 Wireless Telecommunications.....	9
2221 Fundamentals of Voice over IP .....	13
2201 The PSTN .....	16
2212 The OSI Layers and Protocol Stacks .....	20
2211 LANs, VLANs, Wireless and Optical Ethernet.....	24
2213 IP Networks, Routers and Addresses.....	28
2214 MPLS and Carrier Networks.....	32

Invest in yourself with Teracom’s CTNS Certification Package, **eight** online courses delivering a solid foundation in telecom, datacom and networking: understanding the fundamentals, technologies, jargon and buzzwords, and most importantly, the underlying ideas and how it all fits together... plus TCO Certification to prove it!

Benefit from decades of knowledge, insight and experience distilled into clear lessons, logically organized to build one concept on another. Get a major career-enhancing and productivity-enhancing knowledge upgrade – learning that you can't get on the job, reading magazines or talking to vendors.

Based on Teracom’s famous week-long instructor-led BOOT CAMP, the selection of material, its order, timing, and explanations are field-tested to deliver the core up-to-date knowledge set for today’s telecommunications.

The first four CTNS courses are on telecommunications, beginning with Broadband Converged IP Telecommunications, an introduction and first pass through all of the topics; followed by Introduction to Voice over IP, then Wireless Telecommunications, including 5G and Wi-Fi 6, and the PSTN.

The second half of CTNS is four courses on networking, delivering a practical understanding of Ethernet and its MAC frames, IP packets with IP addresses and routers, and the traffic management system MPLS. We begin with the OSI Reference Model and its Layers as a framework to organize the discussions.

Passing the course exams proves your knowledge and results in your certification as a TCO Certified Telecommunications Network Specialist. You’ll get a full-color certificate from the Telecommunications Certification Organization suitable for framing, plus an exclusive personalized Letter of Introduction / Letter of Reference introducing you and explaining the knowledge your Certification represents.

Your investment is protected with a 30-day, 100% money-back guarantee.

Get started today!

## CTNS Package Overview

The Certified Telecommunications Network Specialist Certification Package consists of eight courses: four courses on telecommunications, plus four courses on networking, with their certification exams.

Detailed lesson-by-lesson descriptions for each course follow this overview.

### Telecommunications Courses

#### **Course 2241 Broadband Converged IP Telecommunications**

A high-level wide-ranging introduction to the world of modern IP telecommunications.

The first course in the CTNS package is based on the first chapter of Teracom's famous instructor-led BOOT CAMP, which gets a full week of training started with an introduction to all of the different aspects of the modern converged IP telecom network.

*Broadband Converged IP Telecommunications* is a first pass through the topics, explaining the fundamental ideas, jargon, equipment and technologies, the services that are sold, the players, where the money is, and how it all fits together... without bogging down in details on any particular topic.

In subsequent courses, we'll take another pass and drill deeper into key areas like Wireless, VoIP, PSTN, Ethernet, IP and MPLS. Sometimes we'll go over an essential concept several times, from different perspectives.

#### **Course 2206 Wireless Telecommunications**

Next is a deeper dive into wireless, including radio fundamentals, cellular and mobile telecommunications plus Wi-Fi and more. Fully up-to-date for the 2020s with 5G, Wi-Fi 6 (802.11ax) and Starlink.

We begin with basic concepts and terminology involved in mobile networks, including base stations and transceivers, mobile switches and backhaul, handoffs, cellular radio concepts and digital radio concepts.

You'll understand how a phone call connects from a cell phone to a landline, and the different methods of allowing other devices to use a smartphone's mobile Internet connection.

The course is completed with communications satellites, in Geosynchronous Earth Orbit and Low Earth Orbit, including Iridium Next and Starlink.

#### **Course 2221 Fundamentals of Voice over IP**

A complete introduction to everything Voice over IP. You'll learn the fundamental ideas and principles of a VoIP telephone system, VoIP, SIP & all the other jargon - what it actually means and how it all works together.

We'll explain VoIP buzzwords, VoIP phone system components and operation, and how voice packetization works end-to-end, microphone to speaker, in plain English.

We'll sort out SIP, Softswitches & SIP Trunking, VoIP on LANs and WANs, VoIP phones, Softswitch as a Service (SaaS) in the Cloud, and a peek at The Future.

You will gain career-enhancing knowledge of the components and operation of Voice over IP systems, and learn what all of the jargon and buzzwords mean.

## **Course 2201 The PSTN**

The final telecommunications courses in the CTNS package is a history lesson, understanding how and why telephone networks and the companies that provide them are organized into local access and inter-city transmission, or as we will see, Local Exchange Carriers (LECs) and Inter-Exchange Carriers (IXCs), to form the Public Switched Telephone Network.

The structure, components and operations described in this course were built worldwide, in every country on earth, during the period 1970 - 2000. Though all new builds are Ethernet and IP, knowledge of the structure and jargon of the PSTN is part of the required knowledge in telecom while there remains a large installed base.

In fact, understanding DS0 channels and circuit-switching is necessary to know how a phone call from a cellphone on a wireless network connects to a phone plugged into a competitor's cable modem in another city.

### Networking Courses

The second half of CTNS is four courses focusing on the three main enabling technologies for the modern telecom network: Ethernet, IP and MPLS. We begin with the OSI model and its Layers to establish a framework for understanding what each does and how they work together... and all the other things that have to be done.

## **Course 2212 The OSI Layers and Protocol Stacks**

The OSI 7-Layer Reference Model organizes the functions that need to be performed to communicate into logical groups of separable functions called *layers*, to be able to discuss separate issues separately and not get things jumbled up.

First, we'll define the term "protocol" and compare that to a standard. Then we'll define "layer" and how a layered architecture operates, and provide an overview of the name, purpose and function of each of the seven layers in the OSI model.

Then, we'll go back through the story more slowly, with one lesson for each of the layers, examining in greater detail the functions that have to be performed and giving examples of protocols and how and where they are used to implement particular layers.

The result is a protocol stack, one protocol on top of another on top of another to fulfill all of the required functions. To make this more understandable, this course ends with the famous FedEx Analogy illustrating the concepts using company-to-company communications, and an analogy of Babushka dolls to illustrate how the protocol headers are nested at the bits level.

## **Course 2211 LANs, VLANs, Wireless and Optical Ethernet: Layer 2**

As we will have established in the previous course, Layer 2 is all about communications between two devices that are on the same circuit, or more precisely, in the same broadcast domain. It turns out that this is implemented by moving frames with link addresses over physical connections following the 802 series of standards, colloquially referred to as Ethernet, MAC frames and MAC addresses.

This course includes the important concept of VLANs: defining broadcast domains in software, a key part of basic network security practice, and finishes with a lesson on Optical Ethernet, which implements the pipes in the plumbing of an IP network.

We'll begin with the fundamentals: Ethernet and its bus topology, defining "broadcast domain" and explaining the fundamental operation of a LAN: sending MAC frames to MAC addresses, and how an Ethernet or Layer 2 switch works.

We'll cover the IEEE 802 standards from 10BASE-T to 100GBASE-ER4, LAN cables and TIA-568 cable categories and in-building cabling design, plus Wi-Fi wireless LANs.

### **Course 2213 IP Networks, Routers and Addresses: Layer 3**

A comprehensive course on Layer 3 of the OSI Model, concentrating on IP addresses, routers and packets.

We begin with the two basic principles of packet networks: bandwidth on demand, also known as overbooking, oversubscription and statistical multiplexing; and packet-switching, also known as packet forwarding or routing.

We'll understand what routers do and where they are located, routing tables and the basic operation of a router and the standard strategy deploying an edge router between the LANs and the WAN at each location.

Then we'll cover IP version 4: address classes and how they are assigned to Regional Internet Registries then ISPs then end-users, dotted-decimal notation, static addresses, dynamic addresses and DHCP, public addresses, private addresses and NAT.

The course concludes with IPv6: the IPv6 packet and changes from IPv4, IPv6 address allocations and assignments and end up understanding how IPv6 subnets will be assigned to broadcast domains and 18 billion billion addresses per residence.

### **Course 2214 MPLS and Carrier Networks**

The structure, components and operation of carrier packet networks and services, how they are implemented, packaged and marketed, and how they are used by government, business and other carriers.

The IP packets and routing of the previous course is one part of the story. Performance guarantees, and methods for quality of service, traffic management, aggregation and integration is another big part of the story, particularly once we leave the lab and venture into the real world and the business of telecommunications services.

We'll begin by establishing a basic model for a customer obtaining service from a provider, defining Customer Edge, Provider Edge, access and core, and a Service Level Agreement: traffic profile vs. Class of Service transmission characteristics.

Next, we'll understand virtual circuits, a powerful tool used for traffic management and variations like connection-oriented vs. connectionless communications and reliable vs. unreliable network services.

With the fundamentals in place, we'll go through the implementation of virtual circuits with MPLS, explaining MPLS-specific jargon, and all of the functions and services it is used to implement in the network core.

## **Detailed Course Descriptions**

### **Course 2241 Broadband Converged IP Telecommunications**

Convergence • Broadband • Network Core and Edge • Protocols • Last Mile Network Access • Residential, Business and Wholesale Services • Network Equipment • Carrier Connections

11 interactive multipart lessons, multiple-choice exam and certificate. Produced 2021.

*Broadband Converged IP Telecommunications* is a high-level wide-ranging introduction to the world of modern IP telecommunications.

This course is based on the first chapter of Teracom's famous instructor-led BOOT CAMP, which gets a full week of training started with an introduction to all of the different aspects of the modern converged IP telecom network.

Designed specifically for Non-Engineering professionals to be a first pass through the topics, explaining the fundamental ideas, jargon, equipment and technologies, the services that are sold, the players, where the money is, and how it all fits together... without bogging down in details on any particular topic.

In subsequent courses, we'll take another pass and drill deeper into key areas like Wireless, VoIP, PSTN, Ethernet, IP and MPLS.

### **Course Outline**

#### 1. Introduction

*Course introduction and overview.*

#### 2. Convergence

*One network carrying all services: telephone, video and Internet. Channels vs. packets.*

#### 3. Broadband

*Bandwidth, and how much "broad" might be*

#### 4. Broadband Converged IP Telecommunications Model

*Graphical model identifying all the main aspects of telecommunications and how they relate*

#### 5. The Network Core

*High-capacity, high-availability connections between aggregation centers. Fiber rings.*

#### 6. Network Protocols: Ethernet, IP and MPLS

*Ethernet moves packets point-to-point. IP address is the final destination. MPLS manages flows.*

#### 7. Network Access: The Last Mile

*Twisted pair, hybrid fiber-coax, Passive Optical Network, Optical Ethernet, cellular, satellite*

#### 8. Anatomy of a Service

*Network access technology, network connection type and billing agreement*

#### 9. Services: Residential, Business and Wholesale

*Comprehensive review of the main dollar-value services in each sector*

#### 10. Network Equipment

*Layer 2 switches, IP routers, MPLS routers, FDM and TDM multiplexers, wavelength cross connects*

#### 11. Carrier Network Interconnect

*Tariffed switched-access for calls involving a PSTN phone number; Internet Exchange transit and peering*

### **Prerequisites**

None.

## **Course Objectives: What You Will Learn**

After taking this course, you will be able to

- Define convergence, and two ways that it might be achieved
- Define bandwidth, explain what broadband means and how much “broad” might be
- Identify all of the main aspects of the modern broadband converged IP network, including the parts of the physical network, the three types of services, the equipment and players
- Describe the network core, its purpose, performance requirements and how they are implemented
- Identify the three primary network protocols: Ethernet, IP and MPLS, and what each does
- Explain how MAC Frames and IP Packets go together
- Identify the essential purpose of an IP address
- Explain the essential advantage of MPLS over IP for routing
- Define the three main technology areas for network access
- List the most popular technologies in each
- Describe the three components of a network service
- Define the three main groupings of telecom services based on customer type
- Describe at least four different meanings of the term VPN
- Differentiate between streaming video vs. video from your ISP, and the essential difference between them
- Explain in general what an MPLS VPN is and who uses it
- Identify the key difference between MPLS VPN services and SD-WAN services
- Explain what SIP trunking is and what legacy service it replaces
- List at least four types of wholesale telecommunications services
- Explain what a Data Center is
- Explain the essential function of a router
- Describe what a Layer 2 switch is used for, and how Layer 2 switches relate to routers
- Define multiplexing
- Identify three technologies that use Frequency-Division Multiplexing
- Identify the name for FDM in the fiber optic world
- Differentiate between FDM and Time-Division Multiplexing
- Describe what a gateway is and the two functions it performs
- Identify the two main ways that carriers connect, and where this happens

This is quite a range of knowledge, and can appear daunting, especially if you are new to telecom. Keep in mind that this course is the introduction, the first pass through all of these topics. No-one is expecting anyone to be an instant expert. In subsequent courses, we take a second and sometimes third pass through the topics and drill deeper to more fully understand the concepts and technologies. With this course, we’re getting started identifying and understanding all of the aspects of modern broadband converged IP telecommunications.

## **Detailed Course Description**

This course is based on the first chapter of Teracom's famous instructor-led BOOT CAMP, which gets a full week of training started with an introduction to all of the different aspects of the modern converged IP telecom network.

*Broadband Converged IP Telecommunications* is a first pass through the topics, explaining the fundamental ideas, jargon, equipment and technologies, the services that are sold, the players, where the money is, and how it all fits together... without bogging down in details on any particular topic.

After defining "broadband" and "convergence", we'll establish a model for the network and all of its related aspects, then go through each part of the model: network core and edge, network protocols, last-mile access technologies, residential, business and wholesale services, network equipment and carrier connections.

In subsequent courses, we'll take another pass and drill deeper into key areas like Wireless, VoIP, PSTN, Ethernet, IP and MPLS. Sometimes we'll go over an essential concept several times, from different perspectives.

### **Lesson 1. Course Introduction**

The first lesson begins the course with an overview of the course and lessons.

This lesson is available for free on [teracomtraining.com](http://teracomtraining.com) and provides both a walkthrough of the course and a sample of the production quality.

### **Lesson 2. Convergence**

Lesson 2 begins the course proper defining convergence or service integration, where all services: voice, video and data are carried together on the same access circuits and same network. We'll see there are two possibilities for convergence: carry everything in channels like voice; or carry everything in packets like data; and after previous failed attempts: ISDN (channels) and ATM (packets), the third time is the charm with everything in IP packets, plus a packet traffic management technology called MPLS.

### **Lesson 3. Broadband**

In this lesson, we'll understand what bandwidth is, in both the analog and digital worlds; or more precisely: in the frequency channel and digital worlds. We'll discuss how much "broad" might be from a regulatory perspective, and from a user requirements perspective; and how broadband access to the Internet will become a right, just as electricity and telephone before it.

### **Lesson 4. Broadband Converged IP Telecommunications Model**

Lesson 4 introduces a graphical model identifying the all of the different aspects of broadband converged IP telecommunications, which are covered in detail in subsequent lessons and courses. We'll understand the parts of the physical network: core, edge and access, and enumerate services grouped by residential, business and wholesale, and see how data centers fit into the picture.

### **Lesson 5. The Network Core**

A closer look at the heart of the model: the network core. The core implements high-capacity, high-availability communications using Optical Ethernet point-to-point links between major switching or aggregation points on a carrier's network. We'll see all the different buildings these could be, how high availability requires redundant connections, how ring patterns are the cheapest way to implement it, and the technologies used for cut line protection switching.

### **Lesson 6. Network Protocols**

Introduces fundamental networking concepts, viewing networks as point-to-point links terminated on routers in different locations. We'll examine the most popular technology for links, Optical Ethernet, which moves bits grouped into MAC frames point-to-point over fiber. You'll learn how IP packets are carried in MAC frames to a router, which uses the destination IP address to make a route decision, then forwards the IP packet in a MAC frame to the next

router. We'll see how MPLS is used instead of IP in the core of big networks, allowing control of the routing of flows of packets by a Network Operations Center.

### **Lesson 7. Network Access: The Last Mile**

This lesson is dedicated to network access technologies, called the "last mile", the physical connection between the user and the network; the face of the telecom network to users. We group access technologies by physical medium: copper, fiber and wireless. Copper includes twisted pair loops, LAN cables and old-fashioned T1s, as well as coaxial cable CATV infrastructure. Fiber means Optical Ethernet, shared links for residences via Passive Optical Networks and dedicated links for businesses. Wireless includes 4G LTE and 5G, used for both fixed and mobile applications, and satellites.

### **Lesson 8. Anatomy of a Service**

We'll define a service provided by a telecommunication service provider as being made of three components: access circuit, network connection type and billing agreement. We'll first understand why people draw networks as clouds in high-level diagrams, to establish the idea of a service versus a circuit. Then we'll explore how access circuits, network connections and billing agreements combine to make a service.

### **Lesson 9. Telecommunications Services**

Lesson 9 is a lengthy introduction to the most popular services sold by service providers, organized into residential, business and wholesale. We'll cover broadband residential Internet, and telephone service, television and video on demand delivered as Internet traffic or delivered direct by your ISP; and the term VPN, which can mean at least four different things. We'll introduce business services, including MPLS VPNs, SD-WANs, Centrex and SIP Trunking to replace PBX trunks; and wholesale services: dark fiber; wavelengths on a fiber; services that moves MAC frames, called a Virtual Private LAN Service (VPLS) or Carrier Ethernet, IP packet communications, Internet transit and peering.

### **Lesson 10. Network Equipment**

Lesson 10 is also a longer lesson, surveying the main types of network equipment in use today, beginning with Layer 2 Switches and Routers, the building blocks of the broadband converged IP network. Then we'll cover Frequency-Division Multiplexers, used in radio and coax, and fiber systems where they are called Wave-Division Multiplexers, plus fiber cross-connects and wavelength add-drop multiplexers. You'll learn the basics of Time-Division Multiplexers and DS0 channels, and gateways that convert media between IP packets and DS0 channels, and signaling between SIP and ISDN messages.

### **Lesson 11. Carrier Network Interconnect**

Lesson 11, the final lesson in this course, covers the two and a half ways that carriers connect to allow communications. First telephone calls to and from PSTN telephone numbers, connecting LECs and IXCs with tandem access trunks at toll center buildings, which is highly regulated and specified in minute detail in tariffs. Second, ISPs exchanging IP packets at Internet Exchange buildings, which is barely regulated if at all. The half is connections for MPLS VPNs across different carriers when they are partnering to provide global communications.

## **Course 2206 Wireless Telecommunications**

Mobile Network Fundamentals • Cellular Principles • Digitized Voice over Radio • Mobile Internet • FDMA, TDMA, CDMA and OFDM • 4G LTE and OFDMA • 5G: New Spectrum, Ultra-Broadband and IoT • Wi-Fi 6 802.11ax • Communication Satellites

10 interactive multipart lessons, multiple-choice exam and certificate. Produced 2020.

Wireless Telecommunications is a comprehensive up-to-date course on cellular plus Wi-Fi and satellites for non-engineering professionals.

Taking this course, you will develop a solid understanding of the fundamental principles of radio, mobility and cellular, network components and operation, digital radio, mobile phone calls and mobile Internet access, spectrum-sharing technologies like OFDM, and LTE and 5G. In addition, you will get up to speed on the components, operation and latest standards for Wi-Fi, and the essentials of satellite communications.

We'll cut through the jargon to demystify wireless, explaining the fundamentals of cellular and mobility, the buzzwords, the network, technologies and generations, the underlying ideas, and how it all works together... in plain English.

### **Course Outline**

#### **1. Introduction**

*Course introduction and overview. Basic radio principles, analog and digital over radio.*

#### **2. Mobile Network Components, Jargon and Basic Operation**

*Handset, base station, airlink, handoffs, connection to wireline systems*

#### **3. Cellular Principles**

*The requirements of coverage, capacity and mobility: cellular for coverage, spectrum sharing for capacity, and handoffs for mobility.*

#### **4. PSTN Calls Using the Native Phone App: "Voice Minutes"**

*Components and operation involved in a phone call: microphone, codec, RF modem, antenna, backhaul and connection to other carriers at the Toll Center building*

#### **5. Mobile Internet: "Data Plan"**

*Mobile Internet via a smartphone; using the RF modem and antenna as a tethered modem, mobile Wi-Fi hotspot.*

#### **6. Spectrum-Sharing Technologies: FDMA, TDMA, CDMA, OFDM**

*Sorting out the generations and standards*

#### **7. 4G LTE: Mobile Broadband**

*Subcarriers, how LTE implements modems on subcarriers, and OFDMA for dynamic capacity sharing.*

#### **8. 5G New Radio: Enhanced Mobile Broadband, IoT Communications**

*New spectrum and use cases: more b/s at conventional frequencies, ultra-broadband in millimeter-wave bands, and low bit rates for IoT devices.*

#### **9. Wi-Fi: 802.11 Wireless LANs**

*Wi-Fi components and principles of operation, 802.11 standards, frequency bands and coverage, including Wi-Fi 6 802.11ax, implementing OFDMA with massive performance increase. Completed with WPA-2 and WPA-3 Wi-Fi security.*

#### **10. Communication Satellites**

*Geosynchronous Earth Orbit and Low Earth Orbit, Iridium Next and Starlink.*

## **Prerequisites**

None. Course 2201 The PSTN has some relevance, as the mobile networks connect to the wireline Public Switched Telephone Network. Courses 2211 Ethernet, LANs and VLANs, and 2213 IP Networks, Routers and Addresses are relevant to Lesson 9.

## **Course Objectives: What You Will Learn**

The objective of this course is to develop a solid understanding of mobile cellular communications networks and technologies. After taking this course, you will be up to speed on the fundamental principles of cellular radio networks, components and operation, digital radio, spectrum-sharing technologies and the four generations of mobile cellular technology. An additional objective is a basic understanding of WiFi and satellites.

On completion of this course, you will be able to:

- Describe the basic concepts of a mobile communication system, identifying the principal components, the objectives of coverage, capacity and mobility, and the operation including registration and handoffs.
- Explain what “cellular” means and why radio systems are designed as cellular systems.
- Explain how digital cellular can be used for what used to be called “data” (now basically Internet access), using a phone as a tethered modem to connect a computer for Internet access, using a phone as a Wi-Fi hotspot for other computers, or of course surfing the web and using apps directly from a smartphone.
- Explain the principles and describe the operation of the different spectrum-sharing technologies: FDMA, TDMA, CDMA and OFDM.
- Define the term subcarrier, how subcarriers are used, and OFDMA.
- Identify the spectrum 5G will be deployed on and use cases for each.
- Explain the basics of 802.11 wireless LANs, Wi-Fi and hotspots and compare and contrast that to cellular radio.
- Describe the two basic strategies for communication satellites and the pros and cons of each.

## **Detailed Course Description**

We begin with basic concepts and terminology involved in mobile networks, including base stations and transceivers, mobile switches and backhaul, handoffs, cellular radio concepts and digital radio concepts.

You'll understand how a phone call connects from a cell phone to a landline, and the different methods of allowing other devices to use a smartphone's mobile Internet connection.

Without bogging down on details, we'll review spectrum-sharing technologies: FDMA for first generation; 2G GSM/TDMA, 3G CDMA and 4G and 5G OFDM.

We'll take some time to understand how modems represent bits on subcarriers, and how OFDMA is used in 4G and 5G to dynamically assign subcarrier(s) to users.

This is followed with Wi-Fi, or more precisely, 802.11 wireless LANs: the system components, frequency bands, bitrates and coverage. We'll also cover WPA-2 and WPA-3 security.

The course is completed with communications satellites, in Geosynchronous Earth Orbit and Low Earth Orbit, including Iridium Next and Starlink.

### **Lesson 1. Course Introduction**

The first lesson begins the course with an overview of the course and lessons, plus general radio principles.

This lesson is available for free on [teracomtraining.com](http://teracomtraining.com) and provides both a walkthrough of the course and a sample of the quality of the course graphics, text and presentation.

### **Lesson 2. Mobile Network Components, Jargon and Operation**

The basic components and operation of a mobile communication network, including handset, airlink, antennas, base station, transceiver, mobile switch, backhaul, registration and handoffs.

### **Lesson 3. Cellular Principles**

In this lesson, we'll begin with the requirements on the communication system: mobility, coverage and capacity, then cover the idea of a cellular radio system, and how it is used to meet the coverage requirement, how frequency-division multiplexing was used to meet the capacity requirement in the first generation of cellular.

### **Lesson 4. PSTN Calls Using the Phone App: "Voice Minutes"**

We'll explore how voice is communicated over the radio access network, and how it connects to the world to make regular telephone calls. In this lesson, we'll understand POPs, Toll Centers and the legacy Tandem Access Trunks used to connect the mobile network to the local phone company, other Local Exchange Carriers like cable TV companies and competing mobile operators, and to Inter-Exchange Carriers.

## **Lesson 5. Mobile Internet: “Data Plan”**

Next, we'll understand how the mobile network connects to the Internet at Internet Exchanges, transit and peering, and how devices can connect to the handset to gain access to its Internet connection, using it as a tethered modem, implementing a Wi-Fi access point in the handset, connecting with Bluetooth; or using the smartphone itself.

## **Lesson 6. Spectrum-Sharing Technologies: FDMA, TDMA, CDMA, OFDM**

Cellphones transmit and receive signals over shared radio bands. To separate users so that they do not interfere with one another, nor hear each other's conversations, service providers use one of four radio band or spectrum sharing methods: Frequency-Division Multiple Access (FDMA), Time-Division Multiple Access (TDMA), Code-Division Multiple Access (CDMA) and Orthogonal Frequency-Division Multiplexing (OFDM).

## **Lesson 7. 4G LTE: Mobile Broadband**

After more than 20 years of incompatible 1G, 2G and 3G systems, 4G was the first world standard for mobile. Since 4G, along with 5G, DSL, Cable modems and Wi-Fi all use OFDM, we'll spend some time understanding OFDM, subcarriers and modulation, and how 4G implements OFDMA to support multiple users.

## **Lesson 8. 5G New Radio: Enhanced Mobile Broadband, IoT**

In the last lesson on mobility, we'll explore the fifth generation, called New Radio in standards committees. You'll learn about the new spectrum for 5G, from the 600 MHz to millimeter-wave bands, and the bit rates to be expected at each. We'll discuss the design goals for 5G, and finish with use cases including low-bandwidth IoT applications and ultra-bandwidth for VR.

## **Lesson 9. 802.11 Wireless LANs - WiFi**

Here, we provide an overview of the 802.11 wireless LAN standards, Wi-Fi and hotspots. We concentrate on understanding the variations of 802.11, the frequency bands they operate in, bit rates to be expected, propagation issues, and Wi-Fi 6, which is 802.11ac, the first to implement OFDMA.

Since 802.11 is wireless LANs, there are a number of associated topics: LAN frames, also called MAC frames, MAC addresses, LAN switches, IP addresses, routers and network address translation. Those topics are covered in other courses, particularly “LANs, VLANs, Wireless and Optical Ethernet”, “Introduction to Datacom and Networking” and “IP Networks, Routers and Addresses”. In this course, we concentrate on radio.

## **Lesson 10. Communication Satellites**

In this last lesson of the course, we will take a quick overview of communication satellites, understanding the basic principles and the advantages and disadvantages of the two main strategies: Geosynchronous Earth Orbit and Low Earth Orbit, with an update on Iridium Next and Elon Musk's Starlink.

## Course 2221 Fundamentals of Voice over IP

Jargon & Buzzwords • VoIP Phone System Components and Operation • Voice Packetization • LANs and WANs • VoIP Phones • SIP, Softswitches & SIP Trunking • Cloud • The Future  
9 interactive multipart lessons, multiple-choice exam and certificate.

Fundamentals of Voice over IP is a complete introduction to everything Voice over IP.

You'll learn the fundamental ideas and principles of a VoIP telephone system, VoIP, SIP & all the other jargon - what it actually means and how it all works together.

At each step, we'll also cover supporting and related technologies like Ethernet MAC frames, codecs and video over IP.

This course can be taken by anyone who needs to get up to speed on all things VoIP. You will gain career-enhancing knowledge of the components and operation of Voice over IP systems, and learn what all of the jargon and buzzwords mean.

You'll gain a solid understanding of the fundamentals of telephone calls via VoIP and the different kinds of equipment involved in telephone calls on the modern broadband converged IP telecom network.

Based on the opening chapter of Teracom's famous instructor-led Course 130, tuned and refined over the course of 20 years of instructor-led training, we'll cut through the jargon to demystify telephony and the telephone system, explaining the jargon and buzzwords, the underlying ideas, and how it all works together... in plain English.

We'll finish with a discussion of where all of this is headed: Broadband IP Dial Tone, where in the future, the Internet and the telephone network will be the same thing.

### Course Outline

#### 1. The Big Picture

*Course introduction and overview.*

#### 2. VoIP Phones and Terminals

*Components of a VoIP phone, speech packetization, codecs, SIP, voice prioritization, LTE and 5G*

#### 3. Voice in IP Packets

*Speech from lips to ear through digitization, RTP, UDP, IP, MAC and copper, fiber or wireless*

#### 4. SIP and Softswitches - SIP Servers / Call Managers

*Video visit to a CO to explain "softswitch", SIP running on softswitch, PBX, Hosted PBX, cloud*

#### 5. Media Servers

*Video and in the future, VR is where the money is. Video over IP, servers, Netflix appliance, DRM*

#### 6. Gateways

*Protocol converters: old channelized DS0 systems ↔ Voice over IP, media and signaling conversion*

#### 7. Connecting: LAN and WAN

*Layer 2 switches and PoE on Cat 6 in-building, Optical Ethernet to carrier services: VPN, SIP Trunking*

#### 8. Key VoIP Standards

*A roundup of standard protocols: SIP and SDP, RTP, UDP vs. TCP, IP, 802, G.711, Cat 6, OE*

#### 9. Where All of This is Headed: IP Dial Tone

*A peek at the Future, when the Internet and the telephone network are the same thing.*

### Prerequisites

None.

## **Course Objectives: What You Will Learn**

The objective of this course is to put in place a solid, structured base of knowledge in the technology and implementation of communicating thoughts from one person's brain to another via a telephone conversation carried in IP packets.

In particular, on completion of this course, you will be able to explain:

- How a VoIP phone is more of a computer than a phone, and its computer functions
- How a VoIP phone digitizes the speech coming into a microphone
- The idea of adding a time stamp to a 20 ms segment of digitized speech
- How UDP adds a port number and error check
- IP adds the called party's telephone's IP address and creates an IP packet
- This is carried in a MAC frame over a physical circuit to the next router
- Reconstructing the speech at the far end
- What happens when packets with voice get delayed or lost
- That SIP is the protocol for exchanging little text messages to start a phone call
- That each end has a SIP server, either running locally, at a remote site or in the cloud
- The calling party asks their SIP server to ask the called party's SIP server if the called party wants to take a call
- If the called party says "yes", the two phones thereafter exchange Voice in IP Packets directly, and the SIP servers drop out of the story.
- That **video** over IP is where the real money is
- What a video server is made of, where it is located, and what it does
- What a gateway is and why it is needed
- What technologies used in old telephone systems have to be converted
- Wiring VoIP phones to Layer 2 aggregation and PoE switches in wiring closets
- Connecting Layer 2 switches to a router to connect to a carrier with Optical Ethernet
- VoIP carrier services, including SIP trunking, MPLS VPN, Internet SD-WAN
- What a Service Level Agreement is
- The key standards related to VoIP from RTP and G.711 to Optical Ethernet
- How basic telecom service will be Broadband IP Dial Tone in the future, as the Internet and the telephone network become the same thing.
- How telephone service becomes a helper application called SIP everyone uses
- How the web is already a helper application called DNS everyone uses
- A voice call is just another kind of traffic on the IP-PSTN

Note: that is a lengthy list of knowledge! This is the introduction, a first pass through all of the above, to get you familiar with the basic structure, components and operation of telephone calls in IP packets. No-one is expecting anyone to be an instant expert.

There are five follow-on courses in the Certified VoIP Analyst CVA Certification Package if you would like to dive deeper.

## **Detailed Course Description**

This course is an introduction to everything VoIP, a broad survey of everything involved in moving speech from lips to ear in IP packets.

### **Lesson 1. Course Introduction**

The first lesson begins the course with an overview of the course and lessons.

This lesson is available for free on [teracomtraining.com](http://teracomtraining.com) and provides both a walkthrough of the course and a sample of the production quality.

### **Lesson 2. VoIP Phones and Terminals**

We'll start at the source: how a VoIP phone creates packets with speech in them to send, and recreates speech from packets received. We'll explain VoIP phone computer functions, telephone functions, speech digitization and codecs, creating IP packets containing voice, SIP for call setup, QoS, softphones and cellphones.

### **Lesson 3. Voice in IP Packets**

Here, we'll trace speech from lips to ear via IP: speech microphone analog voltage, then digitization and packetization, UDP port and error check, IP destination address and routers, Ethernet device address and links, and reconstruction at the far end.

### **Lesson 4. SIP and Softswitches - SIP Servers / Call Managers**

In this lesson we'll explain SIP: how telephone calls are set up in the VoIP world. We'll start with a video visit to an old-style CO switch, then understand what a soft switch is by comparison. We'll look at the different choices for where the softswitch software is running: on a local Call Manager, at a carrier, on a Hosted PBX, in the cloud.

### **Lesson 6. Gateways**

There is an enormous installed base of technology that employs circuit-switching, trunks and trunk carrier systems, built during the last 40 years of the last millennium. Today's IP-based telecommunications will eventually replace all of it; in the meantime, the old and the new have to be connected. We'll see that the device that does this a *gateway*, converting the formatting of the voice, and the call control messages.

### **Lesson 7. VoIP on Copper LANs and Fiber WANs**

This lesson covers in-building wiring, and carrier services for connecting. We'll explain Layer 2 aggregation switches in wiring closets, providing Power over Ethernet (PoE) over Category 6 cable to the phone. You'll understand how those are connected to a router to connect to a carrier, and the VoIP carrier services available: SIP trunking, MPLS VPNs, Internet service and VPNs (SD-WANs), and Service Level Agreements.

### **Lesson 8. Key VoIP Standards**

Here, we'll categorize and summarize the standard protocols used in conjunction with VoIP telephone calls, including SIP and SDP call setup, G.711 / G.729 codecs, RTP time stamps, UDP port numbers, IP addresses and routing, MAC addresses and frames, 802.3 Ethernet on Cat 6 cable, Optical Ethernet and 802.11 wireless links.

### **Lesson 9. Where All of This is Headed: IP Dial Tone**

We'll finish this survey of everything VoIP with a peek at the Future, where the Internet and the telephone network are the same thing, and the basic telecom service is no longer phone calls, but the ability to send an IP packet to anyone on the planet.

## **Course 2201 The PSTN**

Loops and Trunks • Circuit-Switching • LECs and IXCs • Analog • Voiceband • DTMF • SS7

8 interactive multipart lessons, multiple-choice exam and certificate. Produced 2020.

This course is dedicated to the Public Switched Telephone Network (PSTN) and Plain Ordinary Telephone Service (POTS).

One cornerstone of a full, rounded base of knowledge of telecommunications is the structure and operation of the Public Switched Telephone Network, built over the past 135 years, still in operation in every country on earth – knowledge necessary for connecting the PSTN to, and steadily replacing the PSTN with IP telecom technologies.

You'll gain a solid understanding of the fundamentals of the telephone system: customer premise and Central Office, loops, trunks, remotes, circuit switching and how a telephone call is connected end-to-end. We'll cover LECs and IXCs, sound, analog and the voiceband, twisted pair, DTMF and SS7.

Based on Teracom's famous Course 101, tuned and refined over the course of 20 years of instructor-led training, we'll cut through the jargon to demystify telephony and the telephone system, explaining the jargon and buzzwords, the underlying ideas, and how it all works together... in plain English.

Featuring many photos of actual equipment both inside a Central Office and in the outside plant, this multimedia course is an excellent way to get up to speed on traditional telephony.

### **Course Outline**

#### **1. Introduction**

*Course introduction and overview.*

#### **2. History of Telecommunications**

*Local phone companies, long distance; US: Bell System, breakup, LECs and IXCs; Canada*

#### **3. The Public Switched Telephone Network (PSTN)**

*Loops and trunks, CO, customer premise, circuit-switching, outside plant, loop length, remotes*

#### **4. Analog Circuits and Sound**

*What analog means, microphones and speakers, copper wires and electricity, sound: trees falling in the forest*

#### **5. The Voiceband**

*Reproducing thoughts vs. reproducing sound, frequency range, filters, limitations*

#### **6. Plain Ordinary Telephone Service (POTS)**

*Twisted pair, analogs on two wires, dial tone, ringing, supervision, lightning protection*

#### **7. Signaling: Pulse Dialing and DTMF**

*Dial-up, make-or-break signaling, touch-tone, DTMF, in-band signaling*

#### **8. Signaling System 7 (SS7)**

*Control system for the PSTN, SCPs and SSPs, call routing between carriers*

### **Prerequisites**

None.

## **Course Objectives: What You Will Learn**

The objective of this course is to understand how the physical telephone network is organized, the characteristics of basic telephone service, how calls are established end-to-end, and to demystify common telephony jargon and buzzwords.

In particular, on completion of this course, you will be able to explain:

- Why telecom networks are divided into local access wiring and long-distance transmission
- The founding, breakup and re-emergence of AT&T in the US; TELUS and Bell in Canada
- A basic model for the PSTN and its main components
- Loops, why they are called loops and why there is a maximum loop length
- The outside plant
- Circuit-switching
- Central Office and Customer Premise
- How and why remotes are used; fiber to the neighborhood
- Plain Ordinary Telephone Service
- What analog is, and how it relates to copper wires, electricity, circuits and sound
- How microphones and speakers work
- The human hearing range
- Whether trees falling in the forest if no-one is there to hear them cause a sound
- The voiceband
- Why and how the telephone system can limit frequencies to the voiceband
- Why two wires are used
- Why they are twisted together (twisted pair)
- Tip and ring, -48 volts
- Supervision, dial tone, ringing, lightning protection
- Dial-up
- Touch-tone and DTMF
- Basics of SS7
- Examples of sophisticated call routing using SS7

## **Detailed Course Description**

In this course, we'll understand the Public Switched Telephone Network (PSTN), and Plain Ordinary Telephone Service (POTS). Though Voice over IP, SIP and broadband Internet will eventually replace the PSTN and its circuit-switched, channelized and analog technologies, understanding POTS and the PSTN remains one of the cornerstones of a complete understanding of telecom.

Based on Teracom's famous instructor-led Course 101, tuned and refined over twenty years, this course will give you solid foundational knowledge that will be useful to anyone in the telecom business: how the physical telephone network is organized, the characteristics of basic telephone service, how calls are established end-to-end, and understanding of telephony jargon and buzzwords... in plain English.

It is tempting for newcomers to telecom to think "this is old stuff, we don't need to know this, it's all IP now"... but it is not difficult to come up with a list of reasons why understanding The PSTN is still necessary.

There are hundreds of millions of POTS lines and PBX trunks still in service, still being maintained and still generating revenue for carriers. This will not disappear overnight, but will continue to be supported for many years to come, until the last POTS line is disconnected. Broadband Internet service is provided using DSL modems over the wires put in place for POTS.

Even if we were to move to an all-Voice-over-IP network, at least the last foot will still be analog: at residences, a cable modem or fiber terminal performs the functions of a POTS line card: power, dial tones, ringing and analog signals to regular phones via the telephone wires inside the house. At a business, the analog-digital conversion might happen inside a VoIP telephone plugged onto the LAN - but the signals on the curly cord attached to the handset are analog.

Many VoIP systems digitize voice at 64 kb/s, a bit rate that is directly related to the voiceband defined for analog POTS. Legacy SONET and SDH fiber-optic transmission infrastructure are organized into 64 kb/s channels.

Understanding channels and circuit-switching is necessary to know how a phone call from a cellphone on a wireless network connects to a phone plugged into a competitor's cable modem in another city.

There is a huge inertia of regulations, tariffs, accounting and money involved in the Interconnect between local exchange carriers (the "last mile"), and competing inter-exchange carriers, (the "long distance"), that is based on Tandem Access Trunks, channelized PSTN circuit-switched technology.

### **Lesson 1. Course Introduction**

The first lesson begins the course with an overview of the course and lessons.

This lesson is available for free on [teracomtraining.com](http://teracomtraining.com) and provides both a walkthrough of the course and a sample of the production quality.

### **Lesson 2. History of Telecommunications**

We begin the course proper with a history lesson. We'll understand why telecom networks are divided into local access wiring and long-distance transmission, the invention of the telephone and Bell's patent and the emergence of local telephone companies. Then, in the USA: the founding of AT&T, the expiry of the patent and emergence of independents, Federal government action against AT&T resulting in its

breakup, the emergence of cellular and internet telephony, the end of long-distance as a standalone business and the re-combination of pieces of the former AT&T into AT&T and Verizon. An optional section on Canadian telecommunications covers the establishment of provincial telephone companies, then consolidation under TELUS and Bell Canada.

### **Lesson 3. The Public Switched Telephone Network (PSTN)**

In this lesson, we will establish a basic model for the PSTN and understand its main components: Customer Premise, Central Office, loop, trunk, outside plant, circuit switching, attenuation, loop length, remotes, and why knowledge of the characteristics of the loop remains essential knowledge even though we are moving to Voice over IP.

### **Lesson 4. Analog Circuits and Sound**

The technique for representing information on an ordinary local loop is called analog. This term is often thrown about with little regard for its actual meaning, so we will spend a bit of time understanding what is meant by “analog”, how this relates to copper wires, electricity, circuits and sound, the human hearing range, whether trees falling in the forest cause sound if there are no humans present, and choices for designing the telephone system related to that question.

### **Lesson 5. The Voiceband**

In this lesson, we examine the bandwidth provided with Plain Ordinary Telephone Service, which is often referred to as *the voiceband*. We’ll understand what the term “bandwidth” means, and how it is measured in the analog world. We’ll look at the details of the voiceband, what frequencies it covers and why, and its limitations.

### **Lesson 6. Plain Ordinary Telephone Service**

Loops, trunks, circuit-switching and the voiceband are all aspects of Plain Ordinary Telephone Service (POTS). In this lesson, we will cover the remaining principal aspects of POTS along with associated jargon and buzzwords including twisted pair, the function of the microphone, speaker and hybrid converter, how the voltage analogs for each direction are added together on the loop, supervision, loop-start signaling and ringing and lightning protection.

### **Lesson 7. Signaling: Pulse Dialing and DTMF**

This lesson covers one last principal aspect of POTS: the mechanism for signaling the called party telephone number from the calling party’s telephone to the line card. We first cover the original design, using a rotary dial, then an improvement using tones called Dual Tone Multiple Frequency (DTMF) signaling.

### **Lesson 8. Signaling System 7 (SS7)**

This lesson provides a top-level overview of the system used for signaling the called number from the near-end switch to the far-end switch, which is part of the call setup function. This called Signaling System 7 (SS7) in the USA and Canada. It is used for many functions in addition to call setup. In the rest of the world, other systems are used, including ISDN and proprietary systems. This lesson covers SS7, though the basic principles are applicable to any network signaling system.

## Course 2212 The OSI Layers and Protocol Stacks

Protocols & Standards • Open Systems • OSI Model • Layers • Protocol Stacks • FedEx Analogy  
14 interactive multipart lessons, multiple-choice exam and certificate. Produced 2020.

The OSI Layers and Protocol Stacks begins the discussion of IP-based telecom in the Certified Telecommunications Network Specialist (CTNS) certification package. It is the first course in the Certified IP Telecom Network Specialist (CIPTS) package.

This course establishes a framework for all of the subsequent discussions: the OSI 7-Layer Reference Model, which identifies and divides the functions to be performed into groups called *layers*. This framework is required to sort out the many functions that need to be performed, and to be able to discuss separate issues separately.

You'll learn what a layer is, the purpose of each layer, see examples of protocols used to implement each layer, and learn how a protocol stack really works with the famous "FedEx Analogy" presented as an embedded video by our top instructor, Eric Coll.

We'll cut through the jargon to demystify layers, explaining jargon and buzzwords, and most importantly, the underlying ideas, and how it all works together... in plain English.

### Course Outline

#### 1. Introduction

*Course introduction and overview.*

#### 2. Open Systems

*Open systems vs. proprietary systems.*

#### 3. Protocols and Standards

*The difference between a protocol and a standard.*

#### 4. ISO OSI 7-Layer Reference Model

*Top-level overview and introduction to Layers*

#### 5. The Physical Layer

*Fiber, Twisted Pair, Cable and Wireless*

#### 6. Data Link Layer

*LANs and MAC Addresses*

#### 7. Network Layer

*IP, MPLS, Packets and Routers*

#### 8. Transport Layer

*Reliability, Connections, Ports and Sockets*

#### 9. Session Layer

*SIP, POP and HTTP*

#### 10. Presentation Layer

*ASCII, MIME, Compression, Encryption, Codecs*

#### 11. Application Layer

*SMTP, HTML and English*

#### 12. Protocol Stacks

*The FedEx Analogy*

#### 13. Protocol Headers

*Babushka Dolls*

#### 14. Standards Organizations

## **Prerequisites**

None. This is the best course to begin learning about IP and MPLS networking.

## **Course Objectives: What You Will Learn**

This course can be taken by both those who need simply an overview and introduction to the idea of layers and the OSI model, and by those embarking on a certification and/or planning to take further courses.

If you're in the first group, the objective is not to become an instant expert, but rather to become familiar with the structure that is used to be able to discuss separate issues separately, what a layer is, the basic functions of each layer, what a protocol stack is and how it works, and where things you've heard of before like Ethernet, IP and TCP fit into the picture... to demystify the jargon and buzzwords, to eliminate frustration and increase your confidence and effectiveness.

If you're in the second group, and your objective is to put in place a structure for subsequent courses, following is a list of concrete objectives. On completion of this course, you will be able to explain:

- The concept of an open system and its advantages
- What a protocol is and what a standard is
- The OSI Model and its purpose
- What a Layer is
- The seven layers of the OSI model
- The name of each layer
- The functions each layer is responsible for
- Examples of actual protocols for each layer
- What a protocol stack is and how it operates
- Examples of standards organizations that publish protocols

## **Detailed Course Description**

There are so many functions that need to be performed to be able to interwork different systems, a structure is required to be able to categorize and separate functions, so that it is possible to discuss separate issues separately and not mix things up. The method most commonly used to enable discussion of separate issues separately is the ISO OSI 7-layer Reference Model.

We'll start our discussion with some definitions, then an overview of the OSI model, introducing the ideas of layers, layered architectures and protocol stacks. Then we'll go through the layers individually and give examples of protocols like IP, TCP, LANs and DSL to see where they fit into the stack. We'll finish off understanding how a protocol stack actually works in operation, and conclude the course with a review of different active standards organizations.

**Lesson 1. Course Introduction**

The first lesson begins the course with a preview of the different functions that must be performed with a multimedia slideshow to illustrate the functions, then an overview of the course and lessons.

This lesson is available for free on [teracomtraining.com](http://teracomtraining.com) and provides both a walkthrough of the course and a sample of the quality of the course graphics, text and presentation.

**Lesson 2. Open Systems**

In this lesson, we'll understand what is meant by an "open" system, and its advantages over proprietary systems and previous methods of interoperation.

**Lesson 3. Protocols and Standards**

Here, we'll sort out what is meant by the term "protocol", and how that relates to the concept of a standard. We will also start considering how many functions have to be performed to interoperate systems, and how these functions might be organized.

**Lesson 4. The ISO OSI 7-Layer Reference Model**

The ISO OSI 7-Layer Reference Model is the model most commonly used to define the structure of the "set of structured protocols" introduced in the previous lesson. We'll understand the reference model and how it operates, then introduce the layers in the OSI model, the name of each layer and the functions of each layer. In subsequent lessons, we'll go over the story again, more slowly, one layer at a time.

**Lesson 5. The Physical Layer: Fiber, Twisted Pair, Cable and Wireless**

Layer 1 is moving bits over Fiber, Twisted Pair, Cable and Wireless

**Lesson 6. The Data Link Layer: LANs and MAC Addresses**

Next is Layer 2, the Data Link Layer, responsible for managing aspects of communications between two stations on the same circuit. We'll cover frames, LANs and MAC addresses.

**Lesson 7. The Network Layer: IP, MPLS, Packets and Routers**

Here, we'll see that the definition of a network is connecting many data links together with network equipment, usually with redundant paths for availability and performance reasons. This implies the requirement to make route decisions. We'll see that the two basic kinds of networks are circuit-switched, i.e. the traditional telephone network, and packet-switched, networks using routers to forward packets from one link to another.

**Lesson 8. The Transport Layer, Ports and Sockets**

In this lesson, we'll cover Layer 4: the Transport Layer. We will see that there are two main functions: reliability of communications between the two end-point devices, and narrowing down the communications to particular software applications running on the devices. TCP and UDP are Layer 4 protocols in the OSI Model.

**Lesson 9. The Session Layer: SIP, POP and HTTP**

Layers 5, 6 and 7 are referred to as the “upper layers”. In this lesson, we will understand the functions associated with Layer 5: the session layer, responsible for initiating, maintaining and terminating sessions between software applications on different machines connected by a transport service. We will see that the usual implementation follows a client-server scenario, with the client logging on the server with a user name and password and having permissions after being authenticated. In other cases, the session establishment is less sophisticated, for example, no authentication and a session that lasts for the transfer of one web page; and in yet other cases is more sophisticated, involving the communication of the endpoints’ IP addresses to each other so they can subsequently communicate directly as is the case with SIP.

**Lesson 10. The Presentation Layer: ASCII, MIME, Compression, Encryption, Codecs**

Layer 6 is the Presentation Layer, a very important discussion, as this is the coding step, where messages are coded into 1s and 0s for eventual communication. ASCII, MIME, compression, encryption, and codecs all fit into this layer.

**Lesson 11. The Application Layer: SMTP, HTML and English**

In this lesson, we’ll examine the uppermost layer of the OSI model, Layer 7, the application layer. We will see that the application layer specifies the message to be transmitted to another system. It defines the format, vocabulary and syntax of messages. The same software that implements the application layer usually also implements a Human-Machine Interface... since in many instances, a human generates the content of the message.

**Lesson 12. Protocol Stacks: The FedEx Analogy**

In this lesson, we’ll employ an analogy of business-to-business communications using FedEx to illustrate how a protocol stack works, and better understand the OSI layers from a procedural point of view: how information travels down through the protocol stack on the left, through the network equipment in the center, and back up the protocol stack on the right. This lesson features video of our top instructor, Eric Coll, explaining the FedEx analogy to you via the camera on the left side of the screen, plus a graphical illustration on the right. Enjoy!

**Lesson 13. Protocol Headers and Babushka Dolls**

We’ll understand how a protocol stack works from a bits point of view: how one layer passes a block of 1s and 0s called a Protocol Data Unit to a lower layer, which performs its functions and adds control information in a header to create a bigger PDU, which is then passed down to the next lower layer. The result is like Russian Babushka dolls: a small doll inside a bigger one, inside a bigger one, inside a bigger one... and in our case, repeating seven times.

**Lesson 14. Standards Organizations**

The last lesson in this course is Standards Organizations, a brief overview of organizations that publish what they hope will become standard protocols for communications.

## Course 2211 LANs, VLANs, Wireless and Optical Ethernet

MAC Addresses • Frames • Layer 2 Switches • VLANs • Ethernet on Copper • 1000BASE-T • Power over Ethernet • Cable Categories • Office Wiring Plan • Wireless Ethernet (Wi-Fi) • Optical Ethernet • Ethernet in the Core, MANs and PONs • Fiber Types • SFP Transceivers • Optical Ethernet Field Installation

7 interactive multipart lessons, multiple-choice exam and certificate. Produced 2020.

This course is all about Ethernet: the fundamentals, equipment and implementations, including twisted-pair copper cables, wireless and optical; in-building, in the network core, in MANs and PONs.

Based on Teracom's famous Course 101, tuned and refined over the course of more than 25 years and counting of instructor-led training.

We'll cut through the jargon to demystify Ethernet, MAC addresses, LANs and VLANs, Ethernet on copper wires, Ethernet over the Ether (Wi-Fi) and Ethernet on fiber: Optical Ethernet.

You'll understand the jargon and buzzwords, the underlying ideas, and how Ethernet in all its forms is the pipes that make up the broadband converged IP telecom network.

### Course Outline

#### 1. Introduction

*Course introduction and overview*

#### 2. Broadcast Domains, MAC Addresses and MAC Frames

*How devices are identified and communicate on a LAN. Security concept of a broadcast domain*

#### 3. LAN Switches, a.k.a. Layer 2 Switches

*The purpose of Layer 2 switches, how they forward frames and learn MAC addresses*

#### 4. VLANs

*The important software tool used to segregate traffic at the lowest level*

#### 5. 802 Physical Standards: 802.3 Twisted Pair and 802.11 Wi-Fi

*IEEE 802.3 copper from 10BASE-T → Gigabit Ethernet, 802.11 wireless Wi-Fi to 802.11ax*

#### 6. Twisted-Pair LAN Cables, Categories, Wiring Plan and Switch Hierarchy

*Category 5, 5e and 6 cables, basic cabling design, Power over Ethernet (PoE)*

#### 7. Optical Ethernet and Fiber Links

*Communicating MAC frames by flashing a light inside a glass tube. Field installation photos.*

### Prerequisites

None. Course 2212 The OSI Layers and Protocol Stacks is useful to understand where LANs fit into the overall picture and how LANs and VLANs relate to routers and IP.

## **Course Objectives: What You Will Learn**

The objective of taking this course is to become familiar with the standard technology used to implement Layer 2 in IP-based packet networks. After taking this course, you will be up to speed on MAC addresses and MAC frames, broadcast domains, LAN cables and LAN switches, VLANs and Optical Ethernet.

In particular, on completion of this course, you will be able to explain:

- The idea of a broadcast domain.
- The idea of a MAC addresses to identify a LAN interface on a station in a broadcast domain.
- What MAC frames are, and what purpose they serve.
- What a LAN switch is, and what it does.
- How VLANs can be used to segregate devices into different broadcast domains.
- The IEEE 802 series of standards: The 802.3 standards from communicating MAC frames at 10 Mb/s on coaxial cables to Gigabit Ethernet on copper and fiber.
- What the code 1000BASE-T means.
- MAC frames over the Ether, a.k.a. Wi-Fi, the 2.4 and 5 GHz unlicensed bands, and the fundamentals of how the bits in MAC frames are communicated using radio carrier frequencies.
- Wiring Ethernet to the work area with Cat 5, Cat 5e and Cat 6 twisted-pair copper-wire cables. Wiring closets and Layer 2 aggregation switches. Power over Ethernet.
- What Optical Ethernet is, and how it is the building block of telecom networks, including Metropolitan Area Networks (MANs), carrier MPLS networks, and Passive Optical Networks (PONs) for fiber to the home.
- The fundamentals of how the bits in MAC frames are communicated using light guided in glass tubes.
- How fiber cables are deployed and connected to equipment at each end.
- What designations like 100GBASE-ER4 mean.

## **Detailed Course Description**

This course is all about Ethernet: the fundamentals, equipment and implementations including twisted-pair copper cables, wireless and fiber, in-building, in the network core, MANs and PONs.

Ethernet implements the equivalent of pipe physically connecting two devices. IP and MPLS are used to move packets from one pipe to another. They are covered in the next two courses.

Ethernet and its MAC frames has fulfilled one of the Holy Grails of telecom, packaging everything the same way on all kind of links: copper wire, fiber and wireless - in the core of the network, in the access network, and in the customer premise. Standardizing on MAC frames across the board makes interworking simpler, more reliable and cheaper to implement. One can only stand back in awe and admire.

We'll begin with the fundamental idea of a broadcast domain, first implemented with a bus cable. We'll understand LAN interfaces, and how each interface has a hard-coded MAC addresses, and how the address field in a MAC frame is used to indicate for whom a frame is intended, since all stations in a broadcast domain receive it.

We'll then understand how the bus is now inside a box called an Ethernet switch, LAN switch or Layer 2 switch, how the switch learns the MAC address of each station, and how the LAN switch forwards MAC frames to one or more stations.

Then we'll go over the important idea of VLANs, which are broadcast domains defined in software, and how VLANs can be used to segregate traffic by device type and by work area at the enterprise level, and segregate traffic by customer at the carrier level.

You'll learn about the many standards for implementing Ethernet, 802.3 from the original 10BASE-5 to 1000BASE-T on Categories of twisted-pair cables, 802.11 wireless LANs and Wi-Fi certification.

We'll finish with a compressive lesson on Optical Ethernet: Ethernet on fiber, which is the basis of today's telecom network. You'll learn how bits are represented on fiber, how fiber cables are installed underground, and how fiber splicing is used to connect bulk fiber to equipment. We'll review Optical Ethernet standards from 1 Gb/s to 100 Gb/s.

## **Course Lessons**

### **Lesson 1. Course Introduction**

The first lesson begins the course with an overview of the course and lessons.

This lesson is available for free on [teracomtraining.com](http://teracomtraining.com) and provides both a walkthrough of the course and a sample of the quality of the course graphics, text and presentation.

### **Lesson 2. Broadcast Domains, MAC Addresses and MAC Frames**

The fundamental idea of devices connected together in a broadcast domain, and how stations communicate using MAC addresses.

### **Lesson 3. LAN Switches, a.k.a. Layer 2 Switches**

How LAN switches are at the center of practical implementation of connecting stations, and how they forward frames between stations in a broadcast domain.

### **Lesson 4. VLANs**

Defining broadcast domains in software to segregate traffic. Used to separate customer traffic on carrier MANs, and used in-building as a basic network security measure.

### **Lesson 5. 802 Physical Standards: 802.3 Twisted Pair and 802.11 Wi-Fi**

Ethernet on copper wires, and standards like 1000BASE-T. Ethernet over the Ether, usually called Wi-Fi, and how MAC frames are communicated using radio carrier frequencies.

### **Lesson 6. Twisted-Pair LAN Cables, Categories, Wiring Plan and Switch Hierarchy Wiring**

Ethernet to the work area with Cat 5, Cat 5e and Cat 6 twisted-pair copper-wire cables, wiring closets and Layer 2 aggregation switches.

### **Lesson 7. Optical Ethernet and Fiber Links**

The fundamental idea of representing the 1s and 0s that make up a MAC frame using light carried in a glass tube, how fibers are actually installed and commissioned, and review the Optical Ethernet implementations in the 802.3 standard.

## Course 2213 IP Networks, Routers and Addresses

IP Packets • Networks • Routers • Static, Dynamic, Public, Private Addresses • NAT • IPv6  
11 interactive multipart lessons, multiple-choice exam and certificate. Produced 2020.

IP Networks, Routers and Addresses is a comprehensive course on IP networking fundamentals: IP packets, IP addressing and IP routers.

We'll see how routers implement the network with packet-switching, that is, relaying packets from one circuit to another, and how routers are a point of control for network security. We'll introduce the term Customer Edge (CE), and understand the basic structure and content of a routing table.

Then we'll cover the many aspects of IP addressing: IPv4 address classes, dotted decimal, static vs. dynamic addresses, DHCP, public vs. private addresses, Network Address Translation, and finish with an overview of IPv6.

Based on Teracom's famous Course 101, tuned and refined over 20+ years of instructor-led training, we'll cut through the jargon to clearly explain IP, routers, packets and addresses, the underlying ideas, and how it all works together... in plain English.

### Course Outline

#### 1. Introduction

*Course introduction and overview*

#### 2. Review: Channelized Time-Division Multiplexing (TDM)

*Traditional TDM – and why it is inefficient*

#### 3. Statistical Time-Division Multiplexing: Bandwidth-on-Demand

*Overbooking and opportunistic capacity*

#### 4. Network: Bandwidth on Demand + Routing

*The simplest framework for understanding routers and bandwidth on demand*

#### 5. Routers

*Routers and routing tables. Packet forwarding and packet filtering. Customer Edge.*

#### 6. IPv4 Addresses

*Address classes and dotted-decimal notation.*

#### 7. DHCP

*Dynamic addresses and static addresses – and how both are assigned using DHCP*

#### 8. Public and Private IPv4 Addresses

*How to obtain public addresses, and why private addresses are used in many cases*

#### 9. Network Address Translation

*How a NAT glues private IPv4 addressing used in-building to public addressing used on the Internet*

#### 10. IPv6 Overview

*Introduction to IPv6, what's new, the improvements on IPv4 and the IPv6 packet format.*

#### 11. IPv6 Address Allocations and Assignment

*Types of IPv6 addresses, registries and allocations to ISPs. How subnets are assigned to end-users.*

### Prerequisites

None. Course 2212 The OSI Layers and Protocol Stacks is useful to understand where IP and packets fit into the picture. Course 2211 LANs, VLANs, Wireless and Optical Ethernet complements this course, as IP packets are usually carried on Ethernet.

## **Course Objectives: What You Will Learn**

The objective of this course is to develop a solid understanding of IP. After taking this course, you will be up to speed on the fundamental principles of packet networks: bandwidth on demand, also known as overbooking or oversubscription, and packet forwarding. You will know the IP packet format and how IP addresses are allocated, assigned and displayed. You will know the difference between static and dynamic addresses, public and private addresses and how Network Address Translation works. An additional objective is to become familiar with the basics of IPv6.

In particular, on completion of this course, you will be able to explain:

- The concept of statistical multiplexing, also known as oversubscription, overbooking and bandwidth on demand, why and how it can be implemented and its benefits.
- What a private network is
- What a router is and how it implements the network by connecting data links
- How routers move packets between broadcast domains, including VLANs
- How routers also act as a point of control for traffic, called packet filtering
- The basic structure and contents of a routing table
- The Customer Edge
- IPv4 address blocks: Class A, Class B and Class C, and dotted-decimal notation
- Static addresses and dynamic addresses, and how and why DHCP is used to assign both
- Public addresses and private addresses, how, why and where each is used
- Network Address Translation for interfacing domains where public addresses are used with those where private addresses are used
- The improvements and changes between IPv4 and IPv6, and
- The types of IPv6 addresses, how IPv6 addresses are allocated to ISPs then assigned to users, and how each residence gets 18 billion billion IPv6 addresses.

## **Detailed Course Description**

Packet networks embody two main ideas: bandwidth on demand and packet switching. First, we'll recap channelized TDM and its limitations, then understand statistical TDM or bandwidth on demand. Next, we'll understand how routers implement the network with packet-switching, that is, relaying packets from one circuit to another, and how routers are a point of control for network security. We'll introduce the term Customer Edge (CE), and understand the basic structure and content of a routing table.

Then we'll cover the many aspects of IP addressing – needed to be able to do the packet switching: IPv4 address classes, dotted decimal notation, static vs. dynamic addresses, DHCP, public vs. private addresses, Network Address Translation, and finish with an overview of IPv6 overview and IPv6 address allocation and assignment.

### **Lesson 1. Course Introduction**

The first lesson begins the course with an overview of the course and lessons.

This lesson is available for free on [teracomtraining.com](http://teracomtraining.com) and provides both a walkthrough of the course and a sample of the quality of the course graphics, text and presentation.

### **Lesson 2. Review: Channelized Time-Division Multiplexing (TDM)**

We'll review the idea of channelized Time-Division Multiplexing (TDM), what channels are, and how they can be used to aggregate traffic onto a high-speed circuit. Then we'll raise some questions: is that an efficient way to connect devices that produce traffic in bursts, which means devices that are normally doing nothing? And what about the problem of a single point of failure for all the aggregated traffic? Subsequent lessons explore the answers to those questions.

### **Lesson 3. Statistical Time-Division Multiplexing: Bandwidth-on-Demand**

In this lesson, we'll understand how circuits that move bits constantly can be used efficiently when the user's traffic profile is: "idle most of the time, interspersed with bursts of data every once in a while." The answer is overbooking. This is also called statistical multiplexing and bandwidth-on-demand, and is a key part of a packet network: the internal circuits are heavily overbooked, to give users the highest speed at the lowest cost. It is necessary to know the users' historical demand statistics – also called their traffic profile – to know how much to overbook, hence the term statistical multiplexing.

### **Lesson 4. Private Network: Bandwidth on Demand + Routing**

The purpose of this lesson is to expand the discussion of the previous lesson to include multiple circuits. The result is called a private network, and is the simplest framework for understanding routers, routing, network addresses and bandwidth-on-demand.

### **Lesson 5. Routers**

In this lesson, we'll take a closer look at a router, more precisely identifying the functions a router performs to implement a packet network, and understand how a router routes by examining the basic structure and content of a routing table. We'll also understand how the router can act as a point of control, denying communications based on criteria including network address and port number, why this is implemented and its limitations. The term Customer Edge (CE) is defined in this lesson.

**Lesson 6. IPv4 Addresses**

Here, we'll understand IPv4 addresses, address classes and the dotted-decimal notation used to represent them.

**Lesson 7. DHCP**

In this lesson, we'll cover DHCP: the Dynamic Host Configuration Protocol, and understand the mechanism by which a machine is assigned an IP address. We'll also understand how the "dynamic" host configuration protocol can be used to assign static addresses to machines and the advantages of this method.

**Lesson 8. Public and Private IPv4 Addresses**

The purpose of this lesson is to define the terms "public" and "private" IP address, review how IP addresses are assigned and the costs for those addresses, then cover the ranges of IPv4 addresses that are used as private addresses, and understand how and why they are used.

**Lesson 9. Network Address Translation**

In this lesson, we'll explore how private IPv4 addresses used in-building and a public address required for Internet communications can be joined together with a software function called Network Address Translation.

**Lesson 10. IPv6 Overview**

Completing this course on IP, we'll first review the next generation of IP: IPv6, understand the improvements compared to IPv4 and review the format of the IPv6 packet and its header.

**Lesson 11. IPv6 Address Allocations and Assignment**

Finally, we examine the structure of the 128-bit IPv6 address, review the different kinds of IP addresses, the organizations that allocate them, and the current plans for how addresses will be assigned to end users... and how every residence gets 18 billion billion IPv6 addresses.

## Course 2214 MPLS and Carrier Networks

Carrier Packet Networks • Technologies • MPLS • SLAs • CoS • Integration & Aggregation

11 interactive multipart lessons, multiple-choice exam and certificate. Produced 2020.

MPLS and Carrier Networks is a comprehensive training course designed to build a solid understanding of carrier packet networks and services, the terminology, technologies, configuration, operation and most importantly, the underlying ideas ... in plain English.

We'll cut through the buzzwords and marketing to demystify carrier packet networks and services, explaining Service Level Agreements, traffic profiles, virtual circuits, QoS, Class of Service, Differentiated Services, integration, convergence and aggregation, MPLS and other network technologies, and how they relate to TCP/IP without bogging down on details.

You will gain career- and productivity-enhancing knowledge of the structure, components and operation of carrier packet networks and services, how they are implemented, packaged and marketed by carriers and how they are used by government, business... and other carriers.

### Course Outline

#### 1. Introduction

*Packet Switching and Bandwidth on Demand concepts. Course overview.*

#### 2. Carrier Packet Network Basics

*Customer Edge, Provider Edge, Access and Core*

#### 3. Service Level Agreements

*Traffic Profile and Class of Service*

#### 4. Virtual Circuits

*Traffic Classes, Virtual Circuits and Virtual Circuit IDs*

#### 5. QoS Requirement for Voice over IP

*How packetized voice works and what is needed*

#### 6. MPLS

*MPLS components, jargon, basic operation*

#### 7. TCP/IP over MPLS

*Tracing a file download end-end, MPLS for VPN or VPLS*

#### 8. Differentiated Classes of Service using MPLS

*QoS, traffic classification, Diff-Serv: multiple CoS*

#### 9. Integration and Convergence using MPLS

*Carrying all traffic on a single network technology*

#### 10. Managing Aggregates of Traffic with MPLS Label Stacking

*Carrying virtual circuits on virtual circuits – access and core*

#### 11. MPLS Services vs. Internet Service

*Similarities and differences, pros and cons. The Future.*

### Prerequisites

Courses 2212 OSI Layers, 2211 LANs and 2213 IP are recommended. Those courses, along with this one, are included in both the Certified Telecommunications Network Specialist (CTNS) and the Certified IP Telecom Network Specialist (CIPTS) certification packages.

## **Course Objectives**

This course can be taken by both those who need simply an overview and introduction to carrier packet networks and MPLS, and by those who need to build a solid base and get up to speed on all or most of the listed topics.

If you're in the first group, the objective is not to become an instant expert, but rather to become familiar with the structure, components and operation of carrier packet networks and services, how they are packaged, marketed and used, and to demystify the jargon and buzzwords, to eliminate frustration and increase your confidence and effectiveness.

If you're in the second group, and your objective is to get up to speed on all or most of the listed topics, putting in place a base that project- or job-specific knowledge can be built on, following is a list of concrete objectives. On completion of this course, you will be able to:

- Explain the components and basic structure of a carrier packet network including core, provider edge, access and customer edge,
- List three ways packet services are better than dedicated lines for wide-area networking,
- Define a Service Level Agreement, Class of Service and traffic profile,
- Define a traffic class and explain what a virtual circuit is, and what they are used for,
- Differentiate between a reliable and unreliable Class of Service and what must be done to accommodate the latter, and briefly explain connection-oriented and connectionless communication modes,
- Explain the fundamentals of Frame Relay: how Frame Relay got its name, how IP is carried over Frame Relay, why TCP is also required, and the traffic profiles supported,
- Identify the steps involved in communicating voice in packets, and what transmission characteristics are critical to call quality,
- Briefly describe the characteristics of ATM and the classes of service it was supposed to implement to support telephone calls,
- Show how MPLS is essentially the same thing as X.25, Frame Relay and ATM but with different jargon – and identify that jargon, including defining the meaning and purpose of a label, and identifying where the label is placed in the headers,
- Trace the flow of a message transported by TCP in IP packets over an MPLS network,
- Identify the benefit of MPLS compared to Frame Relay from the user's point of view,
- Explain what Differentiated Services are, and how MPLS labels can be used to implement Diff-Serv, and an alternative,
- Explain how and why MPLS can be used to achieve service integration,
- Show how MPLS can be used to aggregate traffic,
- Explain what exactly someone means when they say "MPLS service" and explain why "IP service with a service level agreement" would be a more accurate term, and
- Identify two differences between MPLS service and Internet service, and the pros and cons of each.

## **Detailed Course Description**

### **Lesson 1. Course Introduction**

The first lesson recaps the concepts of packet switching and bandwidth on demand, then provides an overview of the topics that will be covered, the course objectives and a description of each lesson. This lesson is available for free on [teracomtraining.com](http://teracomtraining.com) and provides both a walkthrough of the course and a sample of the quality of the course graphics, text and presentation.

### **Lesson 2. Carrier Packet Network Basics**

The fundamental concepts of packet switching and bandwidth-on-demand or overbooking, the physical components involved in using a carrier packet network service including Customer Edge, types of access circuits, the Provider Edge and the network core – and why PE equipment is sometimes deployed at the customer premise. This lesson is completed with a roundup of the benefits of packet services over dedicated lines and circuit-switched connections.

### **Lesson 3. Service Level Agreements: Traffic Profile and Class of Service**

How performance is specified, measured, guaranteed and controlled on an overbooked bandwidth-on-demand network – the Service Level Agreement where the network guarantees specified transmission characteristics, sometimes called a Class of Service, on condition that the customer stays within a defined traffic profile ... and what happens to out-of-profile traffic.

### **Lesson 4. Virtual Circuits**

The fundamentals of virtual circuits, an essential part of all packet communication networks. We'll cover the concepts of traffic classes, virtual circuits, virtual circuit IDs and the fundamental principles of operation that are common to all technologies, including MPLS, and how virtual circuits are a powerful traffic management tool.

### **Lesson 5. QoS Requirement for Voice Over IP**

Packet network services were originally designed for datacom. In this lesson, we'll understand how voice is packetized, carried over a packet network, then reconstructed at the far end – and the transmission characteristics necessary for voice quality.

### **Lesson 6. MPLS**

IP has emerged as the standard for packets that will carry all traffic. Since IP provides a connectionless network service, additional protocols are required to implement virtual circuits to enable management and prioritization of traffic. The choice for IP is Multi-Protocol Label Switching (MPLS). The concepts are the same as other virtual circuit technologies X.25, Frame Relay and ATM... but the jargon is changed. We'll begin by identifying MPLS components, jargon and basic principles of operation.

### **Lesson 7. TCP/IP over MPLS**

In this lesson, we'll revisit tracing the path of a file download from server to client, this time over an MPLS network. This will reveal a significant advantage of MPLS-based network services compared to Frame Relay in the user-network interface. We'll also discuss the "M" in MPLS, noting how MPLS can be used to carry frames for VPLS in addition to the usual IP packets.

**Lesson 8. Differentiated Classes of Service using MPLS**

Here, we'll examine how classifying traffic and mapping classes onto virtual circuits can be a Quality of Service (QoS) mechanism to implement multiple Classes of Service on a packet network. This is sometimes referred to as *differentiated services* or *Diff-Serv*, i.e. providing a different Class of Service for each application: VoIP, IPTV, email, web surfing and others.

**Lesson 9. Integration and Convergence using MPLS**

In this lesson, we'll see how virtual circuits and traffic classification can be used to combine all of the types of communications of a business or organization onto a single access circuit. This idea is sometimes called *convergence*, though *service integration* is a more accurate term. It results in a large cost savings compared to one access circuit for each type of communications.

**Lesson 10. Managing Aggregates of Traffic with Label Stacking**

Here, we'll understand how MPLS labels can be stacked... virtual circuits carried over other virtual circuits, and how this is implemented to *aggregate* traffic for both routing and prioritization reasons – both on access circuits and in the network core.

**Lesson 11. MPLS Services vs. Internet or SD-WAN Service**

This lesson completes the course with a discussion of terminology used in sales and marketing of MPLS services, and how that translates to reality. We will use a quiz question-and-answer format to understand the difference between Internet service – which might be called an SD-WAN, and what sales brochures call “MPLS service” ... and what exactly an “MPLS service” is.