OSI Physical Layer

Network Fundamentals – Chapter 8

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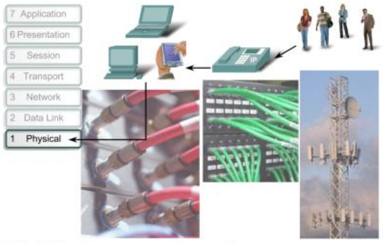
Objectives

- Explain the role of Physical layer protocols and services in supporting communication across data networks.
  - Describe the role of signals used to represent bits as a frame as the frame is transported across the local media
- Describe the purpose of Physical layer signaling and encoding as they are used in networks
- Identify the basic characteristics of copper, fiber and wireless network media
- Describe common uses of copper, fiber and wireless network media

Physical Layer Protocols & Services

- Describe the purpose of the Physical layer in the network and identify the basic elements that enable this layer to fulfill its function

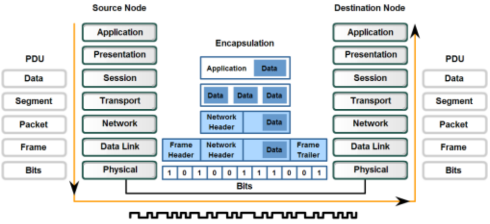


The Physical layer interconnects our data networks.

Physical Layer Protocols & Services

- Describe the role of bits in representing a frame as it is transported across the local media.

Transforming Human Network Communications to Bits



Physical Layer Characteristics

The OSI Physical layer provides the means to transport across the network media the bits that make up a Data Link layer frame.

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 intermediate device.

The delivery of frames across the local media requires the following Physical layer elements:

1. The physical media and associated connectors
2. A representation of bits on the media
3. Encoding of data and control information
4. Transmitter and receiver circuitry on the network devices

Physical Layer Purpose

At this stage of the communication process, the user data has been segmented by the Transport layer, placed into packets by the Network layer, and further encapsulated as frames by the Data Link layer.

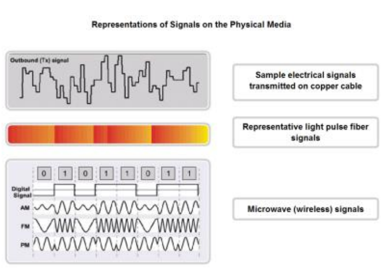
The purpose of the Physical layer is to **create** the **electrical, optical, or microwave signal** that represents the bits in each frame.

These signals are then sent on the media one at a time.

It is also the job of the Physical layer to retrieve these individual signals from the media, restore them to their bit representations, and pass the bits up to the Data Link layer as a complete frame.

Physical Layer Protocols & Services

Describe the role of signaling in the physical media.



Operation

The media does not carry the frame as a single entity. The media carries signals, one at a time, to represent the bits that make up the frame.

There are three basic forms of network media on which data is represented:

1. Copper cable
2. Fiber
3. Wireless

The representation of the bits - that is, the type of signal - depends on the type of media. For copper cable media, the signals are patterns of electrical pulses.

For fiber, the signals are patterns of light. For wireless media, the signals are patterns of radio transmissions.

Frame Identification

When the Physical layer encodes the bits into the signals for a particular medium, it must also distinguish where one frame ends and the next frame begins.

Otherwise, the devices on the media would not recognize when a frame has been fully received.

In that case, the destination device would only receive a string of signals and would not be able to properly reconstruct the frame.

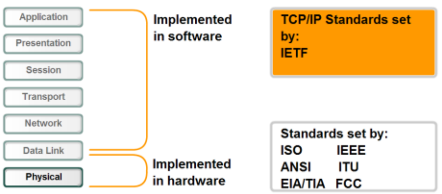
To enable a receiving device to clearly recognize a frame boundary, the transmitting device adds signals to designate the start and end of a frame.

These signals represent particular bit patterns that are only used to denote the start or end of a frame.

Physical Layer Protocols & Services

Distinguish who establishes and maintains standards for the Physical layers compared to those for the other layers of the network

Comparison of Physical layer standards and upper layer standards



Physical Layer Standards

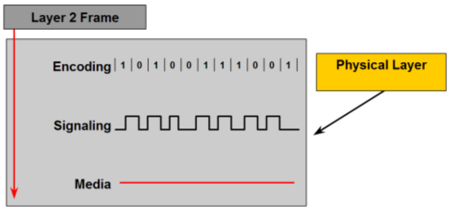
Similar to technologies associated with the Data Link layer, the Physical layer technologies are defined by organizations such as:

1. The International Organization for Standardization (ISO)
2. The Institute of Electrical and Electronics Engineers (IEEE)
3. The American National Standards Institute (ANSI)
4. The International Telecommunication Union (ITU)
5. The Electronics Industry Alliance/Telecommunications Industry Association (EIA/TIA)
6. National telecommunications authorities such as the Federal Communication Commission (FCC) in the USA.

Physical Layer Protocols & Services

Identify hardware components associated with the Physical layer that are governed by standards

Physical Layer Fundamental Principles



Encoding

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 received.

Using predictable patterns helps to distinguish data bits from control bits and provide better media error detection.

In addition to creating codes for data, encoding methods at the Physical layer may also provide codes for control purposes such as identifying the beginning and end of a frame.

The transmitting host will transmit the specific pattern of bits or a code to identify the beginning and end of the frame.

Signalling

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

The method of representing the bits is called the signalling method.

The Physical layer standards must define what type of signal represents a "1" and a "0".

This can be as simple as a change in the level of an electrical signal or optical pulse or a more complex signalling method.

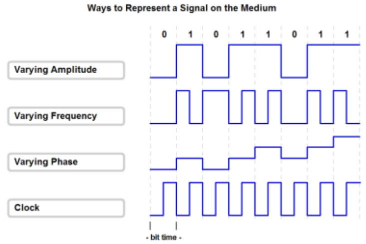
The Physical layer represents each of the bits in the frame as a signal.

Each signal placed onto the media has a specific amount of time to occupy the media.

This is referred to as its bit time. Signals are processed by the receiving device and returned to its representation as bits.

Physical Layer Signaling and Encoding

Explain that network communication at this layer consists of individual bits encoded onto the Physical layer and describe the basic encoding techniques.



Signalling Methods

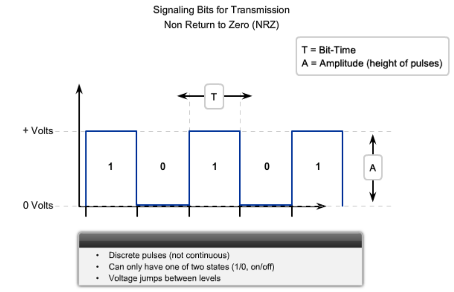
Bits are represented on the medium by changing one or more of the following characteristics of a signal:

1. Amplitude
2. Frequency
3. Phase

The nature of the actual signals representing the bits on the media will depend on the signalling method in use. Some methods may use one attribute of signal to represent a single 0 and use another attribute of signal to represent a single 1.

As an example, with Non-Return to Zero (NRZ), a 0 may be represented by one voltage level on the media during the bit time and a 1 might be represented by a different voltage on the media during the bit time.

NRZ-Signalling



NRZ contd..

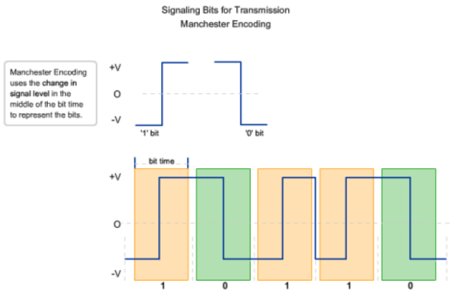
A low voltage value represents a logical 0 and a high voltage value represents a logical 1. The voltage range depends on the particular Physical layer standard in use.

This simple method of signalling is only suited for slow speed data links. **NRZ signalling uses bandwidth inefficiently and is susceptible to electromagnetic interference**.

Additionally, the boundaries between individual bits can be lost when long strings of 1s or 0s are transmitted consecutively.

In that case, no voltage transitions are detectable on the media. Therefore, the receiving nodes do not have a transition to use in resynchronizing bit times with the transmitting node.

Manchester Encoding



Manchester Encoding

Instead of representing bits as pulses of simple voltage values, in the Manchester Encoding scheme, bit values are represented as voltage transitions.

This transition can be used to ensure that the bit times in the receiving nodes are synchronized with the transmitting node

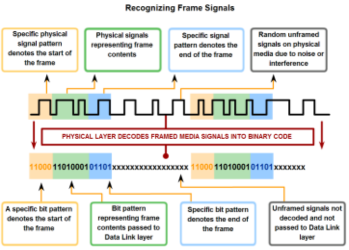
The transition in the middle of the bit time will be either the up or down direction for each unit of time in which a bit is transmitted.

For consecutive bit values, a transition on the bit boundary "sets up" the appropriate mid-bit time transition that represents the bit value.

Although Manchester Encoding is not efficient enough to be used at higher signalling speeds, it is the signalling method employed by 10BaseT Ethernet (Ethernet running at 10 Megabits per second).

Physical Layer Signaling and Encoding

Describe the role of encoding as it applies to the transmission of bits and explain the value of treating a collection of bits as a code.



Why use Encoding?

We use of the word encoding to represent the symbolic grouping of bits prior to being presented to the media.

By using an encoding step before the signals are placed on the media, we improve the efficiency at higher speed data transmission.

As we use higher speeds on the media, we have the possibility that data will be corrupted.

By using the coding groups, we can detect errors more efficiently.

Additionally, as the demand for data speeds increase, we seek ways to represent more data across the media, by transmitting fewer bits.

Coding groups provide a method of making this data representation.

Signal Patterns

One way to provide frame detection is to begin each frame with a pattern of signals representing bits that the

Physical layer recognizes as denoting the start of a frame. Another pattern of bits will signal the end of the frame.

Signal bits not framed in this manner are ignored by the Physical layer standard being used.

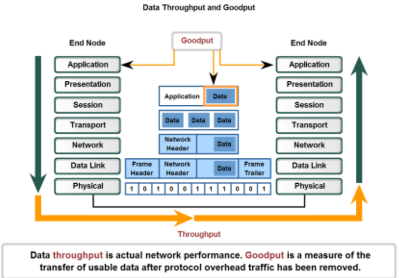
Valid data bits need to be grouped into a frame; otherwise, data bits will be received without any context to give them meaning to the upper layers of the networking model

Signal patterns can indicate: start of frame, end of frame, and frame contents.

These signal patterns can be decoded into bits. The bits are interpreted as codes. The codes indicate where the frames start and stop.

Physical Layer Signaling and Encoding

Define the terms bandwidth, throughput, and goodput



Bandwidth

The capacity of a medium to carry data is described as the raw data bandwidth of the media.

Digital bandwidth measures the amount of information that can flow from one place to another in a given amount of time.

Bandwidth is typically measured in kilobits per second (kbps) or megabits per second (Mbps).

The practical bandwidth of a network is determined by a combination of factors: the properties of the physical media and the technologies chosen for signalling and detecting network signals.

Physical media properties, current technologies, and the laws of physics all play a role in determining available bandwidth.

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 such as Ethernet.

Many factors influence throughput.

Among these factors are the amount of traffic, the type of traffic, and the number of network devices encountered on the network being measured. In a multi-access topology such as Ethernet, nodes are competing for media access and its use.

Therefore, the throughput of each node is degraded as usage of the media increases.

In an internetwork or network with multiple segments, throughput cannot be faster than the slowest link of the path from source to destination.

Even if all or most of the segments have high bandwidth, it will only take one segment in the path with low throughput to create a bottleneck to the throughput of the entire network.

Goodput

A third measurement has been created to measure the transfer of usable data.

That measure is known as goodput.

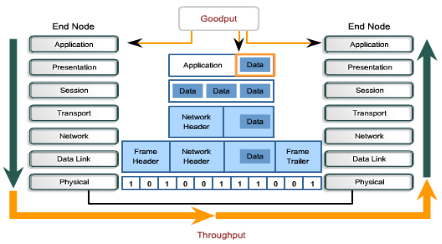
Goodput is the measure of usable data transferred over a given period of time, and is therefore the measure that is of most interest to network users.

Unlike throughput, which measures the transfer of bits and not the transfer of usable data, goodput accounts for bits devoted to protocol overhead.

Goodput is throughput minus traffic overhead for establishing sessions, acknowledgements, and encapsulation.

Throughput and Goodput

Data Throughput and Goodput



Data throughput is actual network performance. Goodput is a measure of the transfer of usable data after protocol overhead traffic has been removed.

Characteristics & Uses of Network Media

Identify several media characteristics defined by Physical layer standards.

Physical Media - Characteristics

Ethernet Media

	10BASE-T	100BASE-TX	100BASE-FX	1000BASE-CX	1000BASE-T	1000BASE-SX	1000BASE-LX	1000BASE-ZX	10GBASE-ZR
Media	EIA/TIA Category 3, 4, 5 UTP, two pair	EIA/TIA Category 3, 4, 5 UTP, two pair	50/62.5 µm multi mode fiber	STP	EIA/TIA Category 3, 4, 5 UTP, four pair	62.5/50 micron multimode fiber	50/62.5 micron multimode fiber or 9 micron single mode fiber	9µm single mode fiber	9µm single mode fiber
Maximum Segment Length	100m (328 feet)	100m (328 feet)	2 km (6562 ft)	25 m (82 feet)	100 m (328 feet)	Up to 550 m (1,804 ft) depending on fiber used	550 m (MMF)10 km (SMF)	Approx. 70 km	Up to 80 km
Topology	Star	Star	Star	Star	Star	Star	Star	Star	Star
Connector	ISO 8877 (RJ-45)	ISO 8877 (RJ-45)		ISO 8877 (RJ-45)	ISO 8877 (RJ-45)				

Wireless Media Characteristics

Physical Media - Characteristics

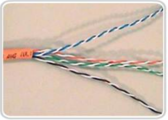
Wireless Media

Standards	Bluetooth 802.15	802.11(a,b,g,n), HiperLAN 2	802, 11, MMDS, LMDS	GSM, GPRS, CDMA, 2.5- 3G
Speed	<1 Mbps	1 - 54+ Mbps	22 Mbps+	10- 384 Kbps
Range	Short	Medium	Medium - long	Long
Applications	Peer-to-peer device-to-device	Enterprise networks	Fixed, last mile access	PDAs, Mobile phones, Cellular access

Copper Media

Copper Media


Coaxial cable


Unshielded twisted-pair cable


RJ-45 connections

Copper Media Characteristics

The most commonly used media for data communications is cabling that uses copper wires to signal data and control bits between network devices.

Cabling used for data communications usually consists of a series of individual copper wires that form circuits dedicated to specific signalling purposes.

Other types of copper cabling, known as coaxial cable, have a single conductor that runs through the centre of the cable that is encased by, but insulated from, the other shield.

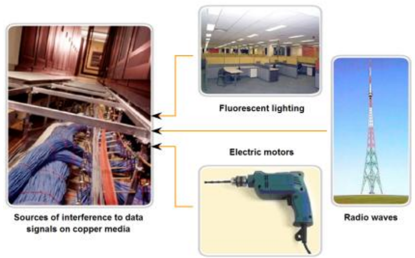
The copper media type chosen is specified by the Physical layer standard required to link the Data Link layers of two or more network devices.

These cables can be used to connect nodes on a LAN to intermediate devices, such as routers and switches.

Characteristics & Uses of Network Media

Describe the impact interference has on throughput and the role of proper cabling in reducing interference

External Interference with Copper Media



External Signal Interference

Data is transmitted on copper cables as electrical pulses.

A detector in the network interface of a destination device must receive a signal that can be successfully decoded to match the signal sent.

The timing and voltage values of these signals are susceptible to interference or "noise" from outside the communications system.

These unwanted signals can distort and corrupt the data signals being carried by copper media.

Radio waves and electromagnetic devices such as fluorescent lights, electric motors, and other devices are potential sources of noise.

Handling Noise

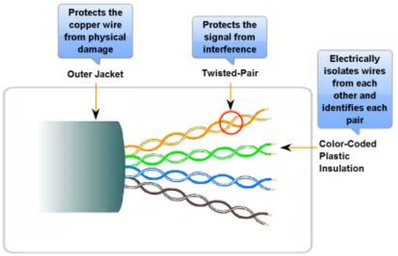
The susceptibility of copper cables to electronic noise can also be limited by:

1. Selecting the cable type or category most suited to protect the data signals in a given networking environment
2. Designing a cable infrastructure to avoid known and potential sources of interference in the building structure
3. Using cabling techniques that include the proper handling and termination of the cables

Characteristics & Uses of Network Media

Identify the basic characteristics of UTP cable

Unshielded Twisted-Pair (UTP) Cable



UTP Cable

Unshielded twisted-pair (UTP) cabling, as it is used in Ethernet LANs, consists of four pairs of colour-coded wires that have been twisted together and then encased in a flexible plastic sheath.

The twisting has the effect of cancelling unwanted signals.

When two wires in an electrical circuit are placed close together, external electromagnetic fields create the same interference in each wire.

The pairs are twisted to keep the wires in as close proximity as is physically possible.

When this common interference is present on the wires in a twisted pair, the receiver processes it in equal yet opposite ways.

As a result, the signals caused by electromagnetic interference from external sources are effectively cancelled.

Cross Talk

This cancellation effect also helps avoid interference from internal sources called crosstalk.

Crosstalk is the interference caused by the magnetic field around the adjacent pairs of wires in the cable.

When electrical current flows through a wire, it creates a circular magnetic field around the wire.

With the current flowing in opposite directions in the two wires in a pair, the magnetic fields - as equal but opposite forces - have a cancellation effect on each other.

Additionally, the different pairs of wires that are twisted in the cable use a different number of twists per meter to help protect the cable from crosstalk between pairs.

Cabling Standards

The UTP cabling commonly found in workplaces, schools, and homes conforms to the standards established jointly by the Telecommunications Industry Association (TIA) and the Electronics Industries Alliance (EIA).

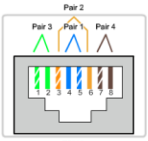
TIA/EIA-568A stipulates the commercial cabling standards for LAN installations and is the standard most commonly used in LAN cabling environments. Some of the elements defined are:

1. Cable types
2. Cable lengths
3. Connectors
4. Cable termination
5. Methods of testing cable

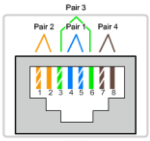
UTP Cable Types

Straight-through, Crossover, and Rollover Cable Types

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



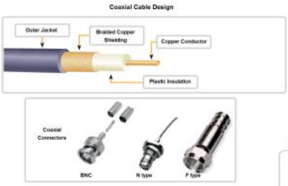
T568A

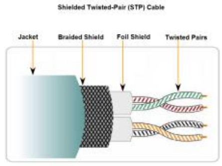


T568B

Characteristics & Uses of Network Media

Identify the basic characteristics of STP and Coaxial cable





Coaxial Cable

Coaxial cable consists of a copper conductor surrounded by a layer of flexible insulation, as shown in the figure.

Over this insulating material is a woven copper braid, or metallic foil, that acts as the second wire in the circuit and as a shield for the inner conductor.

This second layer, or shield, also reduces the amount of outside electromagnetic interference. Covering the shield is the cable jacket.

All the elements of the coaxial cable encircle the center conductor. Because they all share the same axis, this construction is called coaxial, or coax for short.

Coax Uses

Coax is an important type of cable that is used in wireless and cable access technologies.

Coax cables are used to attach antennas to wireless devices. The coaxial cable carries radio frequency (RF) energy between the antennas and the radio equipment.

Coax is also the most widely used media for transporting high radio frequency signals over wire, especially cable television signals.

Traditional cable television, exclusively transmitting in one direction, was composed completely of coax cable.

In the past, coaxial cable was used in Ethernet installations. Today UTP offers lower costs and higher bandwidth than coaxial.

STP

STP uses four pairs of wires that are wrapped in an overall metallic braid or foil.

STP cable shields the entire bundle of wires within the cable as well as the individual wire pairs.

STP provides better noise protection than UTP cabling, however at a significantly higher price.

For many years, STP was the cabling structure specified for use in Token Ring network installations.

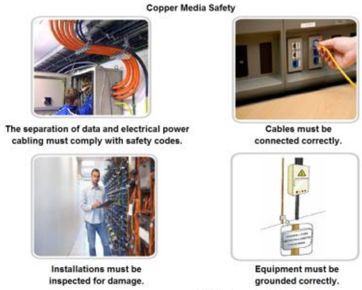
With the use of Token Ring declining, the demand for shielded twisted-pair cabling has also waned.

The new 10 GB standard for Ethernet has a provision for the use of STP cabling.

This may provide a renewed interest in shielded twisted-pair cabling.

Characteristics & Uses of Network Media

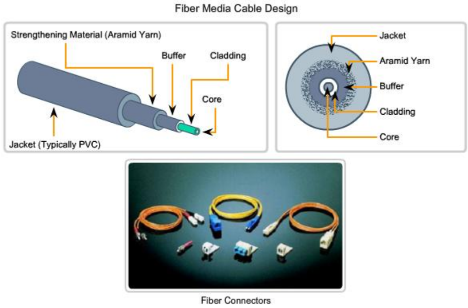
Identify types of safety issues when working with copper cabling



Safety

1. A defective network device could conduct currents to the chassis of other network devices.
2. Additionally, network cabling could present undesirable voltage levels when used to connect devices that have power sources with different ground potentials.
3. Such situations are possible when copper cabling is used to connect networks in different buildings or on different floors of buildings that use different power facilities.
4. Finally, copper cabling may conduct voltages caused by lightning strikes to network devices.
5. The result of undesirable voltages and currents can include damage to network devices and connected computers, or injury to personnel.
6. It is important that copper cabling be installed appropriately, and according to the relevant specifications and building codes, in order to avoid potentially dangerous and damaging situations.

Fiber Media



Fiber Characteristics

Fiber-optic cabling uses either glass or plastic fibers to guide light impulses from source to destination.

The bits are encoded on the fiber as light impulses. Optical fiber cabling is capable of very large raw data bandwidth rates.

Given that the fibers used in fiber-optic media are not electrical conductors, the media is immune to electromagnetic interference and will not conduct unwanted electrical currents due to grounding issues.

Because optical fibers are thin and have relatively low signal loss, they can be operated at much greater lengths than copper media, without the need for signal regeneration.

Some optical fiber Physical layer specifications allow lengths that can reach multiple kilometers.

Fiber Media

Fiber Media Cable Design

Fiber provides full duplex communications with a cable dedicated to each direction.

Fiber Cables

Optical fiber cables consist of a PVC jacket and a series of strengthening materials that surround the optical fiber and its cladding.

The cladding surrounds the actual glass or plastic fiber and is designed to prevent light loss from the fiber.

Because light can only travel in one direction over optical fiber, two fibers are required to support full duplex operation.

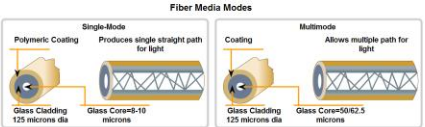
Fiber-optic patch cables bundle together two optical fiber cables and terminate them with a pair of standard single fiber connectors.

Some fiber connectors accept both the transmitting and receiving fibers in a single connector.

Characteristics & Uses of Network Media

Identify several primary characteristics of fiber cabling and its main advantages over other media

Fiber Media Modes



- Small Core
- Less Despersion
- Suited for long distance applications (up to 100 km, 62,14 mi.)
- Uses lasers as the light source often within campus backbones for distance of several thousand meters

- Larger core than single-mode cable (50 microns or greater)
- Allows greater dipersion and therefore, loss of signal
- Used for long distance application, but shoter than single-mode (up to ~2km, 6560 ft)
- Uses LEDs as the light source often within LANs or distances of couple hundred meters within a campus network

Single vs Multimode

Single-mode optical fiber carries a single ray of light, usually emitted from a laser.

Because the laser light is uni-directional and travels down the center of the fiber, this type of fiber can transmit optical pulses for very long distances.

Multimode fiber typically uses LED emitters that do not create a single coherent light wave.

Instead, light from an LED enters the multimode fiber at different angles.

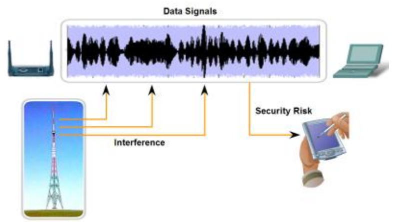
Because light entering the fiber at different angles takes different amounts of time to travel down the fiber, long fiber runs may result in the pulses becoming blurred on reception at the receiving end.

This effect, known as modal dispersion, limits the length of multimode fiber segments.

Characteristics & Uses of Network Media

Describe the role of radio waves when using air as the media and the increased need for security in wireless communications

Wireless Media Signals and Security



Wireless Devices

Wireless data communication technologies work well in open environments.

However, certain construction materials used in buildings and structures, and the local terrain, will limit the effective coverage. I

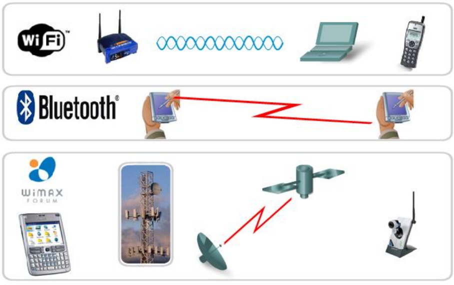
n addition, wireless is susceptible to interference and can be disrupted by such common devices as household cordless phones, some types of fluorescent lights, microwave ovens, and other wireless communications.

Further, because wireless communication coverage requires no access to a physical strand of media, devices and users who are not authorized for access to the network can gain access to the transmission.

Therefore, network security is a major component of wireless network administration.

Standards

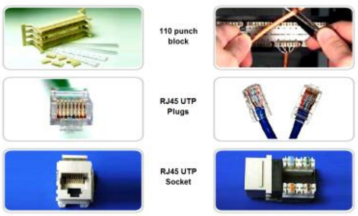
Wireless Media Standards and Types



Characteristics & Uses of Network Media

Identify the characteristics used to categorize connectors, describe some common uses for the same connectors, and identify the consequences for misapplying a connector in a given situation

Copper Media Connectors



Correct Connector Termination

Each time copper cabling is terminated, there is the possibility of signal loss and the introduction of noise to the communication circuit.

Ethernet workplace cabling specifications stipulate the cabling necessary to connect a computer to an active network intermediary device.

When terminated improperly, each cable is a potential source of Physical layer performance degradation. It is essential that all copper media terminations be of high quality to ensure optimum performance with current and future network technologies.

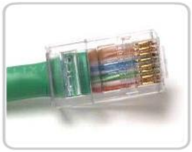
In some cases, for example in some WAN technologies, if an improperly wired RJ-45-terminated cable is used, damaging voltage levels may be applied between interconnected devices.

This type of damage will generally occur when a cable is wired for one Physical layer technology and is used with a different technology

Termination - UTP

Copper Media Connectors
RJ-45 Termination

Bad connector - Wires are untwisted for too great a length.



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

Fiber Connectors

Fiber Media Connectors

ST Connector

Straight Tip (ST) connector is widely used with multimode fiber

SC Connector

Subscriber Connector (SC) is widely used with single-mode fiber

Single-Mode (LC)

Single-Mode Lucent Connector (LC)

Multimode (LC)

Multimode LC Connector

Duplex Multimode (LC)

Duplex Multimode LC Connector

Fiber Termination

Three common types of fiber-optic termination and splicing errors are:

1. Misalignment - the fiber-optic media are not precisely aligned to one another when joined.
2. End gap - the media do not completely touch at the splice or connection.
3. End finish - the media ends are not well polished or dirt is present at the termination.

It is recommended that an Optical Time Domain Reflectometer (OTDR) be used to test each fiber-optic cable segment.

This device injects a test pulse of light into the cable and measures back scatter and reflection of light detected as a function of time.

The OTDR will calculate the approximate distance at which these faults are detected along the length of the cable.

Packet Tracer Lab

Packet Tracer Exploration:
Skills Integration Challenge: Connecting Devices and Exploring the Physical View

Packet Tracer Lab

Packet Tracer Exploration:
Simple Wireless LAN Model

Summary

In this chapter, you learned to:

- Explain the role of Physical layer protocols and services in supporting communication across data networks.
- Describe the purpose of Physical layer signaling and encoding as they are used in networks.
- Describe the role of signals used to represent bits as a frame is transported across the local media.
- Identify the basic characteristics of copper, fiber, and wireless network media.
- Describe common uses of copper, fiber, and wireless network media.