CHƯƠNG 8

LỚP VẬT LÝ

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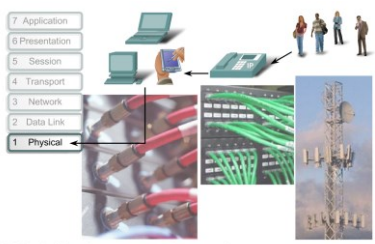
Objectives

- 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

Physical Layer Protocols & Services



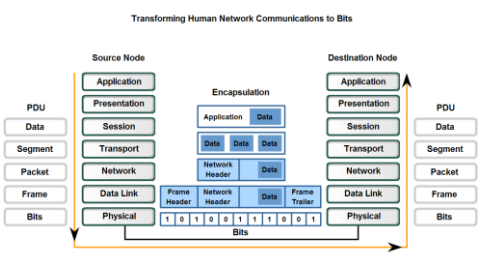
The Physical layer interconnects our data networks.

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

Physical Layer Protocols & Services

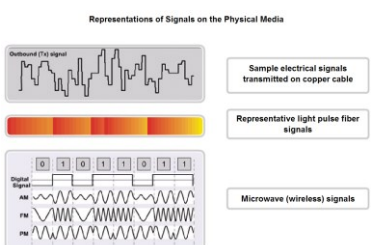
- Physical layer elements:
  - The physical media and associated connectors
  - A representation of bits on the media
  - Encoding of data and control information
  - Transmitter and receiver circuitry on the network devices
- At this stage of the communication process, the user data has been segmented by the Transport layer, placed into packets by the Network layer, and further encapsulated as frames by the Data Link layer. The purpose

Physical Layer Protocols & Services



- Retrieve individual signals from the media, restore them to their bit representations, and pass the bits up to the Data Link layer as a

Physical Layer Protocols & Services

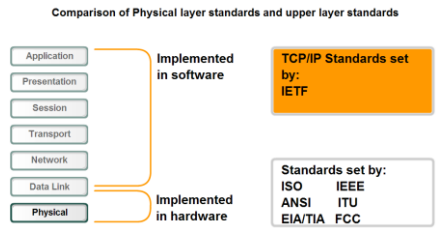


- The media does not carry the frame as a single entity. The media carries signals, one at a time, to represent the bits that

Physical Layer Protocols & Services

- There are three basic forms of network media on which data is represented:
  - Copper cable
  - Fiber
  - Wireless
- Identifying a Frame
  - Encodes the bits into the signals for a particular medium
  - Distinguish where one frame ends and the next frame begins.
  - In many technologies, the Physical layer may add its own signals to indicate the beginning and end of the frame.
  - To the receiving device can 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



- The services and protocols in the TCP/IP suite are defined by the Internet Engineering Task Force (IETF) in RFCs.

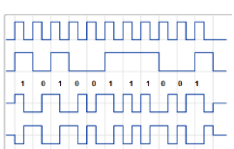
Physical Layer Protocols & Services

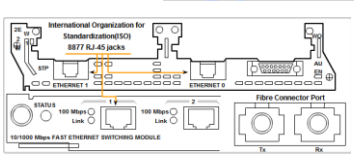
- The protocols and operations of the upper OSI layers are performed by software and are designed by software engineers and computer scientists. The services and protocols in the TCP/IP suite are defined by the Internet Engineering Task Force (IETF) in RFCs.
- The Physical layer technologies are defined by organizations such as:
  - The International Organization for Standardization (ISO)
  - The Institute of Electrical and Electronics Engineers (IEEE)
  - The American National Standards Institute (ANSI)
  - The International Telecommunication Union (ITU)
  - The Electronics Industry Alliance/Telecommunications Industry Association (EIA/TIA)
  - National telecommunications authorities such as the Federal Communication Commission (FCC) in the USA.

Physical Layer Protocols & Services

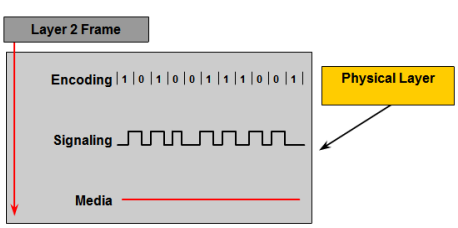
- Four areas of the Physical layer standards:
  - Physical and electrical properties of the media
  - Mechanical properties (materials, dimensions, pinouts) of the connectors
  - Bit representation by the signals (encoding)
  - Definition of control information signals
- Hardware components such as network adapters (NICs), interfaces and connectors, cable materials, and cable designs are all specified in standards associated with the Physical layer.

Physical Layer Protocols & Services





Physical Layer Protocols & Services



- Three fundamental functions of the Physical layer:
  - The physical components
  - Data encoding

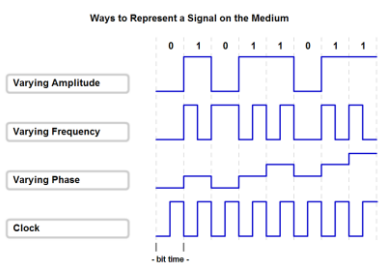
Physical Layer Protocols & Services

- Encoding
  - A method of converting a stream of data bits into a predefined "code".
  - Code: grouping of bits used to provide a predictable pattern, can be recognized by both the sender and the received.
  - Predictable patterns: distinguish data bits from control bits; provide better media error detection.
  - Encoding methods provide codes for control purposes such as identifying the beginning and end of a frame.
- Signaling
  - The method of representing the bits is called the signaling method.
  - The Physical layer standards must define what type of signal represents a "1" and a "0" on the media. This can be as simple as a change in the level of an electrical signal or optical pulse or a more complex signaling method.

Physical Layer Signaling and Encoding

- The transmission of the frame across the media occurs as a stream of bits sent one at a time. 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.
- At the Physical layer of the receiving node, the signals are converted back into bits. The bits are then examined for the start of frame and end of frame bit patterns to determine that a complete frame has been

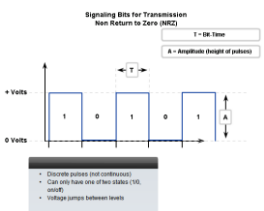
Physical Layer Signaling and Encoding



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

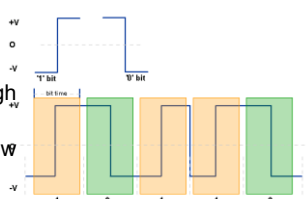
Physical Layer Signaling and Encoding

- Non Return to Zero (NRZ): the bit stream is transmitted as a series of voltage values
  - 0: low voltage
  - 1: high voltage
- Suite for slow speed data links
- Inefficient bandwidth, susceptible to electromagnetic interference.
- 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.

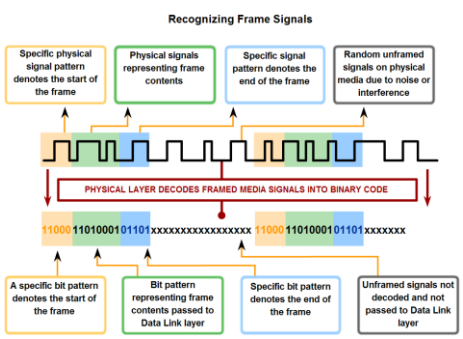


Physical Layer Signaling and Encoding

- Manchester Encoding: bit values are represented as voltage transitions.
  - 1: low voltage to high voltage
  - 0: high voltage to low voltage
- One voltage transition must occur in the middle of each bit time.



Physical Layer Signaling and Encoding

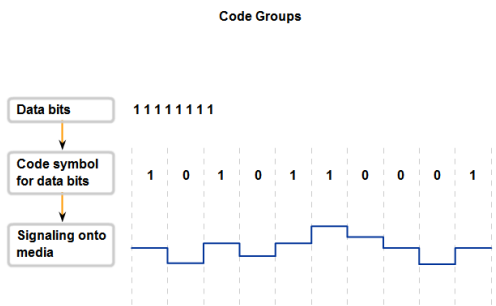


Physical Layer Signaling and Encoding

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. Signals bits not framed in this manner are ignored.
- 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.

Physical Layer Signaling and Encoding



Physical Layer Signaling and Encoding

Code Groups

- Code group is a consecutive sequence of code bits that are interpreted and mapped as data bit patterns. For example, code bits 10101 could represent the data bits 0011.
- Code groups are often used as an intermediary encoding technique for higher speed LAN technologies.
- By transmitting symbols, the error detection capabilities and timing synchronization between transmitting and receiving devices are enhanced.

Advantages using code groups include:

- Reducing bit level error
- Limiting the effective energy transmitted into the media
- Helping to distinguish data bits from control bits
- Better media error detection

Physical Layer Signaling and Encoding

- Reducing Bit Level Errors
  - To detect a bit as a 0 or as a 1, the receiver must know how and when to sample the signal on the media. This requires that the timing between the receiver and transmitter be synchronized.
  - If too many 1s or 0s being transmitted on the media, the synchronization may be lost and individual bit error can occur. Code groups are designed so that the symbols force an ample number of bit transitions to occur on the media to synchronize this timing.
- Limiting Energy Transmitted
  - In many code groups, the symbols ensure that the number of 1s and 0s in a string of symbols are evenly balanced, called DC balancing. This prevents excessive amounts of energy from being injected into the media during transmission, thereby reducing the interference radiated from the media. In many media signaling methods, a logic level, for example a 1, is represented by the presence of energy being sent into the media while the opposite logic level, a 0, is represented as the absence of this energy. Transmitting a long series of 1s could overheat the transmitting laser and the photo diodes in the receiver, potentially causing higher error rates.

Physical Layer Signaling and Encoding

Distinguish Data from Control

- The code groups have three types of symbols:
  - Data symbols - Symbols that represent the data of the frame as it is passed down to the Physical layer.
  - Control symbols - Special codes injected by the Physical layer used to control transmission. These include end-of-frame and idle media symbols.
  - Invalid symbols - Symbols that have patterns not allowed on the media. The receipt of an invalid symbol indicates a frame error.
- The symbols encoded onto the media are all unique. The symbols representing the data being sent through the network have different bit patterns than the symbols used for control. These differences allow the Physical layer in the receiving node to immediately distinguish data from control information.

Better Media Error Detection

- In addition to the data symbols and control symbols, code groups contain invalid symbols. These are the symbols that could create long series of 1s or 0s on the media; therefore, they are not used by the transmitting node. If a receiving node receives one of these patterns, the Physical layer can determine that there has been an error in data reception.

Physical Layer Signaling and Encoding

4B/5B Code Symbols

Data Codes

4B Code	5B Symbol
0000	11110
0001	01001
0010	10100
0011	10101
0100	01010
0101	01011
0110	01110
0111	01111
1000	10010
1001	10011
1010	10110
1011	10111
1100	11010
1101	11011
1110	11100
1111	11101

Control and Invalid Codes

4B Code	5B Symbol
idle	11111
start of stream	11000
start of stream	10001
end of stream	01101
end of stream	00111
transmit error	00111
invalid	00000
invalid	00001
invalid	00010
invalid	00011
invalid	00100
invalid	00101
invalid	00110
invalid	01000
invalid	10000
invalid	11001

Physical Layer Signaling and Encoding

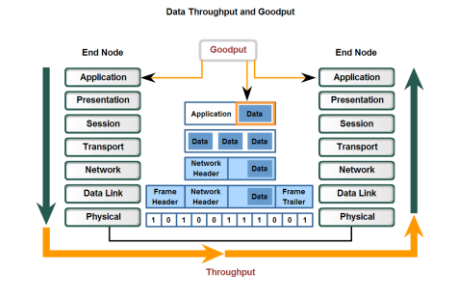
Unit of Bandwidth	Abbreviation	Equivalence
Bits per second	bps	1 bps = fundamental unit of bandwidth
Kilobits per second	kbps	1 kbps = 1,000 bps = 10^3 bps
Megabits per second	Mbps	1 Mbps = 1,000,000 bps = 10^6 bps
Gigabits per second	Gbps	1 Gbps = 1,000,000,000 bps = 10^9 bps
Terabits per second	Tbps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

- Data transfer can be measured in three ways:
  - Bandwidth
  - Throughput
  - 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. Measured in kbps or Mbps.
- Determined by a combination of factors: physical media and technologies
- Physical media properties, current technologies, and the laws of physics all play a role in determining available bandwidth.

Physical Layer Signaling and Encoding



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

Physical Layer Signaling and Encoding

Throughput

- The measure of the transfer of bits across the media over a given period of time. Usually does not match the specified bandwidth.
- Factors influence throughput: amount of traffic, type of traffic, number of network devices encountered on the network.
- Throughput cannot be faster than the slowest link of the path from source to destination.

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.
- Goodput measures the effective transfer of user data between Application layer entities.
- 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.

Physical Media

Characteristics & Uses of Network Media

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

- The Physical layer is concerned with network media and signaling. This layer produces the representation and groupings of bits as voltages, radio frequencies, or light pulses.

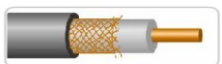
Characteristics & Uses of Network Media

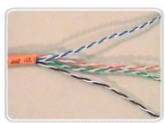
Physical Media - Characteristics

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)				

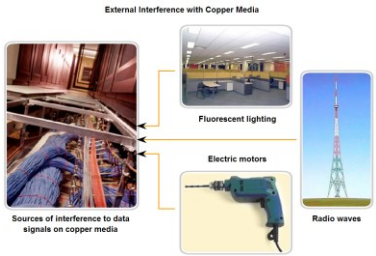
Characteristics & Uses of Network Media





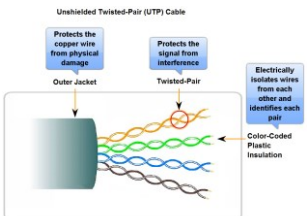
- Copper: The most common media.
- Cables: connect nodes on a LAN to intermediate devices, such as routers and switches, also connect WAN devices to a data services provider such as a telephone company. Each type of connection and the accompanying devices have cabling requirements stipulated by Physical layer standards.

Characteristics & Uses of Network Media



- Cable types with shielding or twisting of the pairs of wires are designed to minimize signal degradation due to electronic noise.

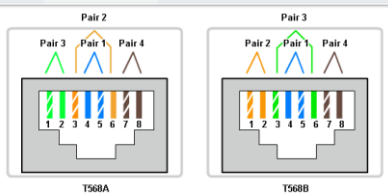
Characteristics & Uses of Network Media



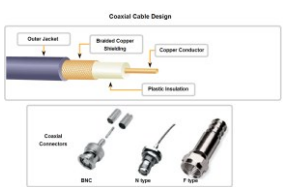
- UTP: four pairs color-coded wires
- Twisting has the effect of canceling unwanted signals.
- Avoid interference from internal sources

Characteristics & Uses of Network Media

Cable Type	Standard	Application
Ethernet Straight-through	Both end T568A or both end 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.

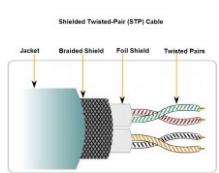


Characteristics & Uses of Network Media



- Be adapted for different purposes: to attach antennas to wireless devices; to carry radio frequency (RF) energy between the antennas and the radio equipment; to transport high RF signals, especially cable television signals.

Characteristics & Uses of Network Media



- 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

Copper Media Safety

The separation of data and electrical power cabling must comply with safety codes.

Cables must be connected correctly.

Installations must be inspected for damage.

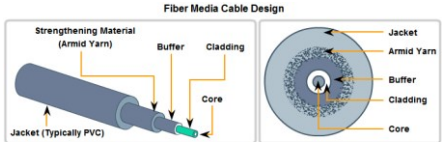
Equipment must be grounded correctly.

Characteristics & Uses of Network Media

- Fiber-optic cable: uses glass or plastic fibers. The bits are encoded on the fiber as light impulses. Very large raw data bandwidth rates.
- Compared to Copper
  - Is immune to electromagnetic interference
  - Not grounding issues.
  - Is thin, low signal loss, so can be operated at much greater lengths than copper media, without the need for signal regeneration, can reach multiple kilometers.
  - More expensive (usually) than copper media over the same distance (but for a higher capacity)
  - Different skills and equipment required to terminate and splice the cable infrastructure
  - More careful handling than copper media
- At present, it is primarily used as backbone cabling for high-traffic point-to-point connections.

Characteristics & Uses of Network Media

Fiber Media Cable Design



Rollover to change perspective.

Fiber Connectors

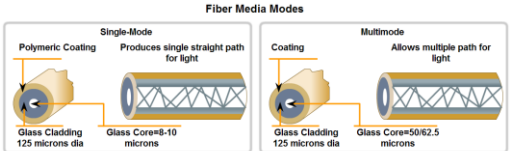
Characteristics & Uses of Network Media

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

- The cladding surrounds the actual glass or plastic fiber and is designed to prevent light loss from the fiber.
- Two fibers are required to support full duplex operation. Fiber-optic patch cables bundle together two optical fiber cables and

Characteristics & Uses of Network Media

Fiber Media Modes

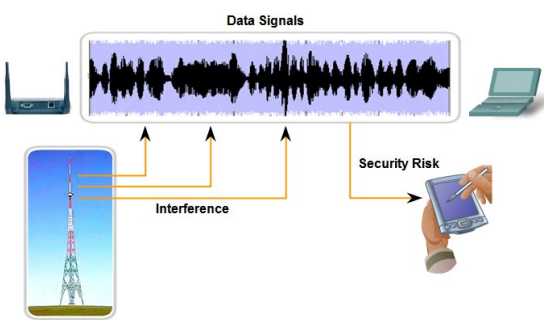


- Small Core
- Less Despersion
- Suited for long distance applications (up to 100 km, 62.14 mi.)
- Uses lasers as the light source often within campus backbones for distance of several thousand meters

- 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

Characteristics & Uses of Network Media

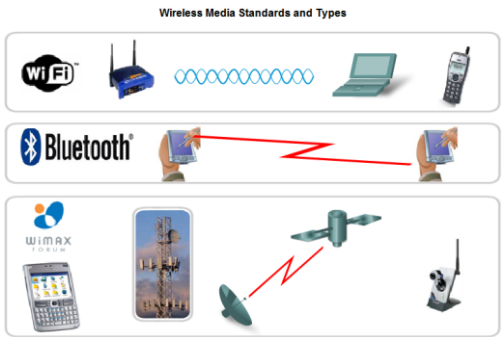
Data Signals



Characteristics & Uses of Network Media

- Carry electromagnetic signals at radio and microwave frequencies that represent the binary digits of data communications.
- Work well in open environments. However, certain construction materials, and the local terrain, will limit the effective coverage.
- 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.

Characteristics & Uses of Network Media



Characteristics & Uses of Network Media

Four common data communications standards

- Standard IEEE 802.11 - Commonly referred to as Wi-Fi, is a Wireless LAN (WLAN) technology that uses a contention or non-deterministic system with a Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) media access process.
- Standard IEEE 802.15 - Wireless Personal Area Network (WPAN) standard, commonly known as "Bluetooth", uses a device pairing process to communicate over distances from 1 to 100 meters.
- Standard IEEE 802.16 - Commonly known as WiMAX (Worldwide Interoperability for Microwave Access), uses a point-to-multipoint topology to provide wireless broadband access.
- Global System for Mobile Communications (GSM) - Includes Physical layer specifications that enable the implementation of the Layer 2 General Packet Radio Service (GPRS) protocol to provide data transfer over mobile cellular telephony networks.

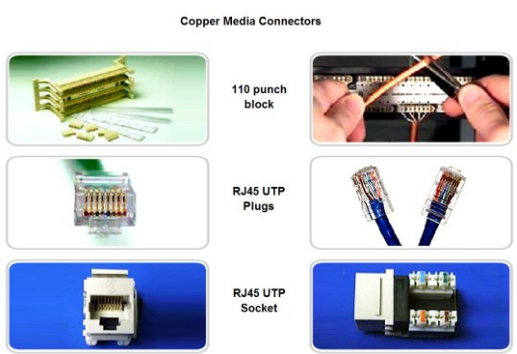
Characteristics & Uses of Network Media

- In general, a wireless LAN requires the following network devices:
- Wireless Access Point (AP) - Concentrates the wireless signals from users and connects, usually through a copper cable, to the existing copper-based network infrastructure such as Ethernet.

Characteristics & Uses of Network Media

- **IEEE 802.11a** - Operates in the 5 GHz frequency band, speed up to 54 Mbps, small coverage area; less effective at penetrating building structures. Not interoperable with the 802.11b and 802.11g standards.
- **IEEE 802.11b** - Operates in the 2.4 GHz frequency band, speed up to 11 Mbps. Longer range and better able to penetrate building structures than devices based on 802.11a.
- **IEEE 802.11g** - Operates in the 2.4 GHz frequency band, speed up to 54 Mbps. Devices implementing this standard therefore operate at the same radio frequency and range as 802.11b but with the bandwidth of 802.11a.
- **IEEE 802.11n** - Is currently in draft form. The proposed standard defines frequency of 2.4 Ghz or 5 GHz. The typical expected data rates are 100 Mbps to 210 Mbps with a distance range of up to 70 meters.
- **The benefits** are evident, especially the savings on costly premises wiring and the convenience of host mobility.
- However, network administrators need to develop and apply stringent security policies and processes to protect WLANs from unauthorized access and damage.

Characteristics & Uses of Network Media



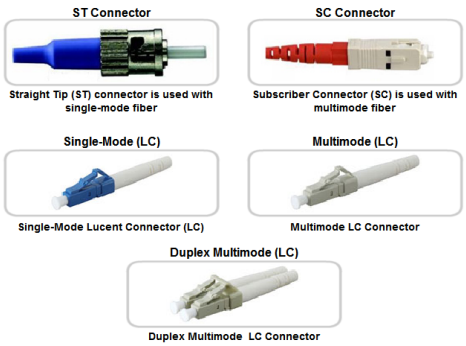
Characteristics & Uses of Network Media

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

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

- It is essential that all copper media terminations be of high quality to ensure optimum performance with current and future network technologies.

Characteristics & Uses of Network Media



Characteristics & Uses of Network Media

- **Straight-Tip** (ST) (trademarked by AT &T) - a very common bayonet style connector widely used with multimode fiber.
- **Subscriber Connector** (SC) - a connector that uses a push-pull mechanism to ensure positive insertion. This connector type is widely used with single-mode fiber.
- **Lucent Connector** (LC) - A small connector becoming popular for use with single-mode fiber and also supports multi-mode fiber.
- Three common types of fiber-optic termination and splicing errors are:
  - **Misalignment** - the fiber-optic media are not precisely aligned to one another when joined.
  - **End gap** - the media do not completely touch at the splice or connection.
  - **End finish** - the media ends are not well polished or dirt is present at the termination.

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.