cisco

Module 4: Physical Layer

Instructor Materials

Introduction to Networks v7.0
(ITN)

Module Objectives

Module Title: Physical Layer

Module Objective: Explain how physical layer protocols, services, and network media support communications across data networks.

Topic Title	Topic Objective
Purpose of the Physical Layer	Describe the purpose and functions of the physical layer in the network.
Physical Layer Characteristics	Describe characteristics of the physical layer.
Copper Cabling	Identify the basic characteristics of copper cabling.
UTP Cabling	Explain how UTP cable is used in Ethernet networks.
Fiber-Optic Cabling	Describe fiber optic cabling and its main advantages over other media.
Wireless Media	Connect devices using wired and wireless media.

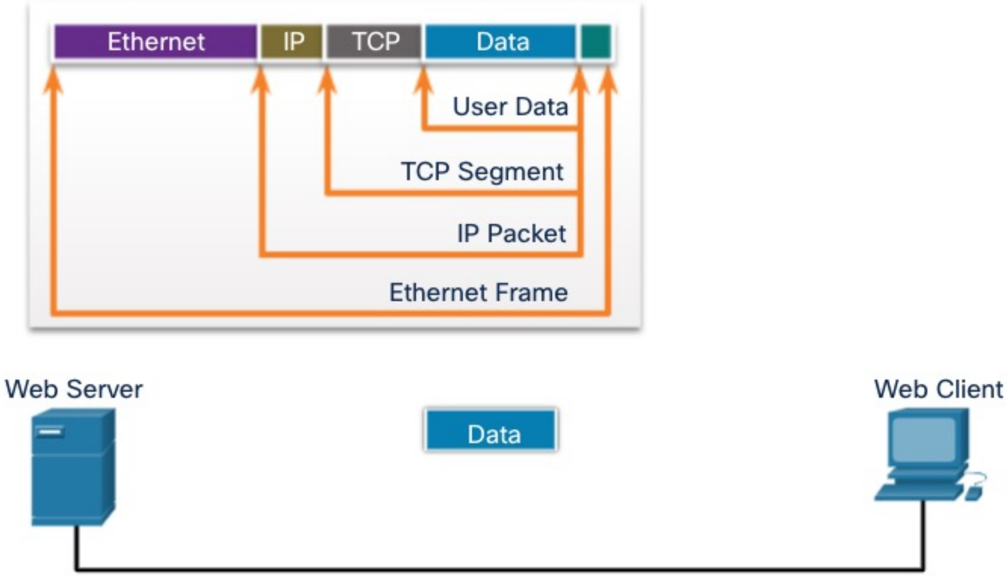
Purpose of the Physical Layer

The Physical Connection

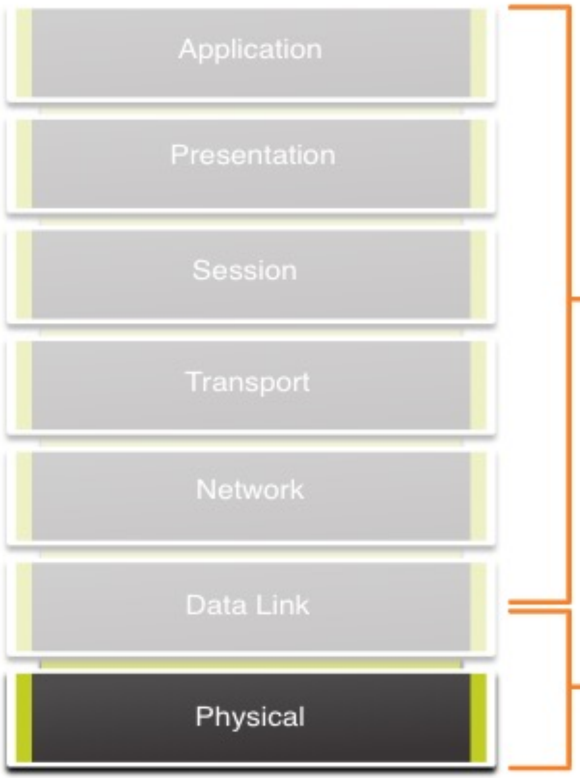
- Before any network communications can occur, a physical connection to a local network must be established.
- This connection could be wired or wireless, depending on the setup of the network.
- This generally applies whether you are considering a corporate office or a home.
- A Network Interface Card (NIC) connects a device to the network.
- Some devices may have just one NIC, while others may have multiple NICs (Wired and/or Wireless, for example).
- Not all physical connections offer the same level of performance.

The Physical Layer

- Transports bits across the network media
- Accepts a complete frame from the Data Link Layer and encodes it as a series of signals that are transmitted to the local media
- This is the last step in the encapsulation process.
- The next device in the path to the destination receives the bits and re-encapsulates the frame, then decides what to do with it.



Physical Layer Characteristics
Physical Layer Standards



The TCP/IP standards are implemented in software and governed by the IETF.

The physical layer standards are implemented in hardware and are governed by many organizations including:

- ISO
- EIA/TIA
- ITU-T
- ANSI
- IEEE

Physical Layer Characteristics
Physical Components

Physical Layer Standards address three functional areas:

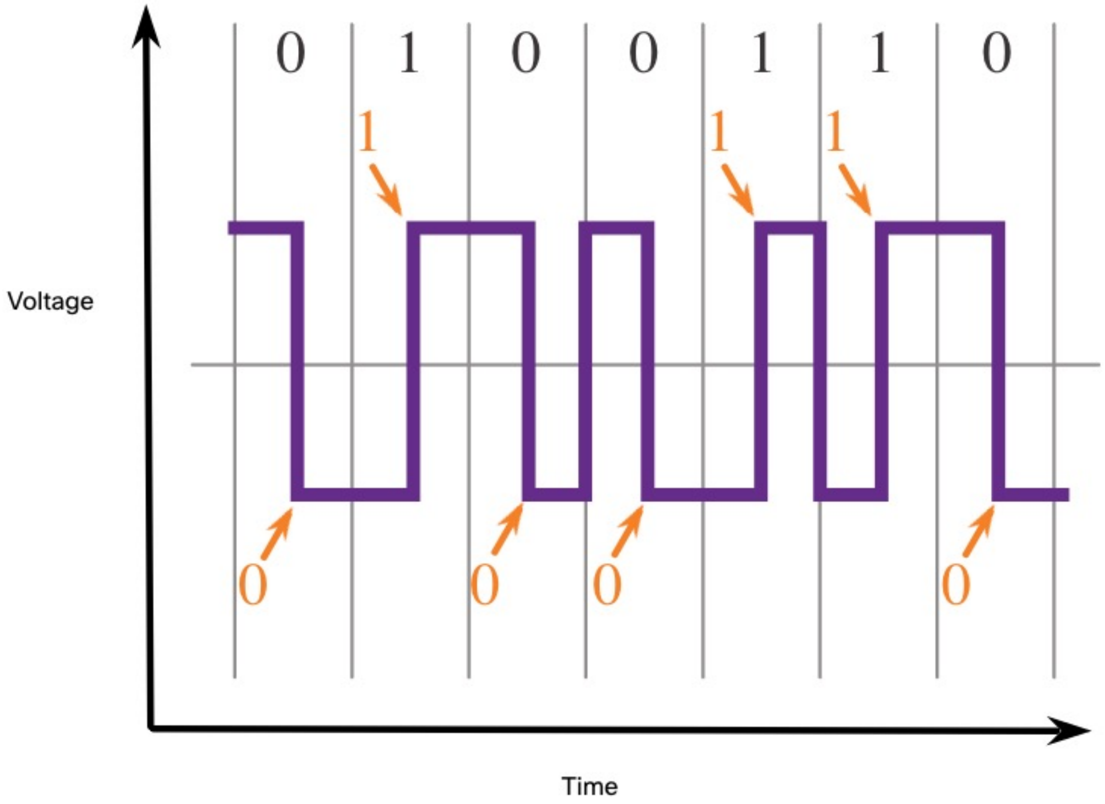
- Physical Components
- Encoding
- Signaling

The Physical Components are the hardware devices, media, and other connectors that transmit the signals that represent the bits.

- Hardware components like NICs, interfaces and connectors, cable materials, and cable designs are all specified in standards associated with the physical layer.

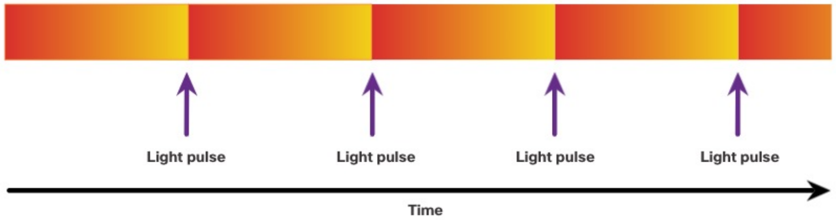
Encoding

- Encoding converts the stream of bits into a format recognizable by the next device in the network path.
- This ‘coding’ provides predictable patterns that can be recognized by the next device.
- Examples of encoding methods include Manchester (shown in the figure), 4B/5B, and 8B/10B.

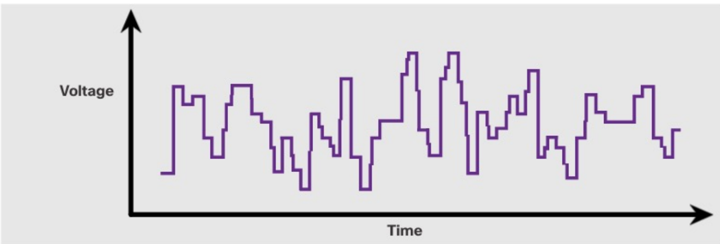


Physical Layer Characteristics
Signaling

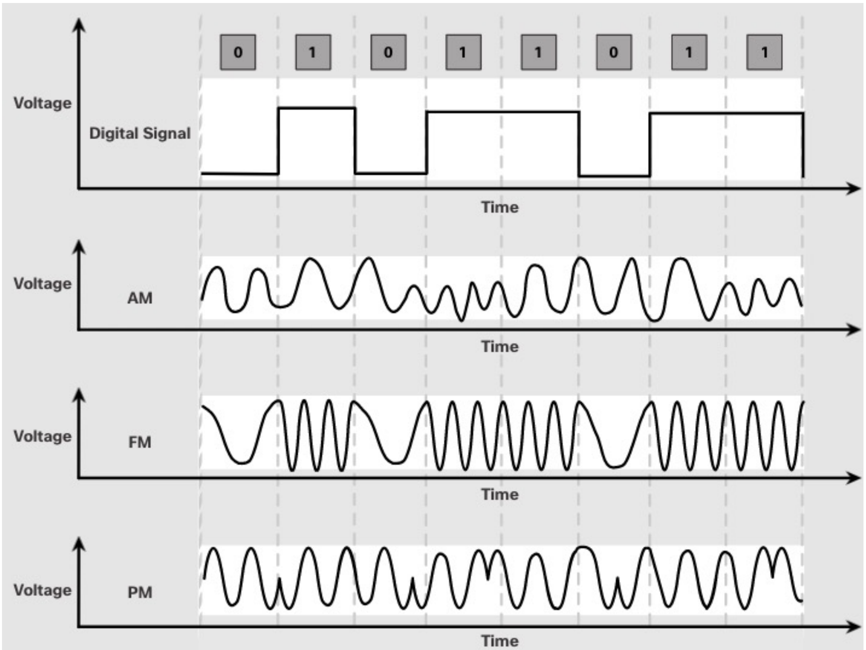
- The signaling method is how the bit values, “1” and “0” are represented on the physical medium.
- The method of signaling will vary based on the type of medium being used.



Light Pulses Over Fiber-Optic Cable



Electrical Signals Over Copper Cable



Microwave Signals Over Wireless

Physical Layer Characteristics
Bandwidth

- Bandwidth is the capacity at which a medium can carry data.
- Digital bandwidth measures the amount of data that can flow from one place to another in a given amount of time; how many bits can be transmitted in a second.
- Physical media properties, current technologies, and the laws of physics play a role in determining available bandwidth.

Unit of Bandwidth	Abbreviation	Equivalence
Bits per second	bps	1 bps = fundamental unit of bandwidth
Kilobits per second	Kbps	1 Kbps = 1,000 bps = 10^3 bps
Megabits per second	Mbps	1 Mbps = 1,000,000 bps = 10^6 bps
Gigabits per second	Gbps	1 Gbps – 1,000,000,000 bps = 10^9 bps
Terabits per second	Tbps	1 Tbps = 1,000,000,000,000 bps = 10^{12} bps

Physical Layer Characteristics
Bandwidth Terminology

Latency

- Amount of time, including delays, for data to travel from one given point to another

Throughput

- The measure of the transfer of bits across the media over a given period of time

Goodput

- The measure of usable data transferred over a given period of time
- Goodput = Throughput - traffic overhead

Characteristics of Copper Cabling

Copper cabling is the most common type of cabling used in networks today. It is inexpensive, easy to install, and has low resistance to electrical current flow.

Limitations:

- Attenuation – the longer the electrical signals have to travel, the weaker they get.
- The electrical signal is susceptible to interference from two sources, which can distort and corrupt the data signals (Electromagnetic Interference (EMI) and Radio Frequency Interference (RFI) and Crosstalk).

Mitigation:

- Strict adherence to cable length limits will mitigate attenuation.
- Some kinds of copper cable mitigate EMI and RFI by using metallic shielding and grounding.
- Some kinds of copper cable mitigate crosstalk by twisting opposing circuit pair wires together.

Copper Cabling

Types of Copper Cabling

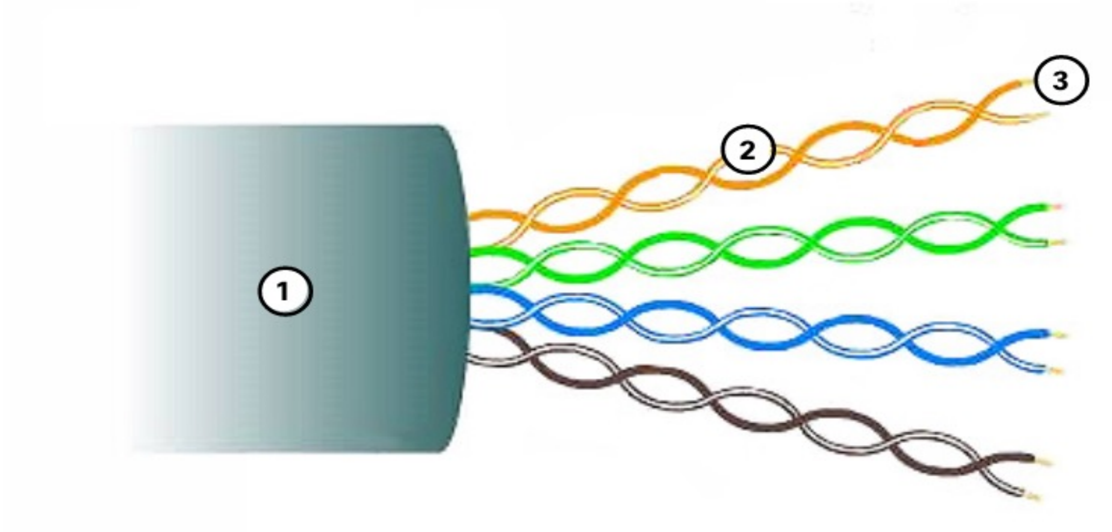
Unshielded Twisted-Pair (UTP) Cable

Shielded Twisted-Pair (STP) Cable

Coaxial Cable

Copper Cabling

Unshielded Twisted Pair (UTP)



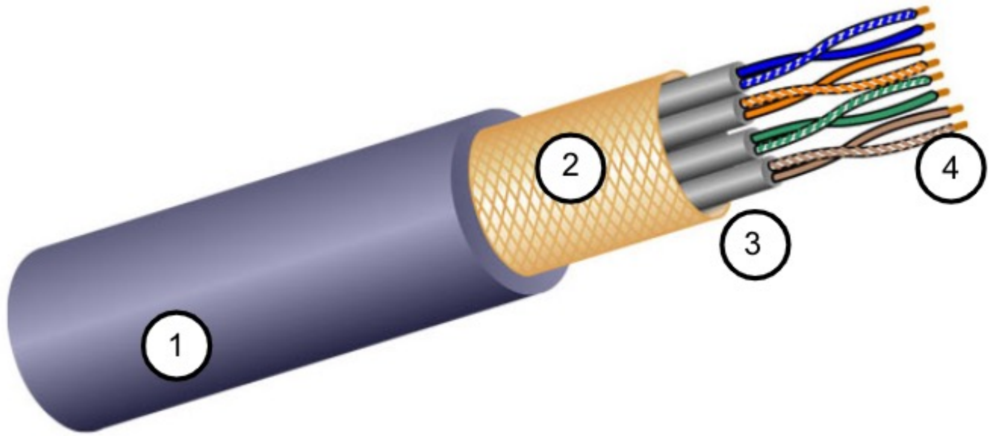
- UTP is the most common networking media.
- Terminated with RJ-45 connectors
- Interconnects hosts with intermediary network devices.

Key Characteristics of UTP

1. The outer jacket protects the copper wires from physical damage.
2. Twisted pairs protect the signal from interference.
3. Color-coded plastic insulation electrically isolates the wires from each other and identifies each pair.

Copper Cabling

Shielded Twisted Pair (STP)



- Better noise protection than UTP
- More expensive than UTP
- Harder to install than UTP
- Terminated with RJ-45 connectors
- Interconnects hosts with intermediary network devices

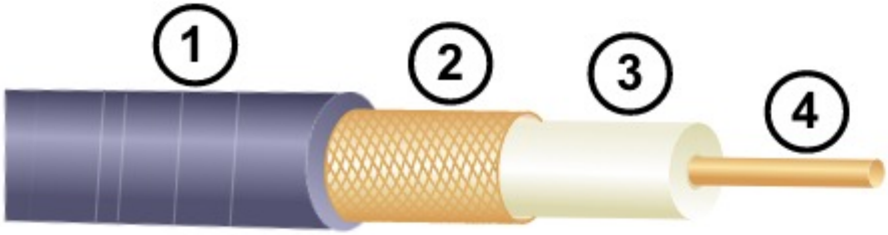
Key Characteristics of STP

1. The outer jacket protects the copper wires from physical damage
2. Braided or foil shield provides EMI/RFI protection
3. Foil shield for each pair of wires provides EMI/RFI protection
4. Color-coded plastic insulation electrically isolates the wires from each other and identifies each pair

Copper Cabling
Coaxial Cable

Consists of the following:

1. Outer cable jacket to prevent minor physical damage
2. A woven copper braid, or metallic foil, acts as the second wire in the circuit and as a shield for the inner conductor.
3. A layer of flexible plastic insulation
4. A copper conductor is used to transmit the electronic signals.



There are different types of connectors used with coax cable.

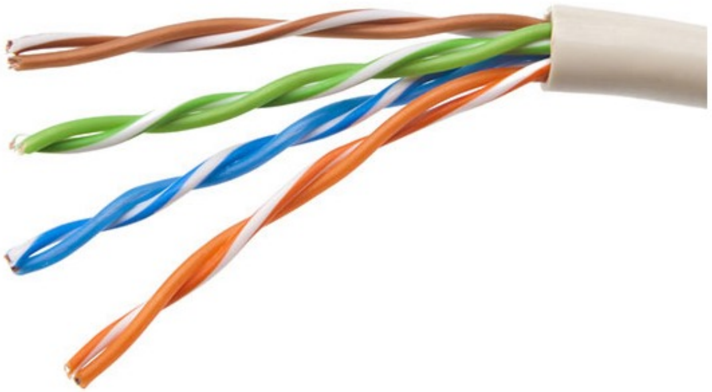
Commonly used in the following situations:

- Wireless installations - attach antennas to wireless devices
- Cable internet installations - customer premises wiring

UTP Cabling
Properties of UTP Cabling

UTP has four pairs of color-coded copper wires twisted together and encased in a flexible plastic sheath. No shielding is used. UTP relies on the following properties to limit crosstalk:

- Cancellation - Each wire in a pair of wires uses opposite polarity. One wire is negative, the other wire is positive. They are twisted together and the magnetic fields effectively cancel each other and outside EMI/RFI.
- Variation in twists per foot in each wire - Each wire is twisted a different amount, which helps prevent crosstalk amongst the wires in the cable.



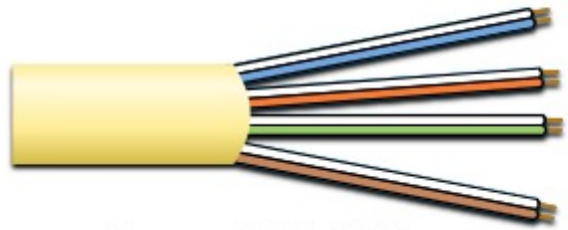
UTP Cabling Standards and Connectors

Standards for UTP are established by the TIA/EIA. TIA/EIA-568 standardizes elements like:

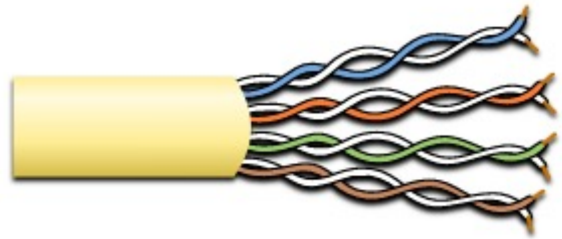
- Cable Types
- Cable Lengths
- Connectors
- Cable Termination
- Testing Methods

Electrical standards for copper cabling are established by the IEEE, which rates cable according to its performance. Examples include:

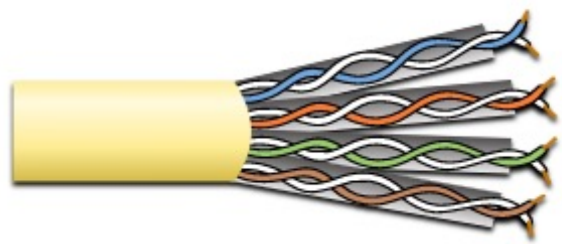
- Category 3
- Category 5 and 5e
- Category 6



Category 3 Cable (UTP)



Category 5 and 5e Cable (UTP)



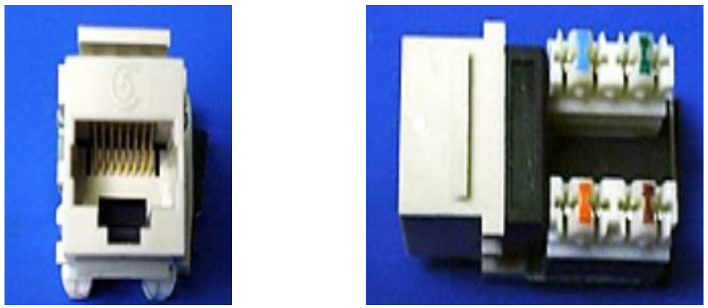
Category 6 Cable (UTP)

UTP Cabling

UTP Cabling Standards and Connectors (Cont.)

RJ-45 Connector

Poorly terminated UTP cable

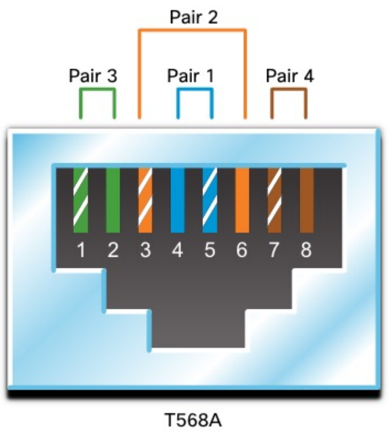


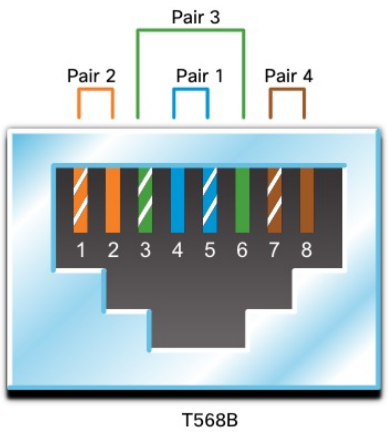
RJ-45 Socket

Properly terminated UTP cable

UTP Cabling

Straight-through and Crossover UTP Cables





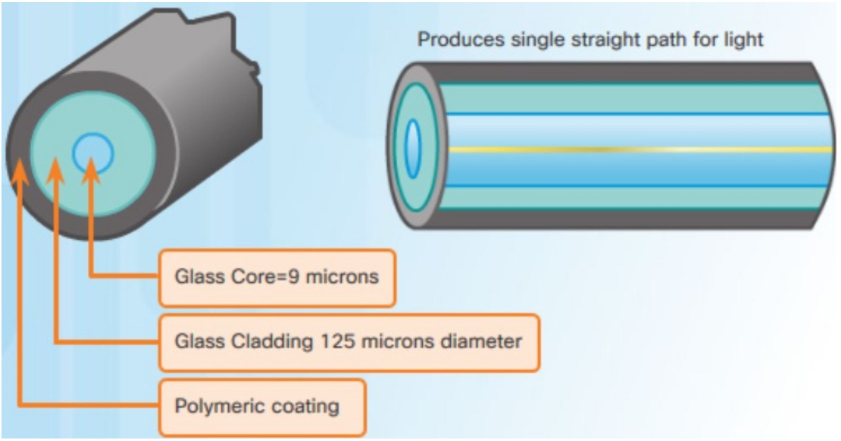
Cable Type	Standard	Application
Ethernet Straight-through	Both ends T568A or T568B	Host to Network Device
Ethernet Crossover *	One end T568A, other end T568B	Host-to-Host, Switch-to-Switch, Router-to-Router
* Considered Legacy due to most NICs using Auto-MDIX to sense cable type and complete connection		
Rollover	Cisco Proprietary	Host serial port to Router or Switch Console Port, using an adapter

Properties of Fiber-Optic Cabling

- Not as common as UTP because of the expense involved
- Ideal for some networking scenarios
- Transmits data over longer distances at higher bandwidth than any other networking media
- Less susceptible to attenuation, and completely immune to EMI/RFI
- Made of flexible, extremely thin strands of very pure glass
- Uses a laser or LED to encode bits as pulses of light
- The fiber-optic cable acts as a wave guide to transmit light between the two ends with minimal signal loss

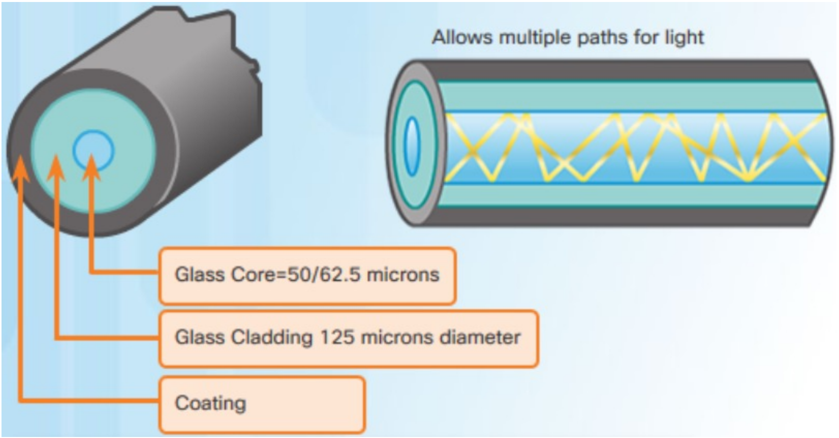
Fiber-Optic Cabling
Types of Fiber Media

Single-Mode Fiber



- Very small core
- Uses expensive lasers
- Long-distance applications

Multimode Fiber



- Larger core
- Uses less expensive LEDs
- LEDs transmit at different angles
- Up to 10 Gbps over 550 meters

Dispersion refers to the spreading out of a light pulse over time. Increased dispersion means increased loss of signal strength. MMF has greater dispersion than SMF, with a the maximum cable distance for MMF is 550 meters.

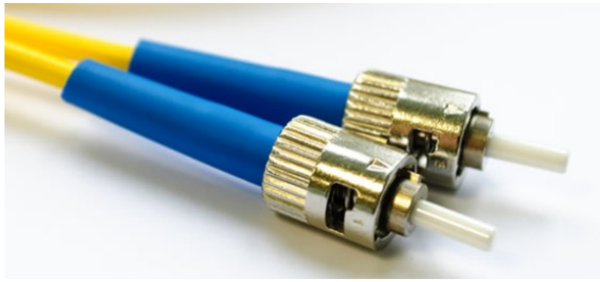
Fiber-Optic Cabling Usage

Fiber-optic cabling is now being used in four types of industry:

1. **Enterprise Networks -** Used for backbone cabling applications and interconnecting infrastructure devices
2. **Fiber-to-the-Home (FTTH) -** Used to provide always-on broadband services to homes and small businesses
3. **Long-Haul Networks -** Used by service providers to connect countries and cities
4. **Submarine Cable Networks -** Used to provide reliable high-speed, high-capacity solutions capable of surviving in harsh undersea environments at up to transoceanic distances.

Our focus in this course is the use of fiber within the enterprise.

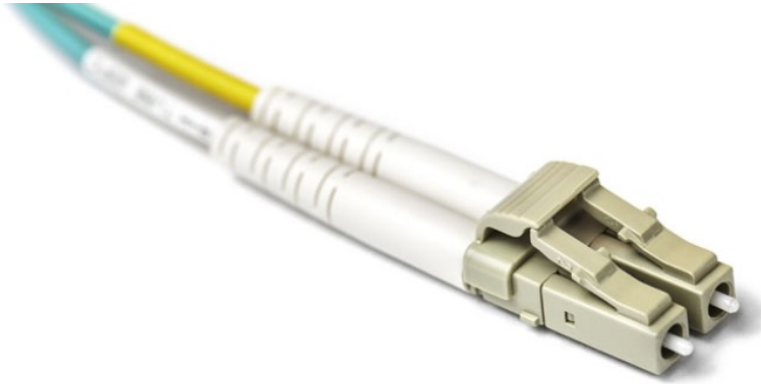
Fiber-Optic Connectors



Straight-Tip (ST) Connectors

Lucent Connector (LC) Simplex Connectors

Subscriber Connector (SC) Connectors



Duplex Multimode LC Connectors

Fiber Patch Cords

SC-SC MM Patch Cord

LC-LC SM Patch Cord

ST-LC MM Patch Cord

ST-SC SM Patch Cord

A yellow jacket is for single-mode fiber cables and orange (or aqua) for multimode fiber cables.

Fiber-Optic Cabling

Fiber versus Copper

Optical fiber is primarily used as backbone cabling for high-traffic, point-to-point connections between data distribution facilities and for the interconnection of buildings in multi-building campuses.

Implementation Issues	UTP Cabling	Fiber-Optic Cabling
Bandwidth supported	10 Mb/s - 10 Gb/s	10 Mb/s - 100 Gb/s
Distance	Relatively short (1 - 100 meters)	Relatively long (1 - 100,000 meters)
Immunity to EMI and RFI	Low	High (Completely immune)
Immunity to electrical hazards	Low	High (Completely immune)
Media and connector costs	Lowest	Highest
Installation skills required	Lowest	Highest
Safety precautions	Lowest	Highest

Wireless Media

Properties of Wireless Media

It carries electromagnetic signals representing binary digits using radio or microwave frequencies. This provides the greatest mobility option. Wireless connection numbers continue to increase.

Some of the limitations of wireless:

- **Coverage area** - Effective coverage can be significantly impacted by the physical characteristics of the deployment location.
- **Interference** - Wireless is susceptible to interference and can be disrupted by many common devices.
- **Security** - Wireless communication coverage requires no access to a physical strand of media, so anyone can gain access to the transmission.
- **Shared medium** - WLANs operate in half-duplex, which means only one device can send or receive at a time. Many users accessing the WLAN simultaneously results in reduced bandwidth for each user.

Wireless Media

Types of Wireless Media

The IEEE and telecommunications industry standards for wireless data communications cover both the data link and physical layers. In each of these standards, physical layer specifications dictate:

- Data to radio signal encoding methods
- Frequency and power of transmission
- Signal reception and decoding requirements
- Antenna design and construction

Wireless Standards:

- **Wi-Fi (IEEE 802.11)** - Wireless LAN (WLAN) technology
- **Bluetooth (IEEE 802.15)** - Wireless Personal Area network (WPAN) standard
- **WiMAX (IEEE 802.16)** - Uses a point-to-multipoint topology to provide broadband wireless access
- **Zigbee (IEEE 802.15.4)** - Low data-rate, low power-consumption communications, primarily for Internet of Things (IoT) applications

Wireless LAN

In general, a Wireless LAN (WLAN) requires the following devices:

- **Wireless Access Point (AP)** - Concentrate wireless signals from users and connect to the existing copper-based network infrastructure
- **Wireless NIC Adapters** - Provide wireless communications capability to network hosts

There are a number of WLAN standards. When purchasing WLAN equipment, ensure compatibility, and interoperability.

Network Administrators must develop and apply stringent security policies and processes to protect WLANs from unauthorized access and damage.

Module Practice and Quiz

What did I learn in this module?

- Before any network communications can occur, a physical connection to a local network, either wired or wireless, must be established.
- The physical layer consists of electronic circuitry, media, and connectors developed by engineers.
- The physical layer standards address three functional areas: physical components, encoding, and signaling.
- Three types of copper cabling are: UTP, STP, and coaxial cable (coax).
- UTP cabling conforms to the standards established jointly by the TIA/EIA. The electrical characteristics of copper cabling are defined by the Institute of Electrical and Electronics Engineers (IEEE).
- The main cable types that are obtained by using specific wiring conventions are Ethernet Straight-through and Ethernet Crossover.

What did I learn in this module (Cont.)?

- Optical fiber cable transmits data over longer distances and at higher bandwidths than any other networking media.
- There are four types of fiber-optic connectors: ST, SC, LC, and duplex multimode LC.
- Fiber-optic patch cords include SC-SC multimode, LC-LC single-mode, ST-LC multimode, and SC-ST single-mode.
- Wireless media carry electromagnetic signals that represent the binary digits of data communications using radio or microwave frequencies. Wireless does have some limitations, including coverage area, interference, security, and the problems that occur with any shared medium.
- Wireless standards include the following: Wi-Fi (IEEE 802.11), Bluetooth (IEEE 802.15), WiMAX (IEEE 802.16), and Zigbee (IEEE 802.15.4).
- Wireless LAN (WLAN) requires a wireless AP and wireless NIC adapters.

Module 5: Number Systems

Instructor Materials

Introduction to Networks v7.0
(ITN)

Module Objectives

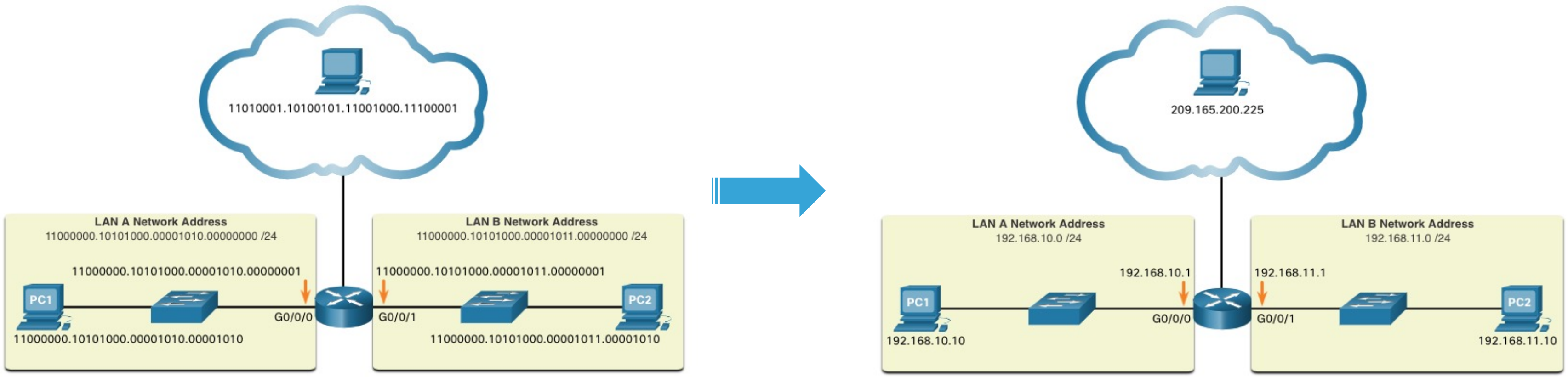
Module Title: Number Systems

Module Objective: Calculate numbers between decimal, binary, and hexadecimal systems.

Topic Title	Topic Objective
Binary Number System	Calculate numbers between decimal and binary systems.
Hexadecimal Number System	Calculate numbers between decimal and hexadecimal systems.

Binary and IPv4 Addresses

- Binary numbering system consists of 1s and 0s, called bits
- Decimal numbering system consists of digits 0 through 9
- Hosts, servers, and network equipment using binary addressing to identify each other.
- Each address is made up of a string of 32 bits, divided into four sections called octets.
- Each octet contains 8 bits (or 1 byte) separated by a dot.
- For ease of use by people, this dotted notation is converted to dotted decimal.



Binary Number System

Binary Positional Notation

- Positional notation means that a digit represents different values depending on the "position" the digit occupies in the sequence of numbers.
- The decimal positional notation system operates as shown in the tables below.

Radix	10	10	10	10
Position in Number	3	2	1	0
Calculate	(10^3)	(10^2)	(10^1)	(10^0)
Position Value	1000	100	10	1

	Thousands	Hundreds	Tens	Ones
Positional Value	1000	100	10	1
Decimal Number (1234)	1	2	3	4
Calculate	1 x 1000	2 x 100	3 x 10	4 x 1
Add them up…	1000	+ 200	+ 30	+ 4
Result	**1,234**			

Binary Positional Notation (Cont.)

The binary positional notation system operates as shown in the tables below.

Radix	2	2	2	2	2	2	2	2
Position in Number	7	6	5	4	3	2	1	0
Calculate	(2^7)	(2^6)	(2^5)	(2^4)	(2^3)	(2^2)	(2^1)	(2^0)
Position Value	128	64	32	16	8	4	2	1

Positional Value	128	64	32	16	8	4	2	1
Binary Number (11000000)	1	1	0	0	0	0	0	0
Calculate	1x128	1x64	0x32	0x16	0x8	0x4	0x2	0x1
Add Them Up…	128	+ 64	+ 0	+ 0	+ 0	+ 0	+ 0	+ 0
Result	192							

Binary Number System

Convert Binary to Decimal

Convert 11000000.10101000.00001011.00001010 to decimal.

Positional Value	128	64	32	16	8	4	2	1
Binary Number (11000000)	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**
Calculate	1x128	1x64	0x32	0x16	0x8	0x4	0x2	0x1
Add Them Up…	128	+ 64	+ 0	+ 0	+ 0	+ 0	+ 0	+ 0
Binary Number (10101000)	**1**	**0**	**1**	**0**	**1**	**0**	**0**	**0**
Calculate	1x128	0x64	1x32	0x16	1x8	0x4	0x2	0x1
Add Them Up…	128	+ 0	+ 32	+ 0	+ 8	+ 0	+ 0	+ 0
Binary Number (00001011)	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**1**
Calculate	0x128	0x64	0x32	0x16	1x8	0x4	1x2	1x1
Add Them Up…	0	+ 0	+ 0	+ 0	+ 8	+ 0	+ 2	+ 1
Binary Number (00001010)	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**0**
Calculate	0x128	0x64	0x32	0x16	1x8	0x4	1x2	0x1
Add Them Up…	0	+ 0	+ 0	+ 0	+ 8	+ 0	+ 2	+ 0

→ 192

→ 168

→ 11

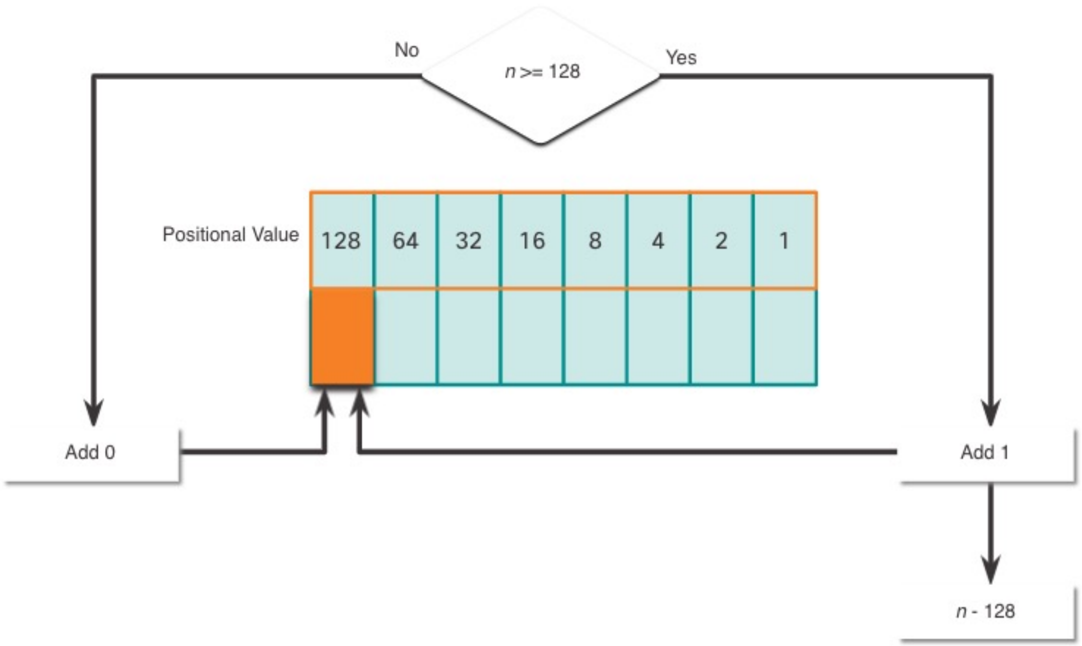
→ 10

192.168.11.10

Binary Number System
Decimal to Binary Conversion

The binary positional value table is useful in converting a dotted decimal IPv4 address to binary.

- Start in the 128 position (the most significant bit). Is the decimal number of the octet (n) equal to or greater than 128?
- If no, record a binary 0 in the 128 positional value and move to the 64 positional value.
- If yes, record a binary 1 in the 128 positional value, subtract 128 from the decimal number, and move to the 64 positional value.
- Repeat these steps through the 1 positional value.



Binary Number System

Decimal to Binary Conversion Example

- Convert decimal 168 to binary

Is 168 > 128?
- Yes, enter 1 in 128 position and subtract 128 (168-128=40)

Is 40 > 64?
- No, enter 0 in 64 position and move on

Is 40 > 32?
- Yes, enter 1 in 32 position and subtract 32 (40-32=8)

Is 8 > 16?
- No, enter 0 in 16 position and move on

Is 8 > 8?
- Equal. Enter 1 in 8 position and subtract 8 (8-8=0)

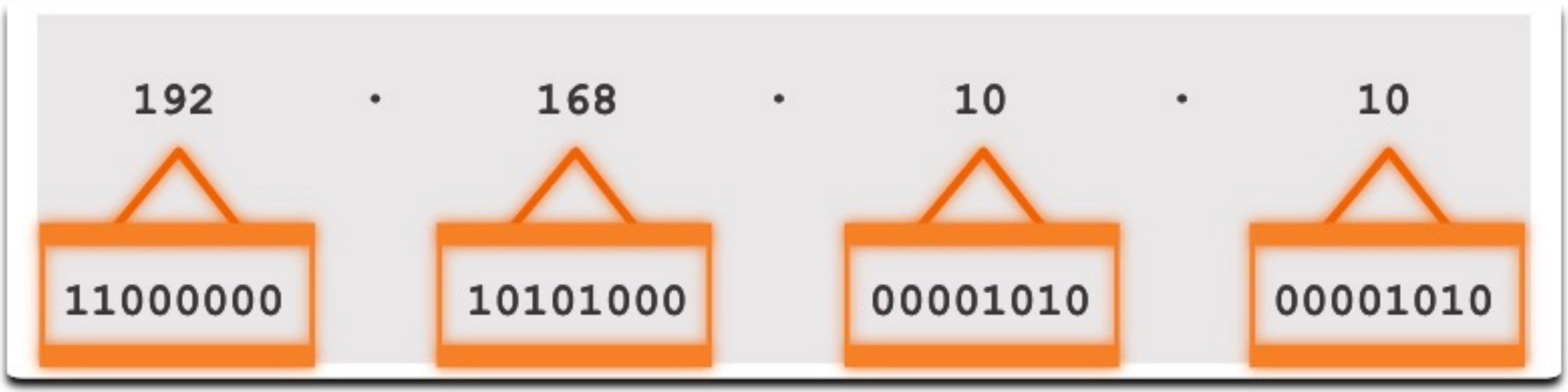
No values left. Enter 0 in remaining binary positions

128	64	32	16	8	4	2	1
1	0	1	0	1	0	0	0

Decimal 168 is written as 10101000 in binary

Binary Number System
IPv4 Addresses

- Routers and computers only understand binary, while humans work in decimal. It is important for you to gain a thorough understanding of these two numbering systems and how they are used in networking.



Hexadecimal Number System

Hexadecimal and IPv6 Addresses

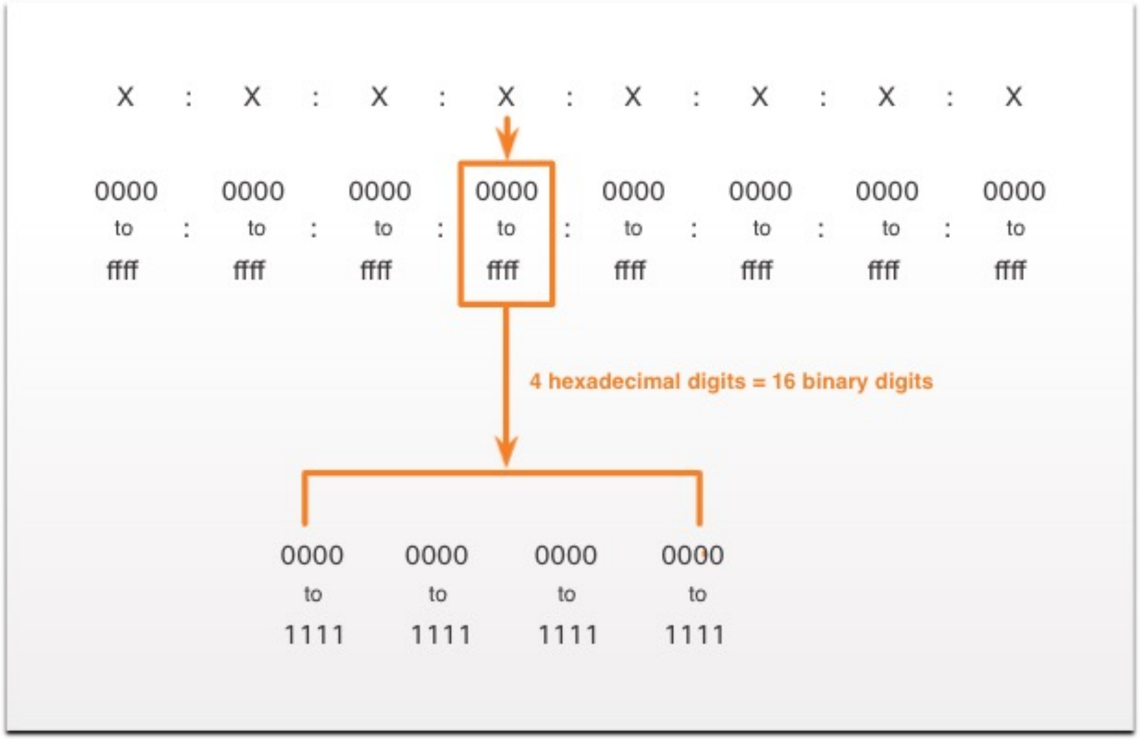
- To understand IPv6 addresses, you must be able to convert hexadecimal to decimal and vice versa.
- Hexadecimal is a base sixteen numbering system, using the digits 0 through 9 and letters A to F.
- It is easier to express a value as a single hexadecimal digit than as four binary bit.
- Hexadecimal is used to represent IPv6 addresses and MAC addresses.

Decimal	Binary	Hexadecimal
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F

Hexadecimal Number System

Hexadecimal and IPv6 Addresses (Cont.)

- IPv6 addresses are 128 bits in length. Every 4 bits is represented by a single hexadecimal digit. That makes the IPv6 address a total of 32 hexadecimal values.
- The figure shows the preferred method of writing out an IPv6 address, with each X representing four hexadecimal values.
- Each four hexadecimal character group is referred to as a hextet.



Decimal to Hexadecimal Conversions

Follow the steps listed to convert decimal numbers to hexadecimal values:

- Convert the decimal number to 8-bit binary strings.
- Divide the binary strings in groups of four starting from the rightmost position.
- Convert each four binary numbers into their equivalent hexadecimal digit.

For example, 168 converted into hex using the three-step process.

- 168 in binary is 10101000.
- 10101000 in two groups of four binary digits is 1010 and 1000.
- 1010 is hex A and 1000 is hex 8, so 168 is A8 in hexadecimal.

Hexadecimal Number System

Hexadecimal to Decimal Conversions

Follow the steps listed to convert hexadecimal numbers to decimal values:

- Convert the hexadecimal number to 4-bit binary strings.
- Create 8-bit binary grouping starting from the rightmost position.
- Convert each 8-bit binary grouping into their equivalent decimal digit.

For example, D2 converted into decimal using the three-step process:

- D2 in 4-bit binary strings is 1101 and 0010.
- 1101 and 0010 is 11010010 in an 8-bit grouping.
- 11010010 in binary is equivalent to 210 in decimal, so D2 is 210 is decimal

Module Practice and Quiz

What did I learn in this module?

- Binary is a base two numbering system that consists of the numbers 0 and 1, called bits.
- Decimal is a base ten numbering system that consists of the numbers 0 through 9.
- Binary is what hosts, servers, and networking equipment uses to identify each other.
- Hexadecimal is a base sixteen numbering system that consists of the numbers 0 through 9 and the letters A to F.
- Hexadecimal is used to represent IPv6 addresses and MAC addresses.
- IPv6 addresses are 128 bits long, and every 4 bits is represented by a hexadecimal digit for a total of 32 hexadecimal digits.
- To convert hexadecimal to decimal, you must first convert the hexadecimal to binary, then convert the binary to decimal.
- To convert decimal to hexadecimal, you must first convert the decimal to binary and then the binary to hexadecimal.

Module 6: Data Link Layer

Instructor Materials

Introduction to Networks v7.0
(ITN)

Module Objectives

Module Title: Data Link Layer

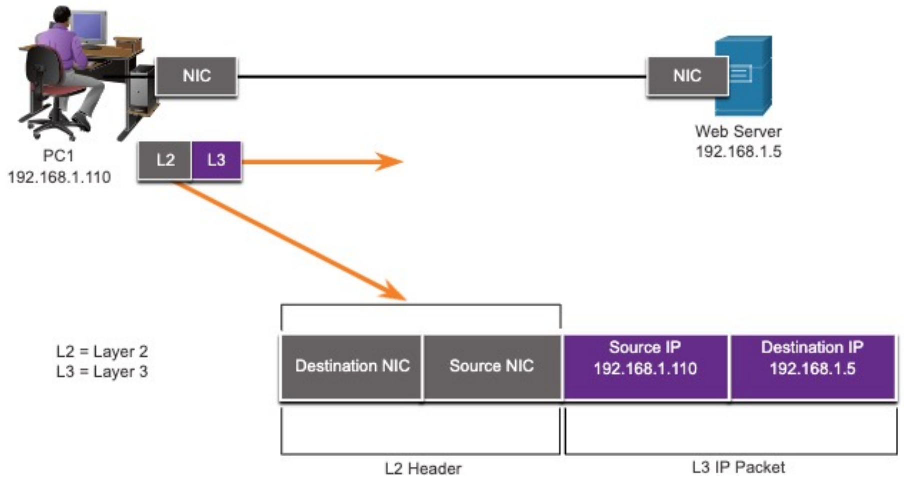
Module Objective: Explain how media access control in the data link layer supports communication across networks.

Topic Title	Topic Objective
Purpose of the Data Link Layer	Describe the purpose and function of the data link layer in preparing communication for transmission on specific media.
Topologies	Compare the characteristics of media access control methods on WAN and LAN topologies.
Data Link Frame	Describe the characteristics and functions of the data link frame.

Purpose of the Data Link Layer

The Data Link Layer

- The Data Link layer is responsible for communications between end-device network interface cards.
- It allows upper layer protocols to access the physical layer media and encapsulates Layer 3 packets (IPv4 and IPv6) into Layer 2 Frames.
- It also performs error detection and rejects corrupts frames.

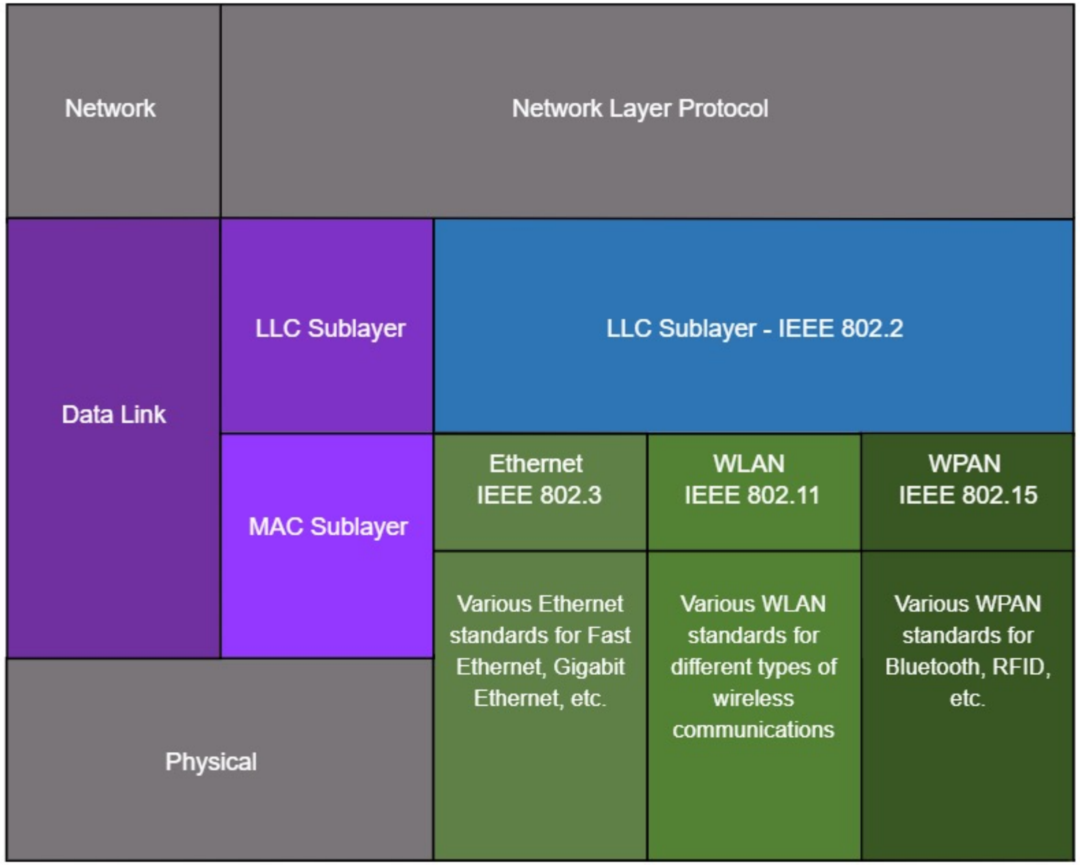


Purpose of the Data Link Layer
IEEE 802 LAN/MAN Data Link Sublayers

IEEE 802 LAN/MAN standards are specific to the type of network (Ethernet, WLAN, WPAN, etc).

The Data Link Layer consists of two sublayers. **Logical Link Control (LLC)** and **Media Access Control (MAC).**

- The LLC sublayer communicates between the networking software at the upper layers and the device hardware at the lower layers.
- The MAC sublayer is responsible for data encapsulation and media access control.



Providing Access to Media

Packets exchanged between nodes may experience numerous data link layers and media transitions.

At each hop along the path, a router performs four basic Layer 2 functions:

- Accepts a frame from the network medium.
- De-encapsulates the frame to expose the encapsulated packet.
- Re-encapsulates the packet into a new frame.
- Forwards the new frame on the medium of the next network segment.

Purpose of the Data Link Layer
Data Link Layer Standards

Data link layer protocols are defined by engineering organizations:

- Institute for Electrical and Electronic Engineers (IEEE).
- International Telecommunications Union (ITU).
- International Organizations for Standardization (ISO).
- American National Standards Institute (ANSI).

Physical and Logical Topologies

The topology of a network is the arrangement and relationship of the network devices and the interconnections between them.

There are two types of topologies used when describing networks:

- **Physical topology** – shows physical connections and how devices are interconnected.
- **Logical topology** – identifies the virtual connections between devices using device interfaces and IP addressing schemes.

Topologies

WAN Topologies

There are three common physical WAN topologies:

- **Point-to-point** – the simplest and most common WAN topology. Consists of a permanent link between two endpoints.
- **Hub and spoke** – similar to a star topology where a central site interconnects branch sites through point-to-point links.
- **Mesh** – provides high availability but requires every end system to be connected to every other end system.

Topologies

Point-to-Point WAN Topology

- Physical point-to-point topologies directly connect two nodes.
- The nodes may not share the media with other hosts.
- Because all frames on the media can only travel to or from the two nodes, Point-to-Point WAN protocols can be very simple.

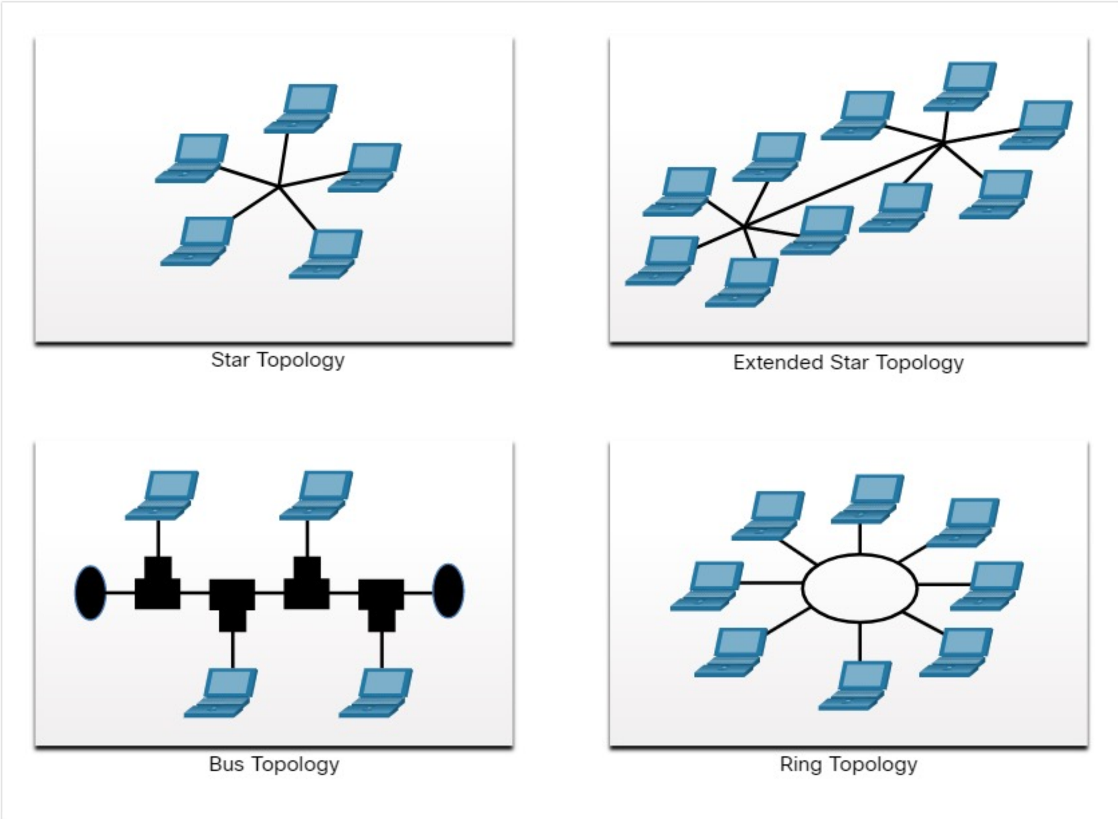
LAN Topologies

End devices on LANs are typically interconnected using a star or extended star topology. Star and extended star topologies are easy to install, very scalable and easy to troubleshoot.

Early Ethernet and Legacy Token Ring technologies provide two additional topologies:

- **Bus** – All end systems chained together and terminated on each end.
- **Ring** – Each end system is connected to its respective neighbors to form a ring.

Physical Topologies



Topologies

Half and Full Duplex Communication

Half-duplex communication

- Only allows one device to send or receive at a time on a shared medium.
- Used on WLANs and legacy bus topologies with Ethernet hubs.

Full-duplex communication

- Allows both devices to simultaneously transmit and receive on a shared medium.
- Ethernet switches operate in full-duplex mode.

Access Control Methods

Contention-based access

All nodes operating in half-duplex, competing for use of the medium. Examples are:

- Carrier sense multiple access with collision detection (CSMA/CD) as used on legacy bus-topology Ethernet.
- Carrier sense multiple access with collision avoidance (CSMA/CA) as used on Wireless LANs.

Controlled access

- Deterministic access where each node has its own time on the medium.
- Used on legacy networks such as Token Ring and ARCNET.

Topologies

Contention-Based Access – CSMA/CD

CSMA/CD

- Used by legacy Ethernet LANs.
- Operates in half-duplex mode where only one device sends or receives at a time.
- Uses a collision detection process to govern when a device can send and what happens if multiple devices send at the same time.

CSMA/CD collision detection process:

- Devices transmitting simultaneously will result in a signal collision on the shared media.
- Devices detect the collision.
- Devices wait a random period of time and retransmit data.

Contention-Based Access – CSMA/CA

CSMA/CA

- Used by IEEE 802.11 WLANs.
- Operates in half-duplex mode where only one device sends or receives at a time.
- Uses a collision avoidance process to govern when a device can send and what happens if multiple devices send at the same time.

CSMA/CA collision avoidance process:

- When transmitting, devices also include the time duration needed for the transmission.
- Other devices on the shared medium receive the time duration information and know how long the medium will be unavailable.

The Frame

Data is encapsulated by the data link layer with a header and a trailer to form a frame.

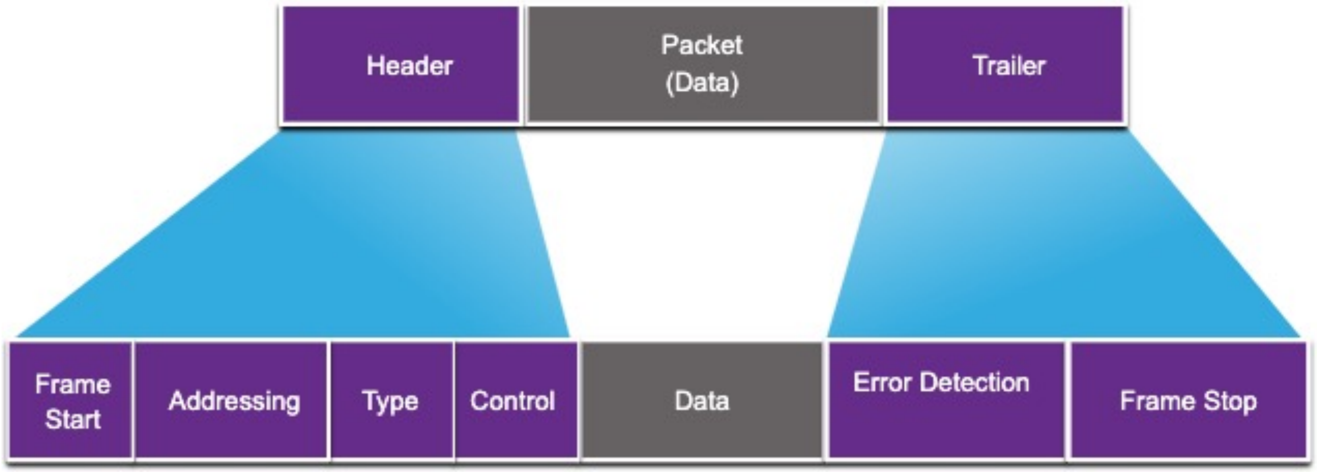
A data link frame has three parts:

- Header
- Data
- Trailer

The fields of the header and trailer vary according to data link layer protocol.

The amount of control information carried with in the frame varies according to access control information and logical topology.

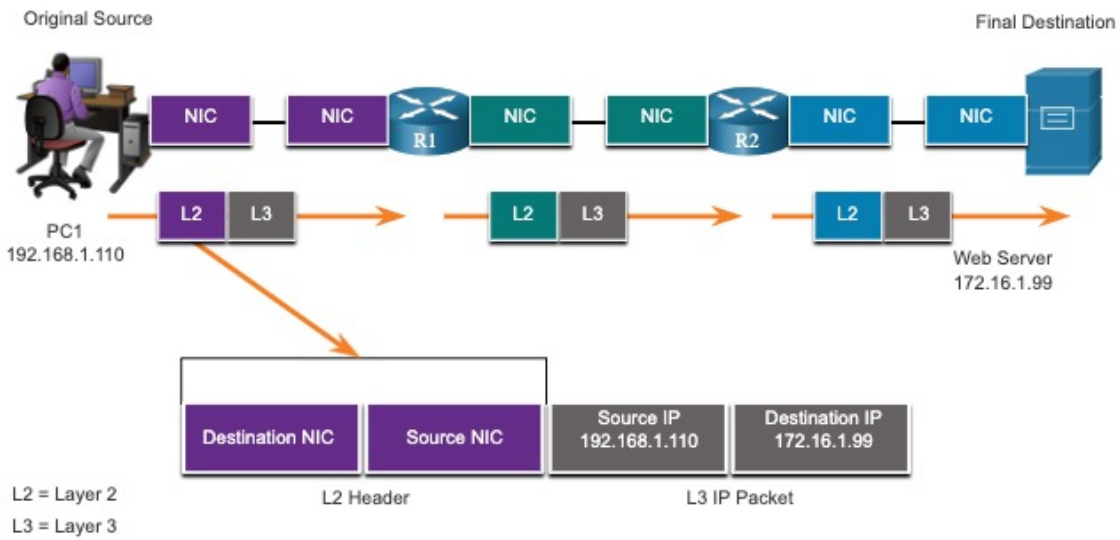
Data Link Frame
Frame Fields



Field	Description
Frame Start and Stop	Identifies beginning and end of frame
Addressing	Indicates source and destination nodes
Type	Identifies encapsulated Layer 3 protocol
Control	Identifies flow control services
Data	Contains the frame payload
Error Detection	Used for determine transmission errors

Data Link Frame
Layer 2 Addresses

- Also referred to as a physical address.
- Contained in the frame header.
- Used only for local delivery of a frame on the link.
- Updated by each device that forwards the frame.



Data Link Frame
LAN and WAN Frames

The logical topology and physical media determine the data link protocol used:

- Ethernet
- 802.11 Wireless
- Point-to-Point (PPP)
- High-Level Data Link Control (HDLC)
- Frame-Relay

Each protocol performs media access control for specified logical topologies.

What did I learn in this module?

- The data link layer of the OSI model (Layer 2) prepares network data for the physical network.
- The data link layer is responsible for network interface card (NIC) to network interface card communications.
- The IEEE 802 LAN/MAN data link layer consists of the following two sublayers: LLC and MAC.
- The two types of topologies used in LAN and WAN networks are physical and logical.
- Three common types of physical WAN topologies are: point-to-point, hub and spoke, and mesh.
- Half-duplex communications exchange data in one direction at a time. Full-duplex sends and receives data simultaneously.
- In contention-based multi-access networks, all nodes are operating in half-duplex.
- Examples of contention-based access methods include: CSMA/CD for bus-topology Ethernet LANs and CSMA/CA for WLANs.
- The data link frame has three basic parts: header, data, and trailer.
- Frame fields include: frame start and stop indicator flags, addressing, type, control, data, and error detection.
- Data link addresses are also known as physical addresses.
- Data link addresses are only used for link local delivery of frames.

