Ch 4: Network Access

Computer Networks Course

BY

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OSI model divides the functions of a data network into layers. Each layer works with the layers above and below to transmit data. Two layers of the OSI model are so closely tied, that according to the TCP/IP model. **Those two layers are the data link layer and the physical layer.**

On the sending device, data link layer prepare data for transmission and control how that data accesses the physical media. However, **the physical layer** controls how the data is transmitted onto the physical media by encoding the binary digits that represent data into signals.

On the receiving end, the **physical layer** receives signals across the connecting media. After decoding the signal back into data, the physical layer passes the frame to the **data link layer** for acceptance and processing.

Types of Connections

A physical connection can be a **wired** connection using a cable or a **wireless** connection using radio waves.

Switch devices and wireless access points are often two separate dedicated devices within a network implementation. However, there are also devices that offer both wired and wireless connectivity. In many homes, for example, individuals are implementing home integrated service routers (ISRs)

Network Interface Cards

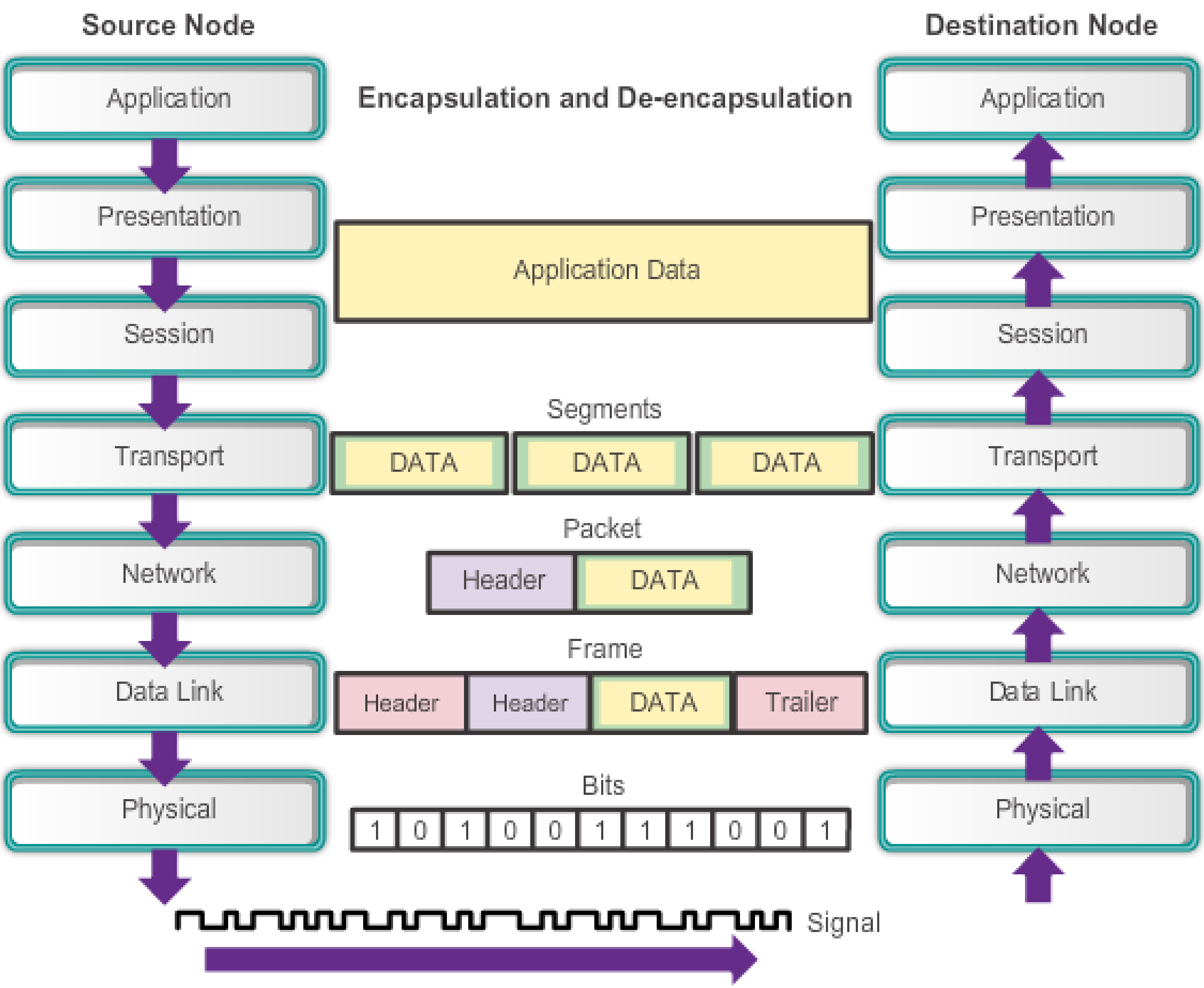
Network Interface Cards (**NICs**) connect a device to the network. Ethernet NICs are used for a wired connection, whereas WLAN **(Wireless Local Area Network) NICs** are used for wireless. **An end-user device may include one or both types of NICs**. A network printer, for example, may only have an Ethernet NIC, and therefore, must connect to the network using an Ethernet cable. Other devices, such as tablets and smartphones, might only contain a WLAN NIC and must use a wireless connection.

The Physical Layer

This layer accepts a complete frame from the data link layer and encodes it as a series of signals that are transmitted onto the local media. The encoded bits that comprise a frame are received by either an end device or an network device.

The process that data undergoes from a source node to a destination node is:

- **The user data is segmented** by the transport layer, placed into **packets by the network layer**, and further **encapsulated into frames by the data link layer**.
- **The physical layer** encodes the frames and creates the electrical, optical, or radio wave signals that represent the bits in each frame.
- These signals are then sent on the media, one at a time.
- **The destination node** physical layer retrieves these individual signals from the **media**, restores them to their bit representations, and passes the bits up to the data link layer as a complete frame.


Source Node
Destination Node
Encapsulation and De-encapsulation
Application
Presentation
Session
Transport
Network
Data Link
Physical
Application
Presentation
Session
Transport
Network
Data Link
Physical
Application Data
Segments
DATA
DATA
DATA
Packet
Header
DATA
Frame
Header
Header
DATA
Trailer
Bits
1 0 1 0 0 1 1 1 0 0 1
Signal

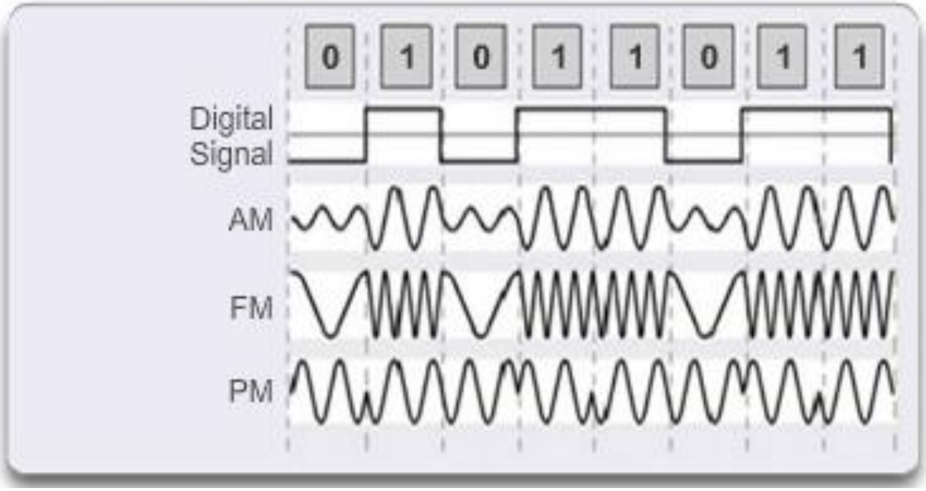
Physical Layer Media

There are three basic forms of network media. The physical layer produces the representation and groupings of bits for each type of media as:

1. **Copper cable**: The signals are patterns of electrical pulses.
2. **Fiber-optic cable**: The signals are patterns of light.
3. **Wireless**: The signals are patterns of microwave transmissions.

Electrical Signals -
Copper cable

Light Pulse -
Fiber-optic cable

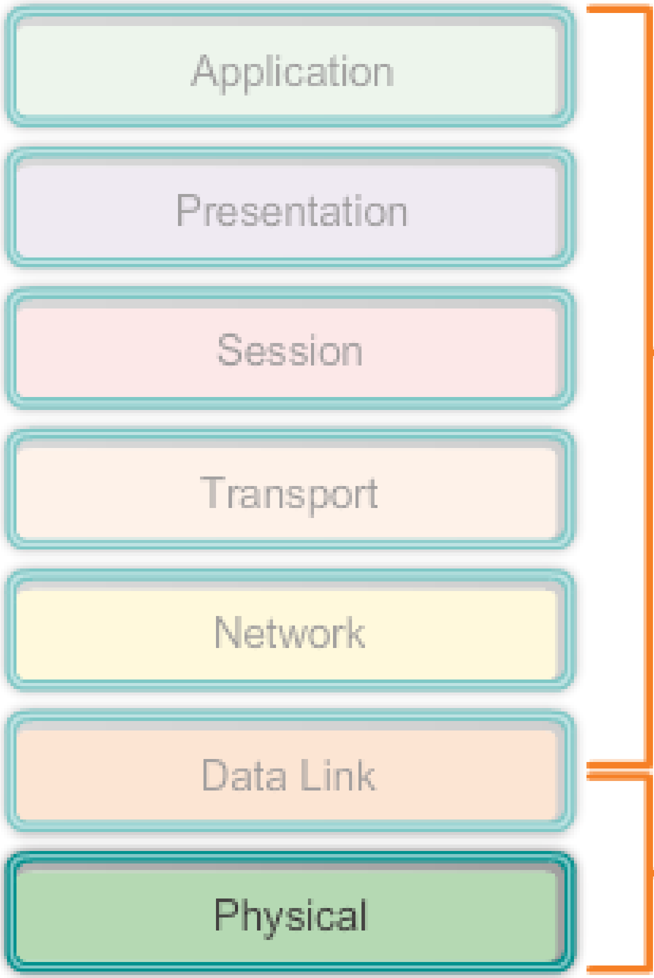


Microwave Signals -
Wireless

Physical Layer Standards

The **protocols** and **operations** of the **upper OSI layers** are performed in **software** designed by **software engineers and computer scientists.** The services and protocols in the TCP/IP suite are defined by the **Internet Engineering Task Force (IETF).**

The physical layer consists of electronic circuits, media, and connectors developed by engineers. Therefore, it is appropriate that the standards governing this hardware are defined by the relevant electrical and communications engineering organizations.



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

Functions

The physical layer standards address three functional areas:

Physical Components

The physical components are the electronic hardware devices, media, and other connectors that transmit and carry the signals to represent the bits. Hardware components such as NICs, interfaces and connectors, cable materials, and cable designs are all specified in standards associated with the physical layer.

Encoding

Encoding or line encoding is a method of converting a stream of data bits into a predefined "code”. Codes are groupings of bits used to provide a predictable pattern that can be recognized by both the sender and the receiver. In the case of networking, encoding is a pattern of voltage or current used to represent bits; the 0s and 1s.

For example, Manchester encoding represents a 0 bit by a high to low voltage transition, and a 1 bit is represented as a low to high voltage transition.

Signaling

The physical layer must generate the electrical, optical, or wireless signals that represent the "1" and "0" on the media.

Bandwidth

Different physical media support the transfer of bits at different **rates**. Data transfer is usually discussed in terms of **bandwidth and throughput.**

Bandwidth is the capacity of a medium to carry data. Digital bandwidth measures the amount of data that can flow from one place to another in a given amount of time. Bandwidth is typically measured in kilobits per second (kb/s), megabits per second (Mb/s), or gigabits per second (Gb/s).

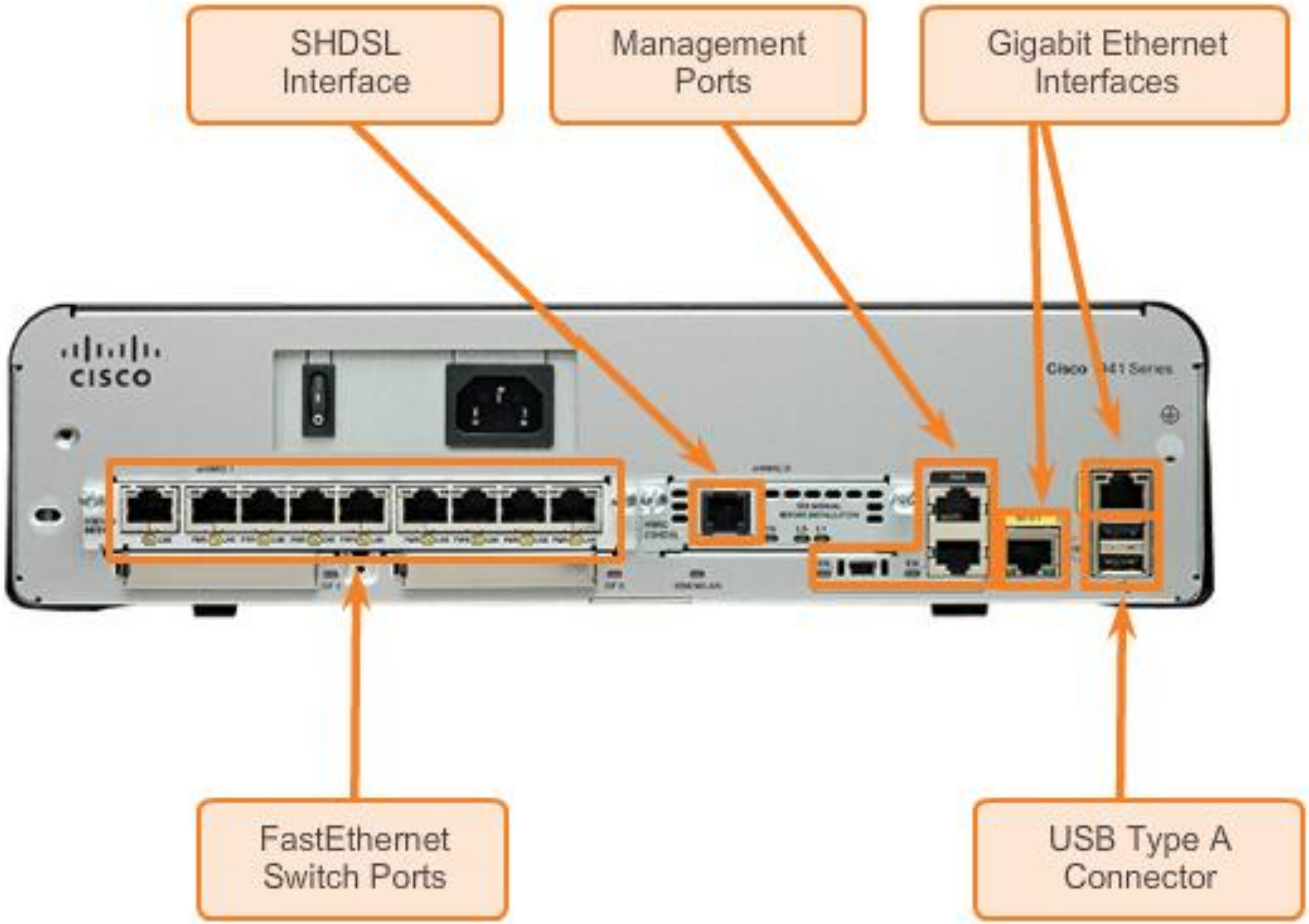
Throughput

Throughput is the measure of the transfer of bits across the media over a given period of time.

Due to a number of factors, throughput usually does not match the specified bandwidth in physical layer implementations. Many factors influence throughput, including:

1. The amount of traffic
2. The type of traffic
3. The latency (delays) created by the number of network devices encountered between source and destination

Different types of interfaces and ports available on a 1941 router.



Characteristics of Copper Cabling

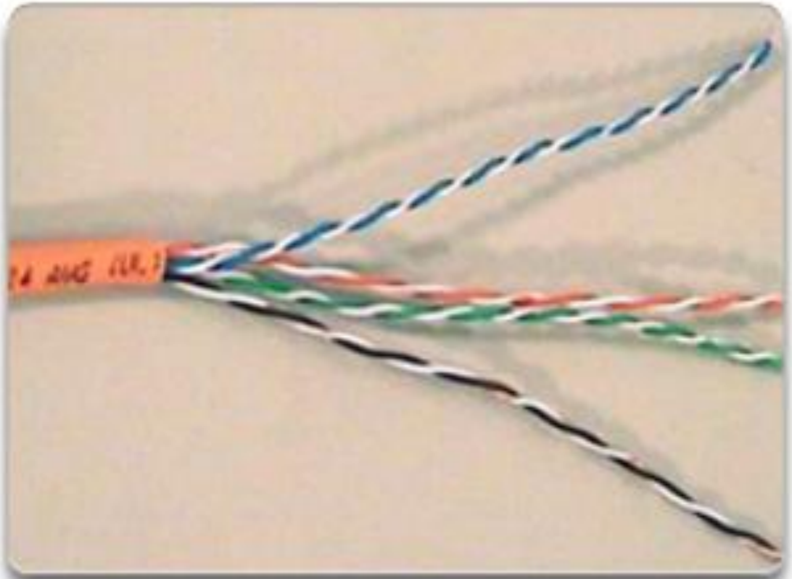
Networks use copper media because it is **inexpensive**, **easy to install** and **has low resistance** to electrical current. However, **copper media is limited by distance and signal interference.**

Copper Media

There are three main types of copper media used in networking:

1. **Unshielded Twisted-Pair (UTP)**
2. **Shielded Twisted-Pair (STP)**
3. **Coaxial**

Different physical layer standards specify the use of different connectors. Networking media use modular **jacks** and **plugs** to provide easy connection and disconnection. Also, a single type of physical connector may be used for multiple types of connections. For example, **the RJ-45 connector** is widely used in LANs with one type of media and in some WANs with another media type.



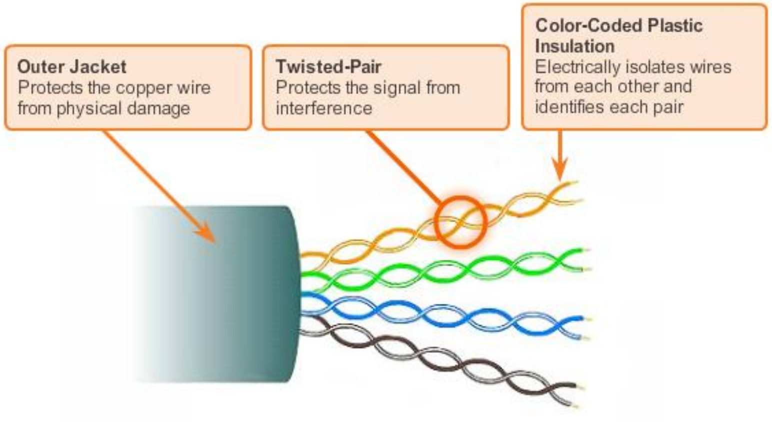
Unshielded Twisted-Pair (UTP) cable

Shielded Twisted-Pair (STP) cable

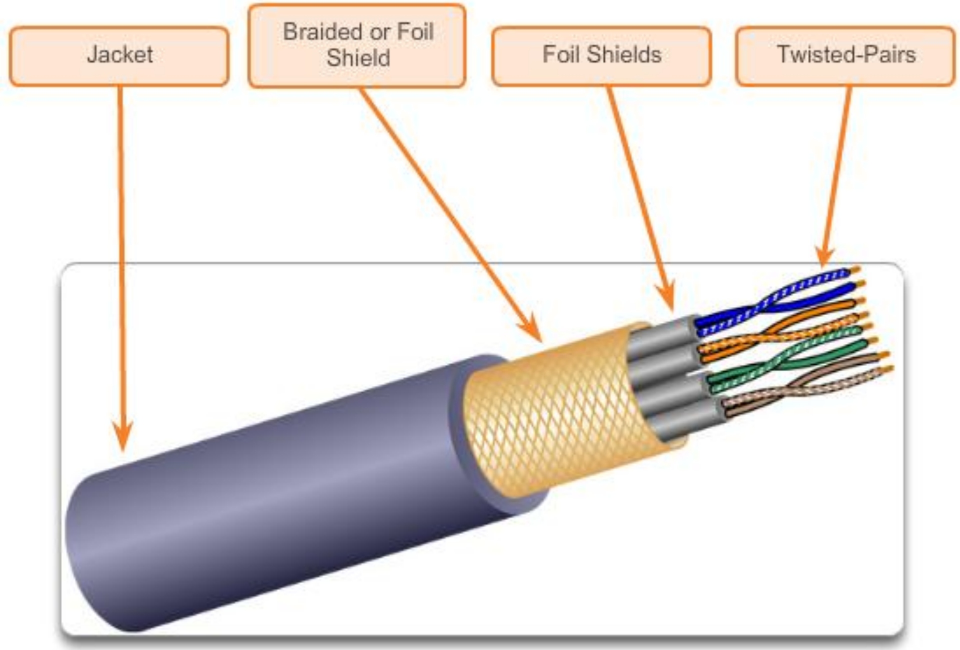
Coaxial cable

Unshielded twisted-pair (UTP) cabling is the most common networking media. UTP cabling, terminated with **RJ-45** connectors, is used for interconnecting network hosts with intermediate networking devices.

In LANs, UTP cable consists of four pairs of color-coded wires that have been twisted together and then encased in a flexible plastic sheath that protects from minor physical damage. The twisting of wires helps protect against signal interference from other wires.

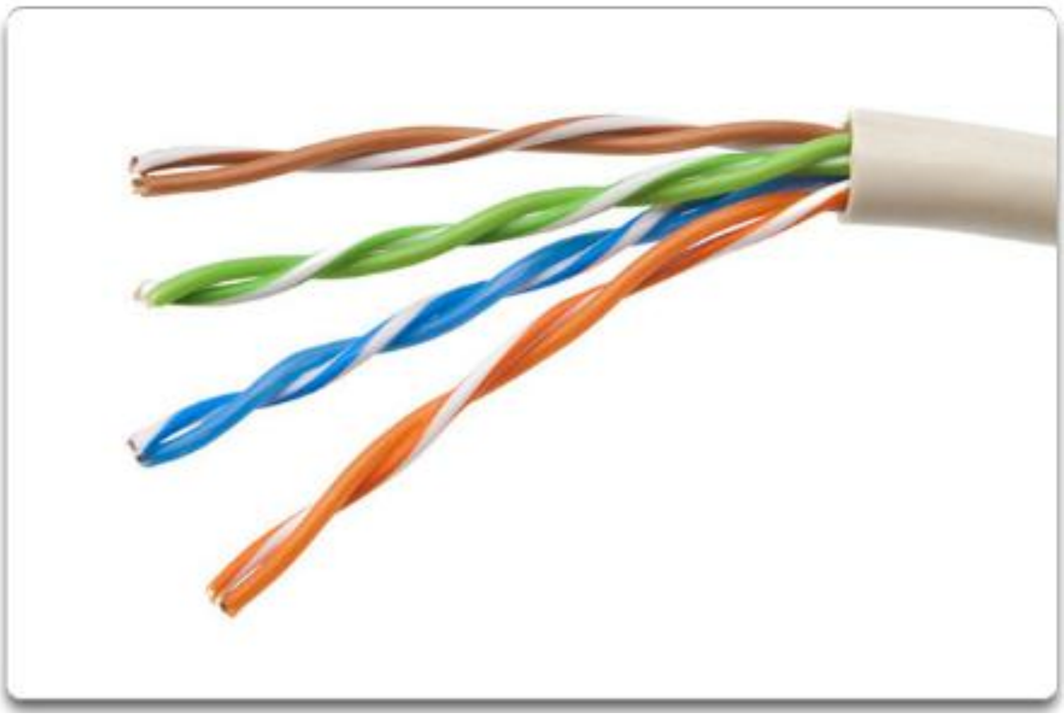


Shielded twisted-pair Cable (STP) provides better noise protection than **UTP** cabling. However, compared to UTP cable, STP cable is significantly more expensive and difficult to install. Like UTP cable, STP uses an **RJ-45** connector.



Properties of UTP Cabling

When used as a networking medium, UTP cabling consists of four pairs of color-coded copper wires that have been twisted together and then encased in a flexible plastic sheath.

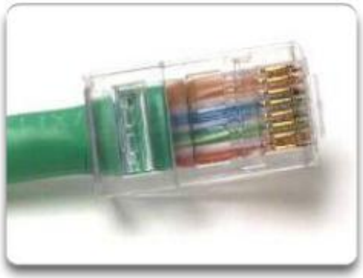


UTP Connectors

UTP cable is usually terminated with an **RJ-45 connector**. This connector is used for a range of physical layer specifications, one of which is Ethernet.

RJ-45 UTP Plugs

Bad connector - Wires are exposed, untwisted, and not entirely covered by the sheath.



Good connector - Wires are untwisted to the extent necessary to attach the connector.

RJ-45 UTP Socket

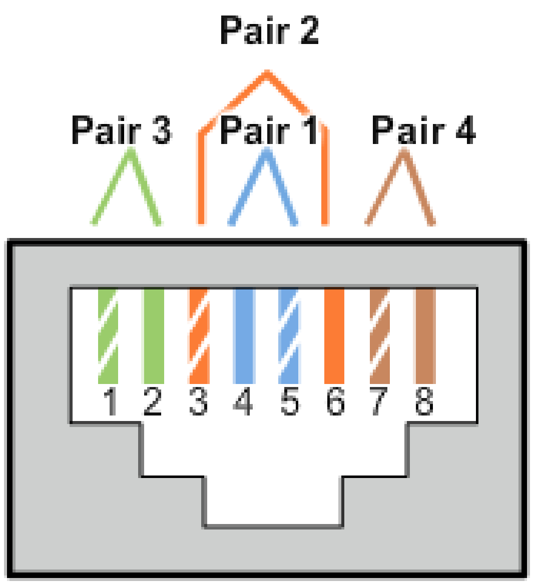
Types of UTP Cable

The following are the main **cable types** that are obtained by using specific wiring conventions:

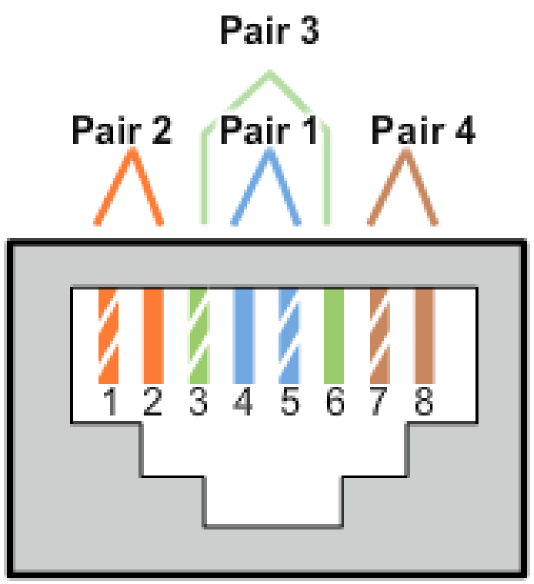
Ethernet Straight-through: It is commonly used to interconnect a host to a switch and a switch to a router.

Ethernet Crossover: Interconnect similar devices. For example to connect a switch to a switch, a host to a host, or a router to a router.

Rollover: A Cisco proprietary cable used to connect a workstation to a router or switch console port.



T568A



T568B

Cable Type	Standard	Application
Ethernet Straight-through	Both ends T568A or both ends T568B	Connects a network host to a network device such as a switch or hub.
Ethernet Crossover	One end T568A, other end T568B	• Connects two network hosts • Connects two network intermediary devices (switch to switch, or router to router)
Rollover	Cisco proprietary	Connects a workstation serial port to a router console port, using an adapter.

Properties of Fiber-Optic Cabling

Optical fiber cable transmits data over longer distances and at higher bandwidths than any other networking media.

Optical fiber is a flexible, but extremely thin, transparent strand of very pure glass, not much bigger than a human hair. Bits are encoded on the fiber as light impulses. The fiber-optic cable acts as a waveguide, or “light pipe,” to transmit light between the two ends with minimal loss of signal.

Types of Fiber Media

Light pulses representing the transmitted data as bits on the media are generated by either:

1. **Lasers**
2. **Light emitting diodes (LEDs)**

Fiber-optic cables are broadly classified into two types:

Single-mode fiber (SMF): Consists of a very small core and uses expensive **laser** technology to send a single ray of light. Popular in long-distance situations spanning **hundreds of kilometers**.

Multimode fiber (MMF): Consists of a larger core and uses LED emitters to send light pulses. Specifically, light from an LED enters the multimode fiber at different angles. Popular in LANs because they can be powered by low-cost LEDs. It provides bandwidth up to 10 Gb/s over link lengths of up to **550 meters**.

Fiber versus Copper

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 high (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 does have some areas of concern, including:

Coverage area: Wireless data communication technologies work well in open environments, limit the effective coverage.

Interference: Wireless is susceptible to interference and can be disrupted by such common devices as household cordless phones, some types of fluorescent lights, microwave ovens, and other wireless communications.

Security: Wireless communication coverage requires no access to a physical strand of media. Therefore, devices and users, not authorized for access to the network, can gain access to the transmission. Network security is a major component of wireless network administration.

Shared medium: WLANs operate in half-duplex, which means only one device can send or receive at a time. The wireless medium is shared amongst all wireless users. The more users needing to access the WLAN simultaneously, results in less bandwidth for each user.

Wireless LAN

Wireless LAN requires the following network devices:

Wireless Access Point (AP): Concentrates the wireless signals from users and connects to the existing copper-based network infrastructure, such as Ethernet. Home and small business wireless routers integrate the functions of a router, switch, and access point into one device as shown in the figure.

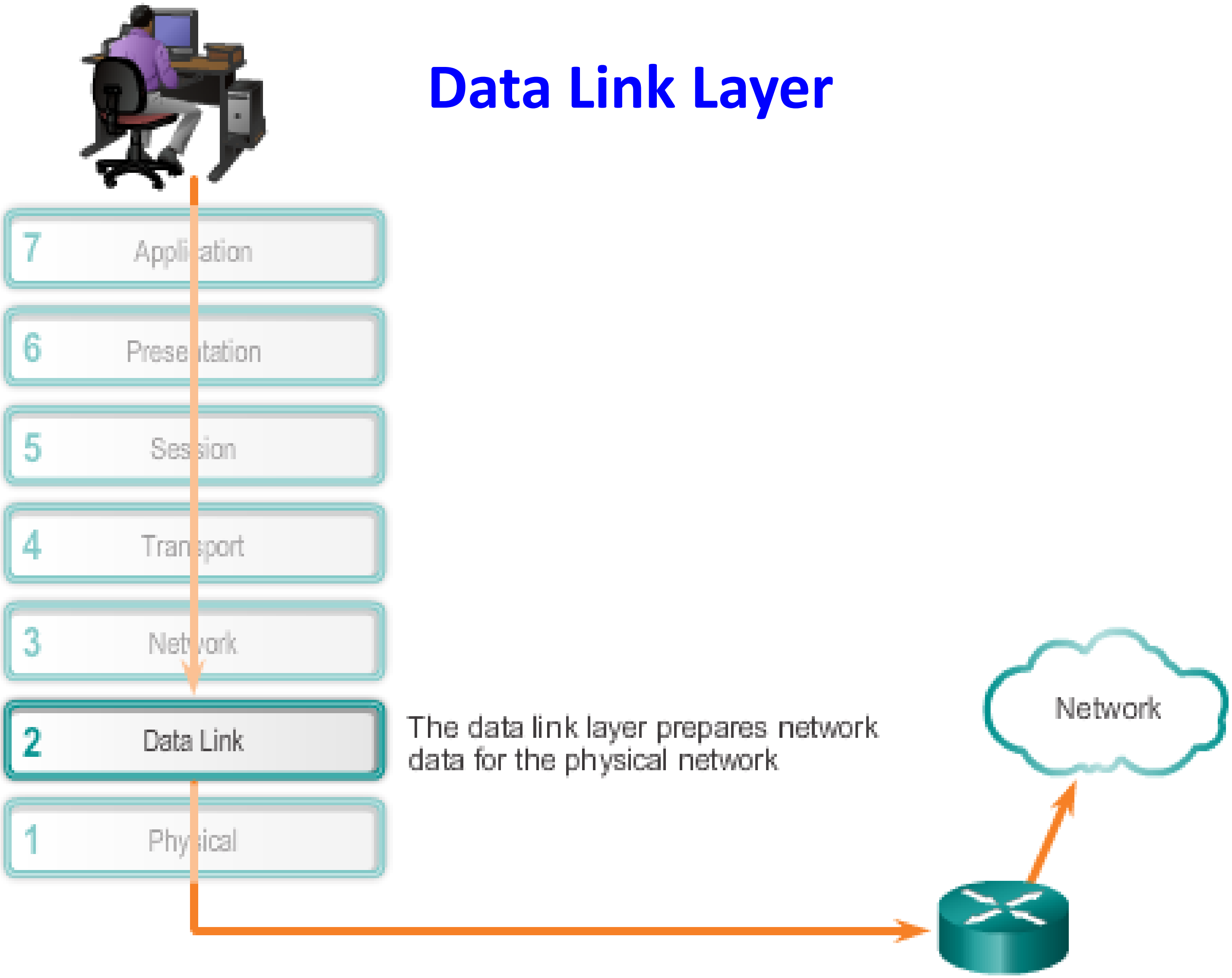
Wireless NIC adapters: Provide wireless communication capability to each network host.

The Data Link Layer (Layer 2)

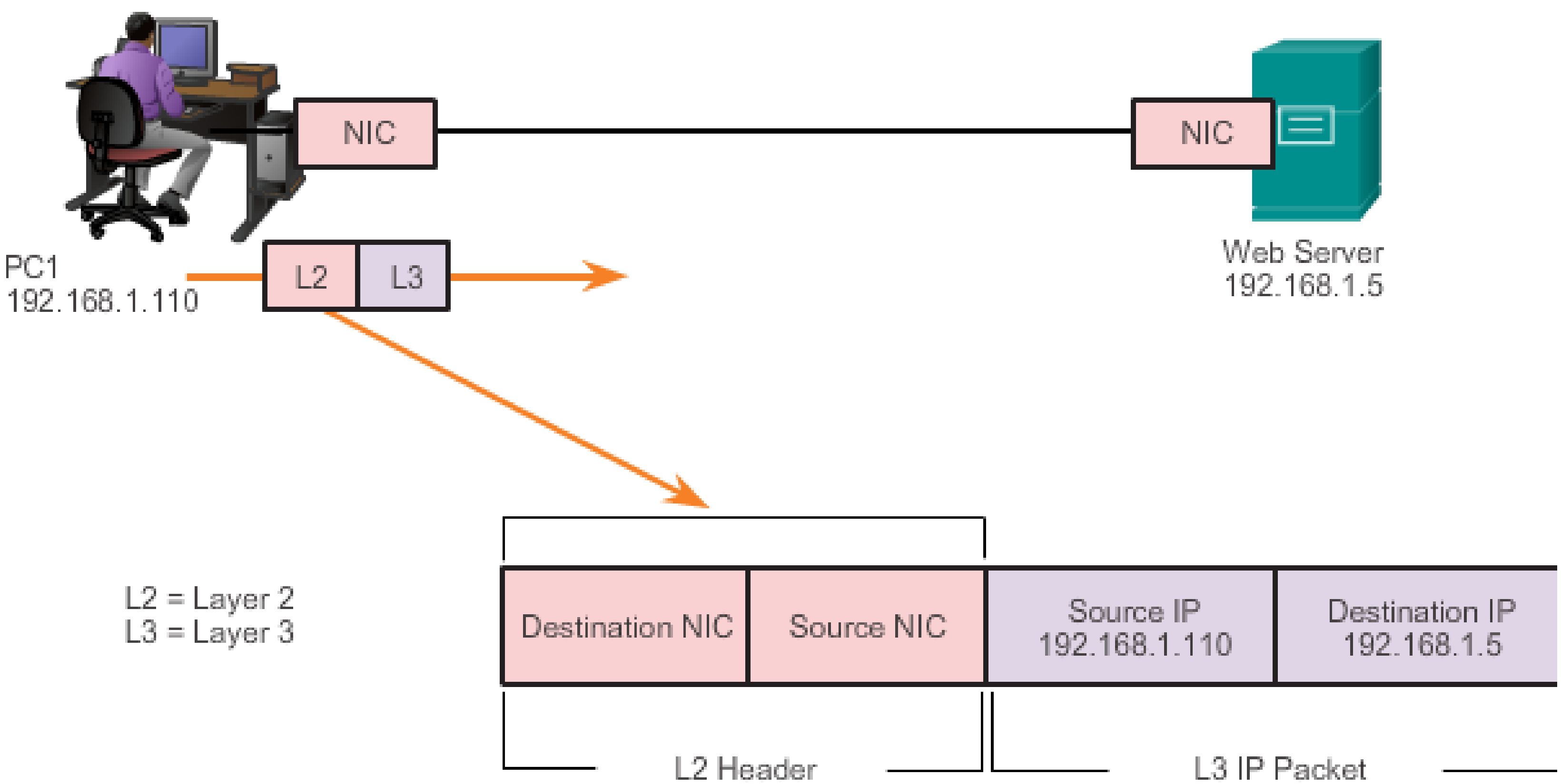
The data link layer of the OSI model (Layer 2), is responsible for:

1. Allowing the upper layers to access the media.
2. Accepting Layer 3 packets and packaging them into frames.
3. Preparing network data for the physical network.
4. Controlling how data is placed and received on the media.
5. Exchanging frames between nodes over a physical network media, such as UTP or fiber-optic.
6. Receiving and directing packets to an upper layer protocol.
7. Performing error detection.

Data Link Layer



Layer 2 Data Link Addresses



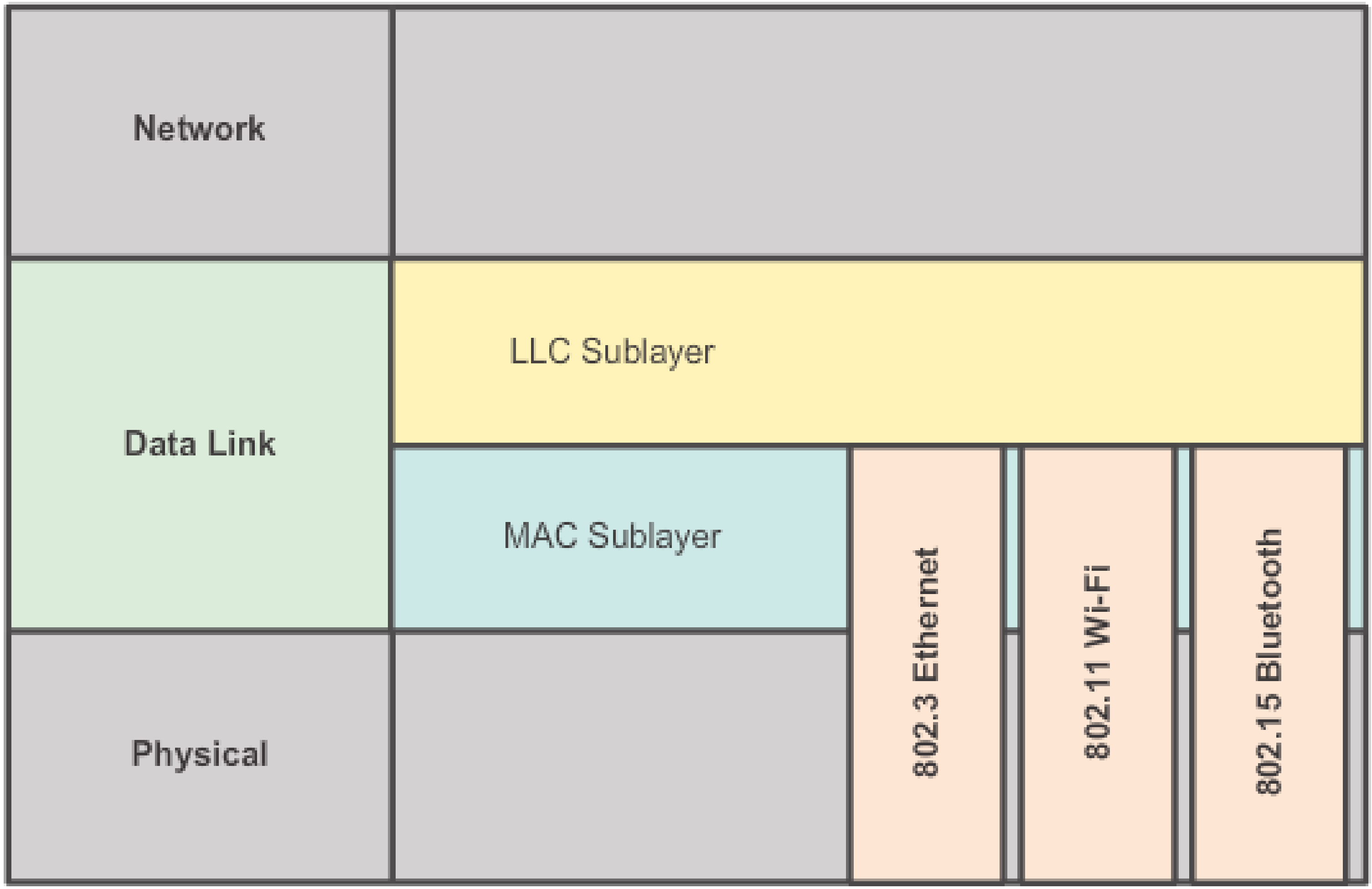
Data Link Sublayers

The data link layer is divided into two sublayers:

Logical Link Control (LLC) - This upper sublayer **communicates with the network layer.** It places information in the frame that identifies which network layer protocol is being used for the frame.

Media Access Control (MAC) - This lower sublayer **defines the media access processes performed by the hardware.** It provides data link layer addressing and access to various network technologies.

Data Link Sublayers



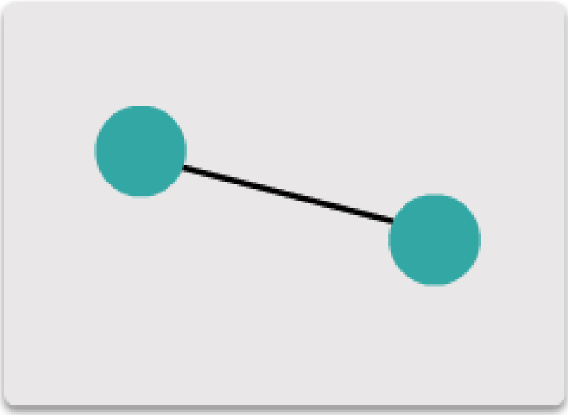
Controlling Access to the Media

The actual media access control method used depends on:

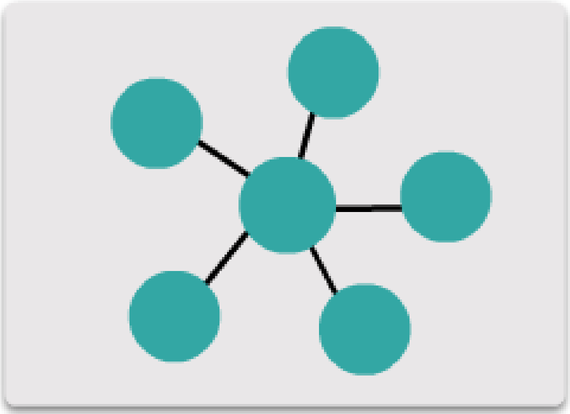
Topology - How the connection between the nodes appears to the data link layer.

Media sharing - How the nodes share the media. The media sharing can be point-to-point, such as in WAN connections, or shared such as in LAN networks.

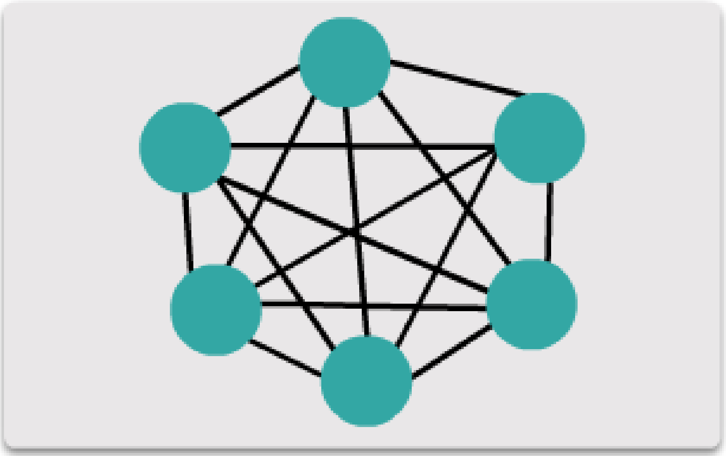
Common Physical WAN Topologies



Point-to-point topology

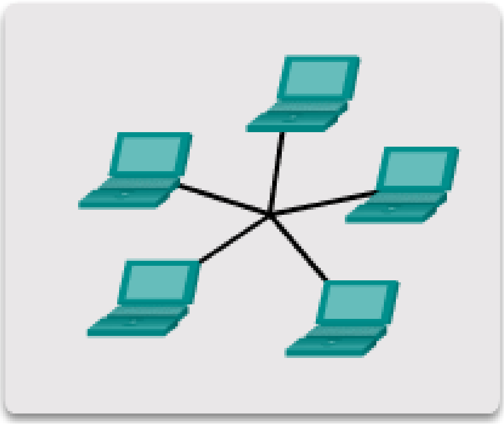


Hub and spoke topology

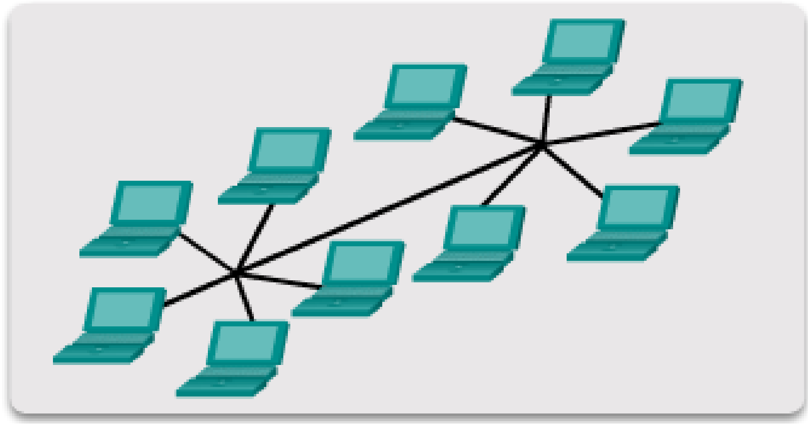


Full mesh topology

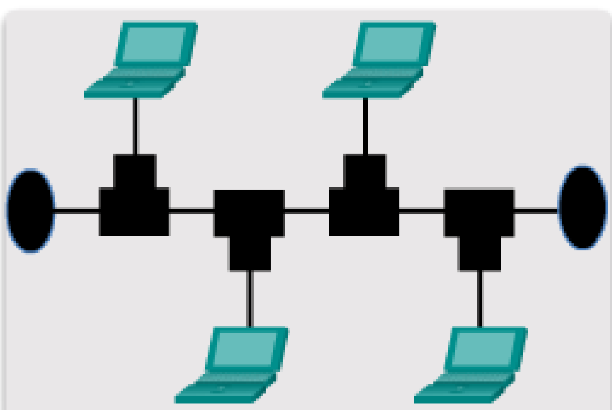
Physical LAN Topologies



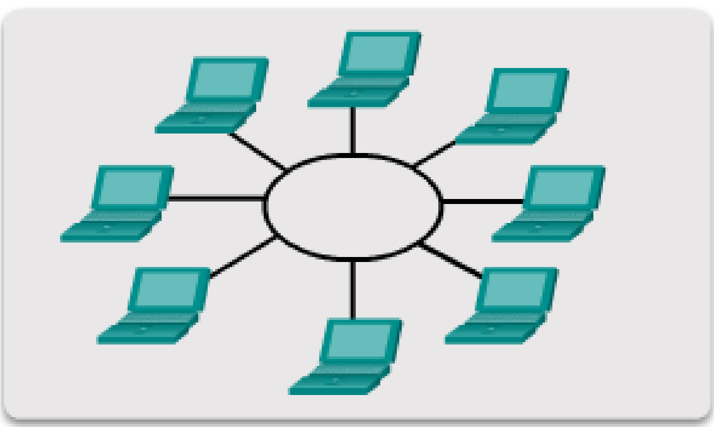
Star topology



Extended star topology



Bus topology



Ring topology

Half and Full Duplex

Duplex communications refer to the direction of data transmission between two devices.

Half-duplex communication - Both devices can transmit and receive on the media but cannot do so simultaneously. The half-duplex mode is used in legacy bus topologies and with Ethernet hubs. WLANs also operate in half-duplex. Half-duplex allows only one device to send or receive at a time on the shared medium and is used with **contention-based access methods**.

Full-duplex communication - Both devices can transmit and receive on the media at the same time. Ethernet switches operate in full-duplex mode by default, but can operate in half-duplex if connecting to a device such as an Ethernet hub.

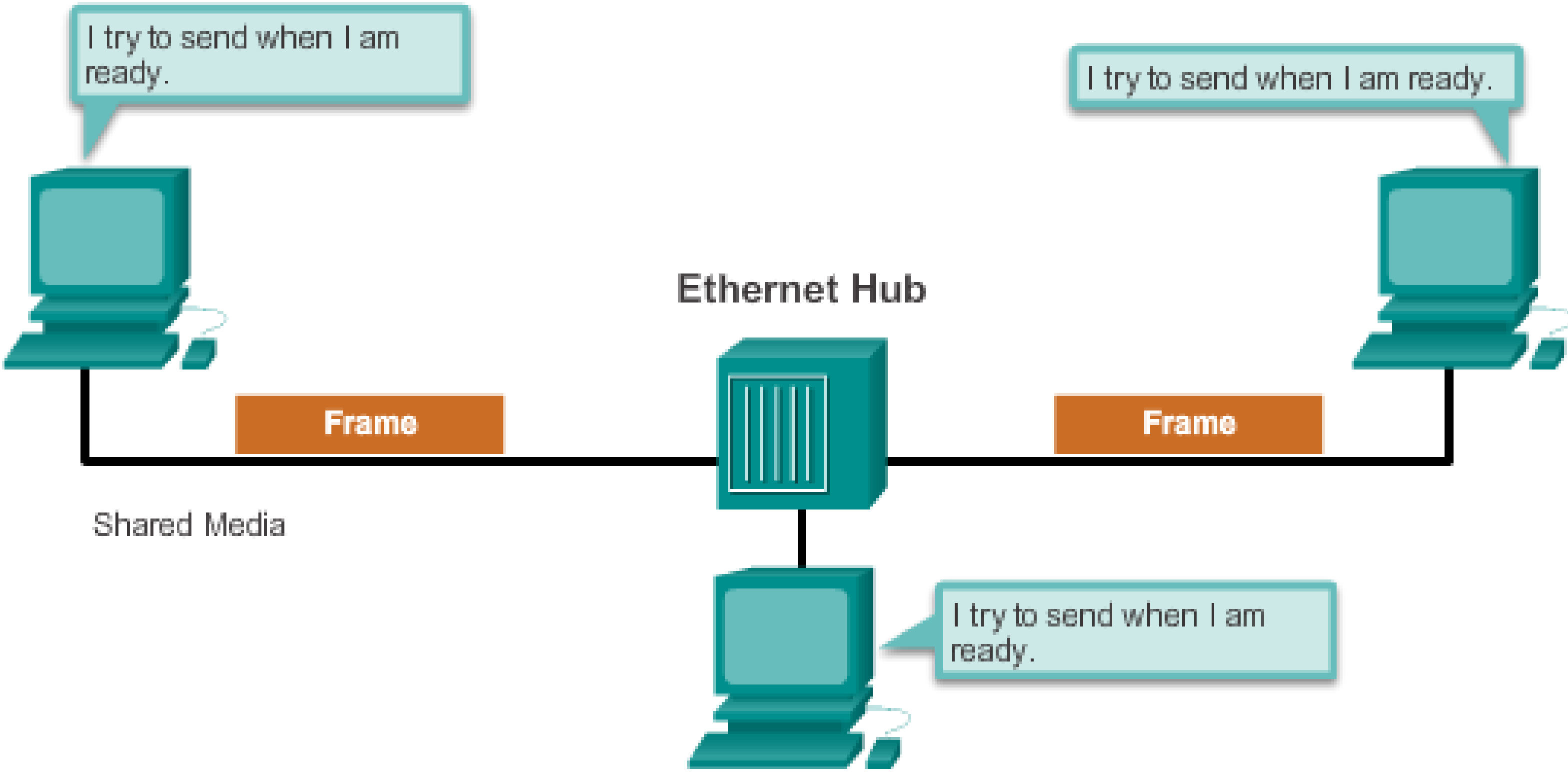
Media Access Control Methods

Some multi-access networks require rules to govern how devices share the physical media. There are two basic **access control methods** for shared media:

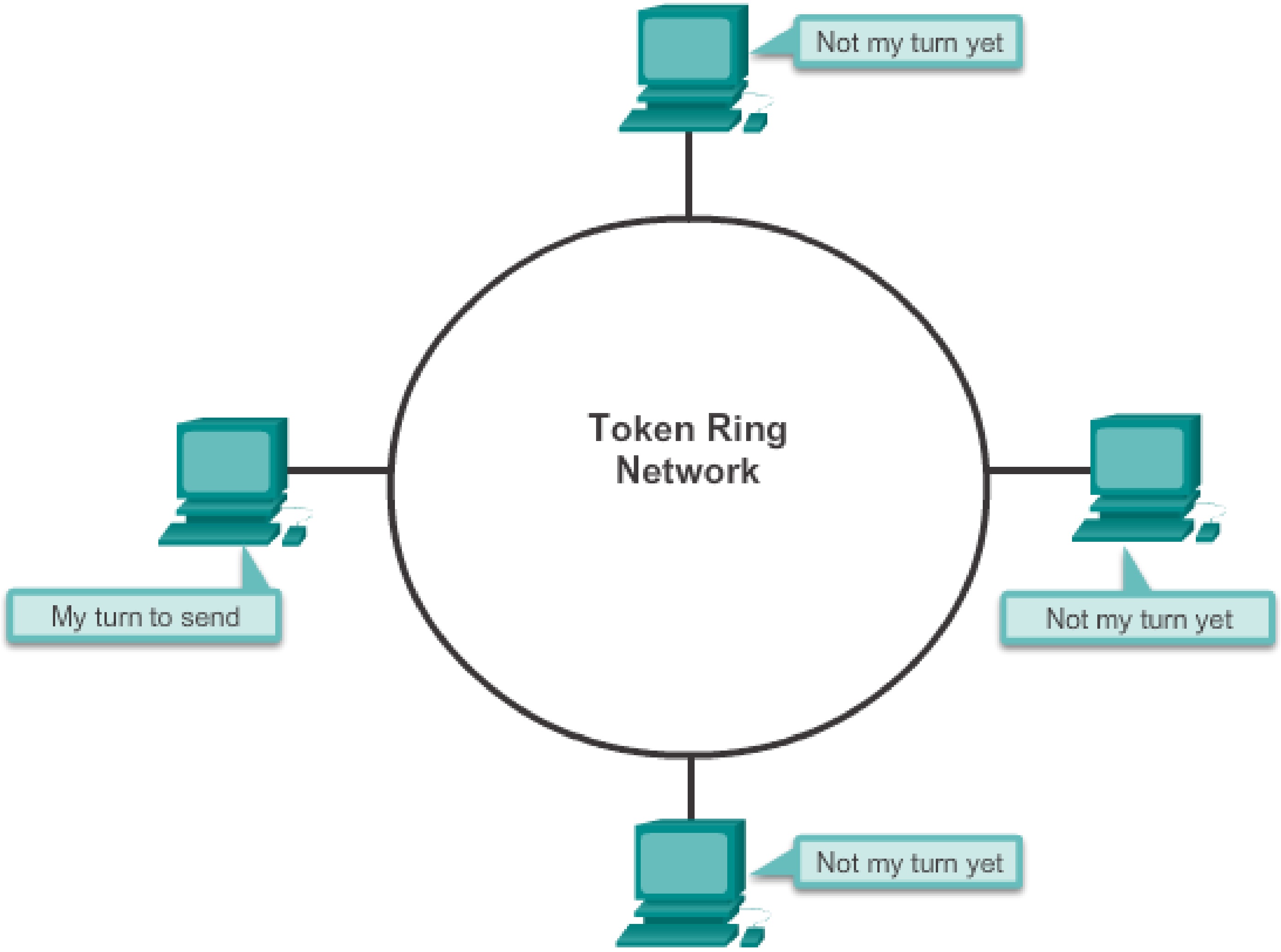
Contention-based access - All nodes operating in **half-duplex** compete for the use of the medium, but only one device can send at a time. However, **there is a process** if more than one device transmits at the same time. Ethernet LANs using hubs and WLANs are examples of this type of access control.

Controlled access - Each node has its own time to use the medium. These deterministic types of networks are inefficient because a device must wait its turn to access the medium.

Contention-Based Access



Controlled Access



Contention-Based Access – CSMA/CD

WLANs, Ethernet LANs with **hubs**, and bus networks are all examples of contention-based access networks. All of these networks operate in half-duplex mode. **This requires a process to govern when a device can send and what happens when multiple devices send at the same time.**

The **Carrier Sense Multiple Access/Collision Detection (CSMA/CD)** process is used in half-duplex Ethernet LANs.

Contention-Based Access – CSMA/CA

IEEE 802.11 WLANs is Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) **does not detect collisions but attempts to avoid them by waiting before transmitting.** Each device that transmits includes the time duration that it needs for the transmission. All other wireless devices receive this information and know how long the medium will be unavailable. After a wireless device sends an 802.11 frame, the receiver returns an acknowledgment so that the sender knows the frame arrived.

The Frame

The data link layer prepares a packet for transport across the local media by encapsulating it with a header and a trailer to create a frame. The description of a frame is a key element of each data link layer protocol. Although there are many different data link layer protocols that describe data link layer frames, **each frame type has three basic parts:**

1. **Header**
2. **Data**
3. **Trailer**

All data link layer protocols encapsulate the Layer 3 PDU within the data field of the frame.

Frame Fields

Frame start and stop indicator flags - Used to identify the beginning and end limits of the frame.

Addressing - Indicates the source and destination nodes on the media.

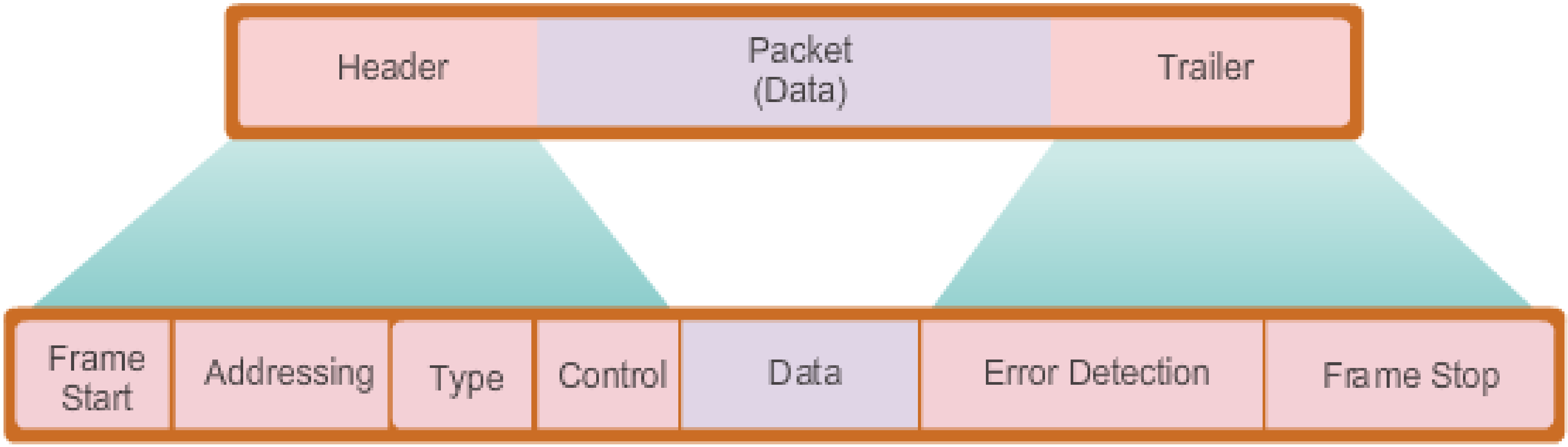
Type - Identifies the Layer 3 protocol in the data field.

Control - Identifies special flow control services such as quality of service (QoS). QoS is used to give forwarding priority to certain types of messages.

Data - Contains the frame **payload** (i.e., packet header, segment header, and the data).

Error Detection - These frame fields are used for error detection and are included after the data to form the trailer.

Frame Fields



Summary

The TCP/IP network access layer is the equivalent of the OSI data link layer (Layer 2) and the physical layer (Layer 1).
The OSI physical layer provides the means to transport the bits that make up a data link layer frame across the network media. The physical components are the electronic hardware devices, media, and other connectors that transmit and carry the signals to represent the bits. Hardware components such as network adapters (NICs), interfaces and connectors, cable materials, and cable designs are all specified in standards associated with the physical layer. The physical layer standards address three functional areas: physical components, frame encoding technique, and signaling method.
Using the proper media is an important part of network communications. Without the proper physical connection, either wired or wireless, communications between any two devices will not occur.
Wired communication consists of copper media and fiber cable:
There are three main types of copper media used in networking: unshielded-twisted pair (UTP), shielded-twisted pair (STP), and coaxial cable. UTP cabling is the most common copper networking media.
Optical fiber cable has become very popular for interconnecting infrastructure network devices. It permits the transmission of data over longer distances and at higher bandwidths (data rates) than any other networking media. Unlike copper wires, fiber-optic cable can transmit signals with less attenuation and is completely immune to EMI and RFI.
Wireless media carry electromagnetic signals that represent the binary digits of data communications using radio or microwave frequencies.
The number of wireless-enabled devices continues to increase. For this reason, wireless has become the medium of choice for home networks and is quickly gaining in popularity in enterprise networks.
The data link layer handles the exchange of frames between nodes over a physical network media. It allows the upper layers to access the media and controls how data is placed and received on the media.
Among the different implementations of the data link layer protocols, there are different methods of controlling access to the media. These media access control techniques define if and how the nodes share the media. The actual media access control method used depends on the topology and media sharing. LAN and WAN topologies can be physical or logical. It is the logical topology that influences the type of network framing and media access control used. WANs are commonly interconnected using the point-to-point, hub and spoke, or mesh physical topologies. In shared media LANs, end devices can be interconnected using the star, bus, ring, or extended star physical topologies.
All data link layer protocols encapsulate the Layer 3 PDU within the data field of the frame. However, the structure of the frame and the fields contained in the header and trailer vary according to the protocol.