Part 1 Fundamentals of Telecom

The first part of the course is the big picture. We begin by establishing a model for the network which we will use throughout the course to relate one component to another, and identifying categories of services and service providers.

Then we start understanding network concepts, technologies and services at the beginning, with the invention of the telephone, and understand the fundamentals of telephony and the public telephone network. The next chapter covers equipment, including CO switches and softswitches, then an in-depth look at the wired telecommunications business, including CLECs and ISPs.

1. INTRODUCTION

We start with a diagram of the main components involved end-to-end in communication from a residence to the world via Mobily fiber. We'll establish a model for the network and discuss different categories of service providers and services.

A. The All-IP Network
B. Convergence and Converged Networks
    1. A Sea Change in Network Technology
    2. Forget ATM, ISDN and SDH – Everything in IP and Ethernet
    3. Opportunities
C. The Network Cloud
    1. The Network Core
    2. The Access Network
    3. Connecting to Other Networks
D. Categories of Service Providers
E. Network Services
    1. Broadband IP Dial Tone
    2. Internet Service
    3. Telephone Service
    4. IPTV Television Delivery
    5. Virtual Private Network Services
    6. Service-Level Agreements and Quality of Service
    7. Network-Based Antivirus
F. Value-Added Services and Applications
    1. IPTV Television/Movie Programming
    2. All Other Content
    3. Messaging
    4. Conferencing
    5. Web Hosting
G. End-to-End Diagram: Landline Telephone/Television/PC, to Mobily Fiber, to the World

2. POTS AND THE PSTN

The all-IP, all-fiber network builds on more than 100 years of development of network technologies, network operations and network business organizations. A fiber-based service must nonetheless support copper-wire analog Plain Ordinary Telephone Service (POTS) to connect regular telephones inside residences. For both of these reasons, we start understanding networks at the beginning of the story, with the invention of the telephone and then the fundamentals of telephony: COs, loops, trunks, voiceband, circuit-switching, switches and remotes and signaling.

A. History of Telecommunications
B. Loops, Trunks and Circuit-Switching
C. Remotes
D. Analog and the Voiceband
E. Plain Ordinary Telephone Service (POTS)
F. Signaling: DTMF and SS7

3. TELECOM EQUIPMENT

We'll round out our discussion of telephony with a practical overview of different types of equipment that can be connected to the telephone network. Without bogging down on details, we'll sort out CO switches, PBXs, softswitches, ACDs, IVRs, Call Centers and modems, including an introduction to the basics of DSL and how it is provided.

A. CO Switches
B. PBX vs. Centrex
C. IVRs, ACDs and Call Centers
D. Modems
E. DSL
F. DSLAMs

4. THE WIRED TELECOMMUNICATIONS BUSINESS

With the fundamentals in place, we'll review the telecommunications business, including players, alliances and competition, interconnections, the components of a modern competitive carrier network, and the IP business on both the retail and wholesale sides.

A. Carriers and Players
B. PSTN Switching Center Hierarchy
C. LECs, IXCs and POPs
D. Switched Access
E. Dedicated Line Access
F. Collocations and CLECs
G. Hybrid Fiber-Coax
H. Competitive Carrier Network: Regional Rings, POPs and MANs
I. ISPs
J. IP Interconnect
    1. Business Customer Services vs. Internet
    2. Peering and Transit
    3. Content Delivery Networks

Part 2 Telecom Networks and Services

The second part of the course covers the fundamentals of telecommunications network technologies, voice digitized at 64 kb/s, legacy/installed base channelized TDM, DS0s and SDH/SONET, next-generation IP packets and Optical Ethernet, and finishing the "Network Cloud", what is inside the cloud and how customer services are actually put in place.

5. FUNDAMENTALS OF "DIGITAL"

In this chapter, we'll discuss what is really meant by "digital" and understand digital voice, digital video and digital "data" services VPNs and Internet.

A. Why Digital?
B. Analog and Digital: What Do We Really Mean?
C. Voice Digitization (Analog-Digital Conversion)
D. Digital Voice: The 64 kb/s G.711 Standard
E. Digital Video: MPEG and H.264
F. Digital Data: Business Customer VPN, Internet

6. CHANNELIZED TIME DIVISION MULTIPLEXING (TDM)

Channelized TDM and digital carrier systems were the basis of telecommunications network infrastructure for over 50 years – meaning a huge installed base to maintain, to interconnect with and to compare newer packetized infrastructure and services to. Without getting bogged down on technical details, we'll explain multiplexing, TDM and channels, and how channels are carried on systems like SONET/SDH and T1/E1.

A. Channelized Digital Hierarchy: DS0-DS3
B. Channelized Carrier Systems: T1/E1, T3, SDH/SONET, ISDN
C. Channelized Time Division Multiplexing
D. TDM Example: T1/E1 Carrier
E. Multiplexers
F. Framing and Channels
G. International Digital Hierarchies
H. Service Integration using Channels

7. STATISTICAL TIME DIVISION MULTIPLEXING (PACKETS)

An IP network transmits interspersed packets instead of interspersed channels. Here, you'll understand why this is called "statistical multiplexing", a "packet-switched network" and "bandwidth on demand" service. We'll explore the advantage over channelized systems, and how, taking advantage of historical demand statistics, the network is oversubscribed to reduce costs – and the resultant need for Quality of Service mechanisms if guarantees are to be offered.

A. Statistical Time Division Multiplexing
B. IP Packets and Ethernet Framing
C. Optical Ethernet
D. Bandwidth on Demand: Oversubscription
E. Service Integration using Packets
F. Class of Service and Service Levels

8. NETWORK SERVICES AND THE NETWORK "CLOUD"

In this chapter, we'll explore the Network Cloud, why someone would draw a picture of a cloud to represent a network, then look inside the cloud to understand what is really going on. We'll show you the three basic kinds of services available, and the circuits and equipment used to actually provide these services… highly useful knowledge when evaluating, ordering or selling these services.

A. Anatomy of a Digital Service
B. Inside the Network Cloud
C. Network Equipment: How and Where Each Is Used
D. How Services are Actually Provided

Part 3 Physical Connections

The third part of the course is devoted to the technologies for physically connections – using fiber optics, using copper wires, and using the air. Most of the effort will be focused on fiber and Fiber to the Premise (FTTP).

9. FIBER OPTICS

In this chapter, we'll understand fundamentals of fiber optics, including fiber construction, cable construction, wavelengths, modes and dispersion, and the important concept of Wave-Division Multiplexing (WDM). We'll cover Optical Ethernet implemented with SFP modules, used in the network core and for business customer access, and Fiber to the Premise using PONs for residential customers. We'll finish with a slideshow of field-splicing fibers.

A. Light as a Carrier
B. Fibers and Cables
C. Optical Wavelengths and Bands
D. Single-mode, Multimode, Dispersion and Repeaters
E. Wave-Division Multiplexing, CWDM and DWDM
F. Optical Ethernet and SFPs
G. Fiber to the Premise (FTTP): Passive Optical Network vs. Active Optical Network vs. MAN
H. Field Splicing Picture Slideshow

10. COPPER: DSL ON TWISTED-PAIR, COAX CABLE MODEMS

This relatively short chapter covers last-mile technologies for broadband to the premise on copper in brownfields to support high-speed Internet and IPTV. A short discussion on Hybrid Fiber-Coax and cable modems is included for comparison.

A. Modems
B. DSL: Broadband on Twisted Pair
C. DSLAMs
D. OPI DSLAMs
E. DSL Technologies and Speeds
F. VDSL2 Bands and Profiles
G. Pair Bonding and Vectoring
H. Hybrid Fiber-Coax and Cable Modems

11. WIRELESS TELECOMMUNICATIONS

We'll round out your knowledge with wireless, concentrating on mobility. We'll cover mobile network jargon and buzzwords, the idea behind cellular, and sort out different cellular technologies: 2G TDMA/GSM, 3G CDMA and 4G LTE. We'll conclude with an overview of WiFi and satellite communications.

A. Wireless
B. Mobile Networks
C. Cellular Radio
D. Second Generation: Digital Cellular
E. Digital Cellular: Voice
F. Internet Access via Cellular
G. Spectrum-Sharing Technologies: FDMA, TDMA, CDMA, OFDMA
H. 3G CDMA 1X, UMTS and HSPA
I. 4G LTE
J. Wireless LANs and WiFi
K. Satellite Communications

Part 4 IP and IP Telecom Networks

This is the biggest and most technical part of the course, covering the whole IP network story from fundamentals of packets and frames, why we call them Layer 3 and Layer 2 respectively, Ethernet, MAC frames, MAC addresses and VLANs for Layer 2, IP packets, IP addresses and IP routing for Layer 3, public and private addresses, network address translation, DHCP, IP version 6, basics of routing, firewalls, encryption and security, MPLS for traffic management, private and Virtual Private Networks for business customers and the Internet (the public IP network).

12. INTRODUCTION TO DATACOM AND NETWORKING

“Data” communications used to be different than voice, different equipment, circuits, services and different people. Since the IP network today used for voice and data and video together began as a data network, we will begin understanding IP network concepts, jargon and buzzwords as if data communications were still a different topic than voice.

We'll introduce a model for data circuits, reviewing each component in the model, and exploring practical examples of circuit and network configurations. Next, we'll introduce the key concepts of IP packets and Ethernet frames and how they relate, and finish by identifying the components required for a communications over a carrier IP network end-to-end.

A. Data Circuit Model: DTEs and DCEs
B. Analog and Digital Circuits
C. Serial and Parallel
D. Multidrop Circuits
E. LANs
F. WANs
G. Formatting Data for Communication: Essential Functions
H. Binary and Hexadecimal
I. Character Coding: ASCII and Unicode
J. Start / Stop / Parity
K. Frames
L. Packets
M. Packets and IP Addresses vs. Frames and MAC Addresses
N. Carrier Packet Network Basics

13. THE OSI LAYERS AND PROTOCOL STACKS

Standards and protocols play a key role in understanding networks and all of the functions required to implement services and applications over a network. We'll begin the third part with the ISO Open Systems Interconnect 7-layer reference model, establishing a structure for understanding how everything fits together. You'll learn what a layer is, the purpose of each layer, protocols including TCP/IP used to implement layers, and learn how a protocol stack really works.

A. Protocols and Standards
B. The ISO OSI 7-Layer Reference Model
C. Understanding the Layers, One-by-One
D. Protocol Stacks
E. Protocol Stacks in Operation: The FedEx Analogy
F. Babushka Dolls
G. Key Standards Organizations

14. ETHERNET, LANS AND VLANS

LANs are the standard method of implementing data links (Layer 2 of the OSI model), originally in-building and now in the access network and the network core. This chapter provides a basic, solid understanding of LANs: Ethernet and the original idea of a bus, how this changed to Gigabit Ethernet on fiber optics connected with LAN switches; MAC addresses and MAC frames. You'll learn about categories of LAN cables, Ethernet over fiber, hubs, switches, routers and VLANs.

A. Bus Topology
B. 802.3 and Ethernet
C. Evolution of Ethernet
D. Gigabit Ethernet
E. LAN Cables: Category 5, 5e and 6
F. Repeaters and Bridges
G. Ethernet Switches
H. VLANs
I. L2 Switch Hierarchy and Trunking
J. Optical Ethernet
K. Metropolitan Area Networks (MANs)
L. Switched Ethernet Service and VPLS
M. Interconnecting LANs with Routers

15. IP NETWORKS, ROUTERS AND ADDRESSES

We begin understanding network technology, Layer 3 of the OSI model, with the simplest example: a private network, to understand routing and bandwidth on demand. We'll examine the functions performed by a router, and the Customer Edge router. Then we will cover IPv4 addressing: IPv4 address classes, static vs. dynamic addresses and DHCP, public and private addresses and NAT. Then we'll review IPv6, and how IPv6 addresses are allocated and assigned, and types of IPv6 addresses. The chapter is completed with an overview of associated protocols like TCP and DNS.

A. Review: Integrating Services by Channelization
B. Efficient Use of Capacity for Bursty Traffic
C. Simplest Framework: Private Network
D. Routers and Customer Edge (CE)
E. IPv4 Address Classes
F. Dynamic Addresses, Static Addresses and DHCP
G. Public and Private IPv4 Addresses
H. Network Address Translation
I. IPv6
J. IPv6 Address Allocation and IPv6 Address Types
K. Next-Generation MAC Addresses: EUI-64
L. DNS, ARP and RARP
M. TCP, UDP, Ports and Sockets
N. Multicasting and IGMP
O. Customer-Premise Networking
    1. Use of Wi-Fi
    2. Port Forwarding

16. IP ROUTING

In this chapter, you'll come to really understand how routing works. Without losing ourselves in unnecessary details, will understand the fundamental concepts and jargon.

A. Networks with Gateways: 1980s IP Thinking
B. Subnets and CIDR
C. Prefix and Subnet Mask
D. Assigning VLANs to Subnets: How and Why
E. Elements of Routing
F. Autonomous Systems
G. Route Discovery Protocols
H. RIP: Routing Information Protocol
I. OSPF: Open Shortest Path First
J. BGP: Border Gateway Protocol
K. Routing Tables
L. Calculating the Next Hop

17. IP SECURITY

Here, you'll get a comprehensive overview of security in the IP world, and an understanding of the tools and techniques used to implement security. We'll begin with a discussion of risk areas, vulnerabilities and measures. Then, we'll cover the critical concept of network segmentation, and how this is implemented by assigning IP subnets to VLANs and requiring traffic to pass through an L2/L3 switch as a point of control between subnet/VLANs. Understanding this concept is yet another reason to attend this course all by itself. Then we'll look at how this "control" is implemented, with firewall technologies; the important topics of encryption, IPsec and VPNs, and malicious software such as Trojans.

A. Risks, Measures and Policy
B. Network Security: Segmentation and Perimeters
C. Mapping VLANs onto IP subnets with L2/L3 Routing Switches
D. Firewalls: Packet Filtering, Proxies and Stateful Packet Inspection
E. IPsec and IP VPNs
F. Public Key Encryption, Authentication
G. Digital Certificates
H. Malicious Software: Viruses, Trojans
I. VoIP Security Risk Areas
J. VoIP Security Measures and Solutions

18. MPLS AND CARRIER NETWORKS

Going forward, IP packet-based services will be used for everything, including phone calls and television. However, traffic management methods are required to be able to guarantee performance on an IP network… and this is MPLS. We'll begin with the important concept of a Service Level Agreement. Then we'll understand MPLS, by first understanding virtual circuits and traffic classes, then previous methods Frame Relay and ATM, then the current MPLS and how it is a traffic management tool used to implement Differentiated Services and Classes of Service, integration and aggregation. We'll conclude the discussion by comparing "MPLS Services" to Internet service.

A. Service Level Agreements and Traffic Profiles
B. Provider Equipment at the Customer Premise
C. Virtual Circuit Technologies
D. Packet-Switching using Virtual Circuits
E. Frame Relay using Virtual Circuits
F. QoS Requirements for Voice over IP
G. ATM
H. MPLS
I. TCP/IP over MPLS
J. Diff-Serv and QoS
K. MPLS to Support Prioritization and Service Classes
L. Traffic Policing and Shaping
M. Queues and How Prioritization is Implemented
N. MPLS for Service Integration
O. MPLS for Traffic Aggregation
P. MPLS VPNs
Q. "MPLS Service" vs. Internet Service

19. VPNS

In this chapter, we'll cover secure data communications: Virtual Private Networks and three ways of implementing VPNs for business customers.

A. Customer-Premise-Based VPN
B. Carrier IP VPNs
C. Carrier MPLS VPNs

20. UNDERSTANDING THE INTERNET

Let's not forget the Internet! In this chapter, we'll review the Internet's past and present, understand what an ISP does, and gain a real understanding of TCP and IP. We'll review HTML, HTTP, secure web pages, Web servers and browsers, and details like the Domain Name System, MIME and Base-64 encoding, and complete the picture with a particular discussion of Internet access via satellite.

A. Internet History
B. Internet Basics
C. Internet Service Providers (ISPs)
D. Domain Name System
E. MIME and Base-64 encoding
F. The World Wide Web, HTML, HTTP, HTTPS and SSL
G. Satellite Internet

Part 5 IPTV and Voice over IP

The final part of the course is a day on applications: IPTV and Voice over IP, plus a wrap-up.

21. IPTV AND VOIP CONCEPTS, EQUIPMENT, STANDARDS, JARGON AND BUZZWORDS

This chapter introduces Television over IP (IPTV) and Voice over IP (VoIP), identifying and explaining key components, jargon and buzzwords. For IPTV we will understand video servers, caching, clients on set-top boxes and smart TVs, HDMI and wireless in-building connections. For VoIP, we will cover soft switches, gateways and terminals, plus the main standards and protocols used to provide telephone service on an IP network and an unbiased look at different implementation choices for business customers.

A. IPTV
   1. Servers, Set-Top Boxes, Smart TVs
   2. In-Building Connections: LAN, Coax, Wireless, HDMI
B. VoIP Components, Jargon and Buzzwords
C. Key VoIP Standards
D. Internet Telephony
E. VoIP from Carriers: Managed IP Telephony (MIPT)
F. Softswitches
G. VoIP PBX vs. IP Centrex vs. Hosted PBX

22. PACKETIZED VOICE, VOICE CODING AND VOICE QUALITY

Here, we'll get down to brass tacks: understanding what exactly packetized voice is, how it happens and the standards and protocols used. You'll learn about codecs and compression, and understand the factors affecting sound quality. We'll listen to sound clips of impairments, and provide you with a practical list of tips and recommendations.

A. Voice Packetization and RTP
B. Protocol Stack: RTP, UDP, IP, MAC
C. Measuring Voice Quality
D. Factors Affecting Voice Quality
E. Codecs: G.711, G.722, G.729
F. Delay and Jitter
G. Packet Loss
H. In-Class Demo: Impairments and Effects on Sound Quality
I. Tips for Maximizing Voice Quality
J. Testing and Troubleshooting Voice Quality

23. SIP AND CALL FLOW IN THE IP WORLD

After understanding how voice is packetized and transported, the next question is how to find and connect to someone else to make a phone call? The answer: SIP, the Session Initiation Protocol. We'll get you fully up to speed on SIP ideas, architecture, terminology, operation, jargon and buzzwords, and trace the establishment of a phone call step-by-step from "dialing" to ringing and answer. At the end of this, you'll understand how softswitches use SIP for call flow in IP telephone systems – another knowledge set perhaps worth attending the course for all by itself! The chapter is completed with an extensive glossary of SIP terms.

A. History: H.323
B. SIP Overview
C. The SIP Trapezoid
D. SIP Addresses: URIs instead of URLs
E. SIP Messages
F. SDP: Session Description Protocol
G. Server Types: Proxy, User Agent, Redirect Server, Registrar
H. Tracing Call Flow Step-by-Step
I. Peer-To-Peer SIP
J. SIP Glossary

24. VOIP - PSTN INTERCONNECT

Here, you will understand in a practical way how to go about connecting a VoIP system to the traditional PSTN, and understand Megaco and PRI vs. SIP trunking. We'll survey methods of connecting IP networks to the PSTN and finish up with connections to carriers from a PBX-type environment.

A. PSTN Interconnect
B. Net to Phone VSPs (DS0 Interconnect to LEC)
C. Net to Phone VSPs (IP Interconnect to LEC)
D. Session Border Controllers
E. Megaco (H.248/RFC2885)
F. ENUM Directory Structure
G. Connecting from a PBX-type Environment
H. SIP Trunking vs. PRI
I. Co-Existence with a Legacy PBX
J. Integrating Integrated Messaging
K. Access Network: IP Video/Data/VoIP Triple Play Delivery Model

25. VOIP CASE STUDIES

Continuing with the practical, to cement your knowledge, we'll present mainstream solutions for deploying VoIP for business customers in a series of interactive, class-participation case studies. The first case studies are VoIP inside the building for business customers; the second set are VoIP for long-distance communications.

A. Case Study: Network-based VoIP Service (IP Centrex)
B. Case Study: PBX-based VoIP
C. Case Study: Softswitch-based VoIP
D. Case Study: Private Network
E. Case Study: Over Data Networks (Frame/ATM)
F. Case Study: VoIP over the Internet
G. Case Study: Internet VPNs (CPE-based IPsec)
H. Case Study: Carrier VPN Service, MPLS, IPsec

26. WRAPPING UP

The final chapter brings all of the concepts together with a top-down review. You'll learn valuable insight in how technology *should* be deployed, and review telecom, datacom and networking technologies, services and solutions. We'll conclude with a view toward the future: the global IP Packet-Switched Telecommunications Network (IP-PSTN).

A. Technology Deployment Steps
B. Requirements Analysis and High-Level Design
C. Review: Circuits and Services
D. Access and Transmission Technology Roundup
E. MPLS and Native IP Services
F. The Mobily triple-play network architecture and plant
G. Tracing the connection from the customer to the world
H. The Future: The global IP-PSTN

