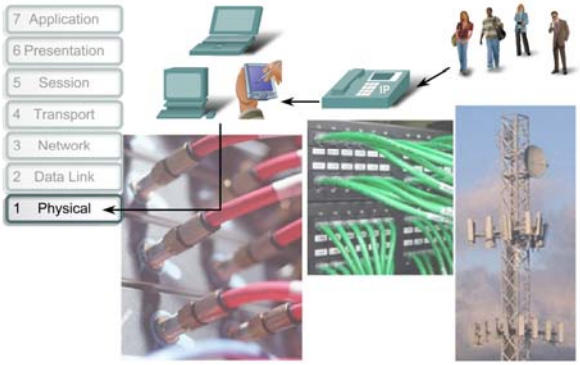
Introduction

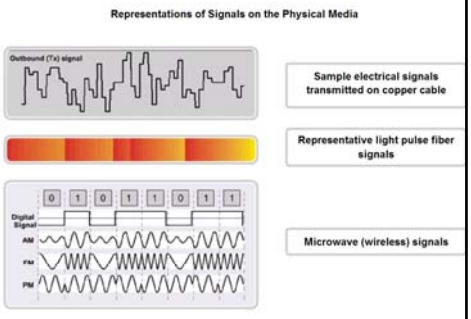
- The Physical layer is concerned with network media and signaling. This layer produces the representation and groupings of bits as voltages, radio frequencies, or light pulses
- The role of the OSI Physical layer is to encode the binary digits that represent Data Link layer frames into signals and to transmit and receive these signals across the physical media - copper wires, optical fiber, and wireless - that connect network devices



The Physical layer interconnects our data networks.

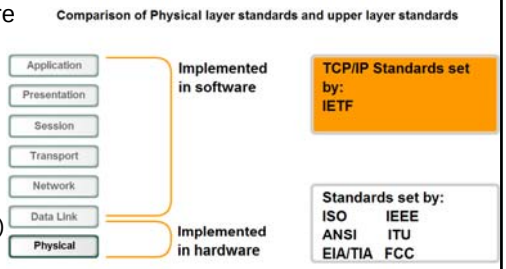
Physical Layer - Operation

- 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.
- Three basic forms of network media:
  - Copper cable: data is represented by patterns of electrical pulses
  - Fiber: data is represented by patterns of light
  - Wireless: data is represented by patterns of radio transmissions
- 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



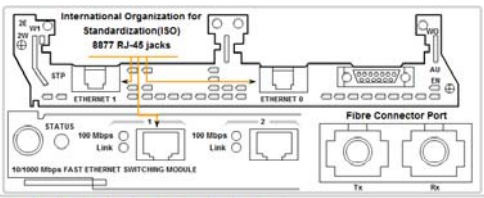
Physical Layer - Standards

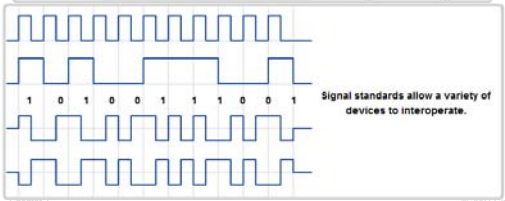
- The Physical layer consists of hardware, developed by engineers, in the form of electronic circuitry, media, and connectors
- the Physical layer technologies are defined by organizations such as:
  - The International Organization for Standardization (ISO)
  - The Institute of Electrical and Electronics 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 - Standards

- The technologies defined by these organizations include 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

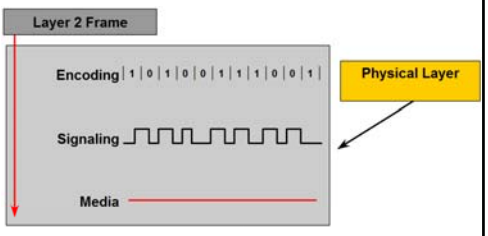




Physical Layer Fundamental Principles

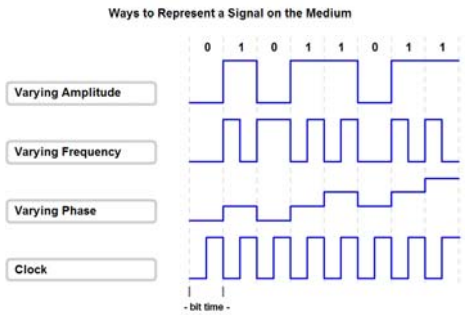
The three fundamental functions of the Physical layer are:

- The physical components: electronic hardware devices, media and connectors .. etc
- Data 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. This helps distinguishing data bits from control bits. (codes for data and control)
- Signaling: generating electrical, optical, or wireless signals that represent 0's and 1's. This could be simple or complex signaling



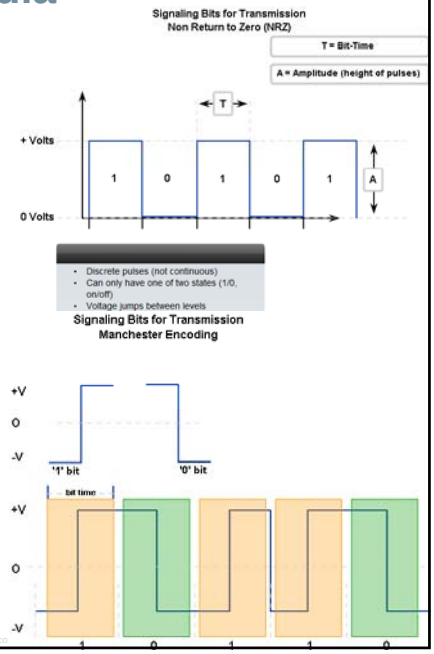
Signaling Bits for the Media

- Bits that represent the frame are changed to signals and sent one at a time
- Each signal placed on the medium has a period of time - bit time
- At the receiver these signals are examined at specific time and converted back to bit
- The bits then grouped and delivered as a frame to the Data Link layer
- Both transmission end need to be synchronized. In LAN is this done by maintaining clocks
- Bit represented on the media by different signaling methods
  - Amplitude
  - Frequency
  - Phase



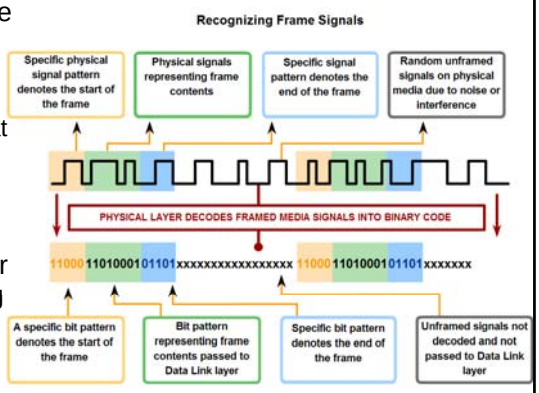
Signaling Bits for the Media

- Non Return to Zero (NRZ)
  - A low voltage value represents a logical 0 and a high voltage value represents a logical 1
  - Use the bandwidth inefficiently
  - Susceptible to EMI
  - Boundaries of bit are lost in long bit stream of 0's or 1's
- Manchester Encoding
  - Transition code i.e. low to high for 1 and high to low for 0
  - Transition at the middle of the bit time
  - It is not efficient at high bit rate
  - Used for 10Mbps Ethernet



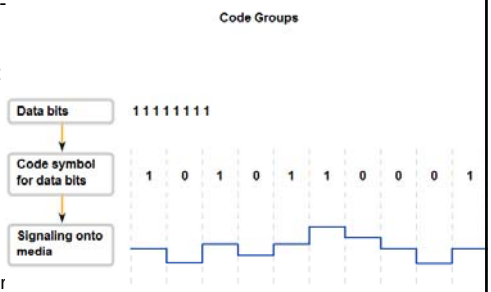
Encoding – Grouping Bits

- Word encoding a group of bit are encode before put to the media
- Word encoding
  - improves the efficiency at higher speed data transmission
  - Error detection
- Remember that the receiver need to know the beginning and the end of the frame
- This can be done by using pattern of signals that represent the start and end of the frame



Encoding – Grouping Bits

- Encoding techniques use bit patterns called symbols
- The Physical layer may use a set of encoded symbols - called code groups - to represent encoded data or control information
- Advantages using code groups include:
  - Reducing bit level error: the symbols force an ample number of bit transitions to occur on the media to synchronize this timing
  - Limiting the effective energy transmitted into the media: balancing the 0's and 1's in the codes (DC balancing) thereby reducing the interference radiated from the media
  - Helping to distinguish data bits from control bits: using different symbols for data and control
  - Better media error detection: errors can be detected easily by detecting invalid symbols



Encoding – 4B/5B Code

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

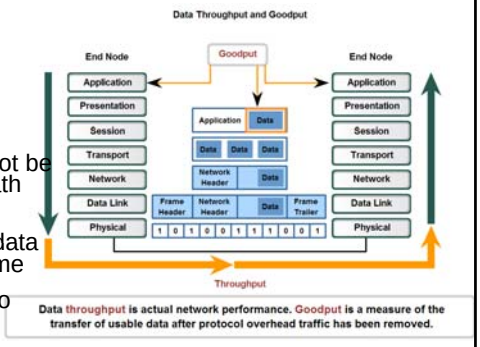
Data Carrying Capacity

- Data transfer can be measured in three ways:
  - Bandwidth
  - Throughput
  - Goodput
- Bandwidth: The capacity of the medium to carry data
- 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 signaling and detecting network signals

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 Carrying Capacity

- Throughput: is the measure of the transfer of bits across the media over a given period of time
- Many factors influence throughput:
  - the amount of traffic
  - the type of traffic
  - the number of network devices encountered on the network
- In an internetwork or network with multiple segments, throughput cannot be faster than the slowest link of the path from source to destination
- Goodput: is the measure of usable data transferred over a given period of time
- Goodput accounts for bits devoted to protocol overhead
- Goodput is throughput minus traffic overhead for establishing sessions, acknowledgements, and encapsulation



Types of Physical Media

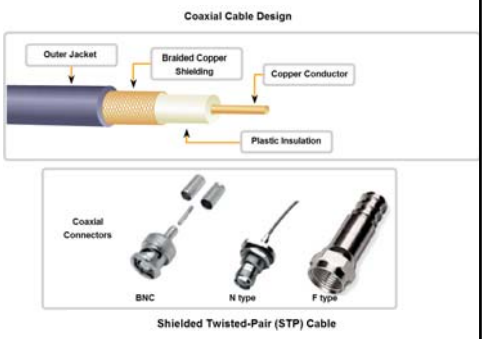
- There various organization contribute to the standard and development physical, electrical, and mechanical properties of the media
- Example, standards for copper media are defined for the:
  - Type of copper cabling used
  - Bandwidth of the communication
  - Type of connectors used
  - Pinout and color codes of connections to the media
  - Maximum distance of the media

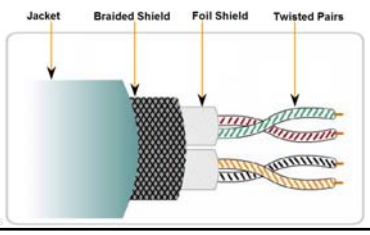
Ethernet Media

	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)				

Copper Media

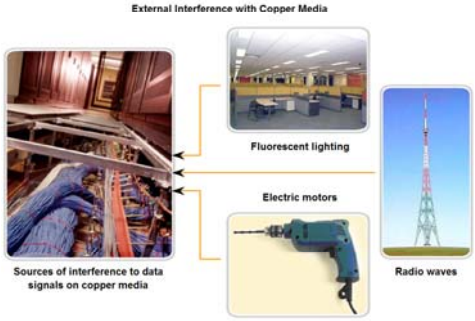
- The most widely used media is the copper wires (coaxial, UTP, STP)
- Copper wires are used to connect nodes and different network devices in LAN and WAN
- The copper media type chosen is specified by the Physical layer standard required to link the Data Link layer
- Network media use different types of modular jacks and plugs
- One type of connector can be used for different types of connection. E.g. RJ45 in LANs and WANs (ISDN)





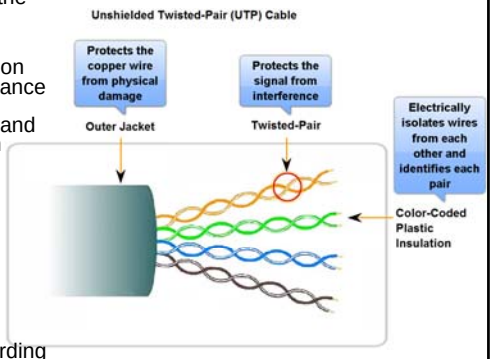
Copper Media – External Signal Interferance

- Signals in electrical cables are susceptible to interferences and noise from the surrounding
- The received signals should be in a good shape so they can be interpreted by the receiver.
- Radio waves (RFI), electromagnetic devices such as fluorescent lights, electric motors (EMI), and other devices are potential sources of noise
- Cable types with shielding or twisting of the pairs of wires are designed to minimize signal degradation due to electronic noise
- The susceptibility of copper cables to electronic noise can also be limited by:
  - Selecting the cable type or category most suited to protect the data signals in a given networking environment
  - Designing a cable infrastructure to avoid known and potential sources of interference in the building structure
  - Using cabling techniques that include the proper handling and termination of the cables



Unshielded Twisted Pair (UTP) Cable

- four pairs of color-coded wires that have been twisted together and then encased in a flexible plastic sheath
- The twisting has the effect of reducing the effect of noise and ***crosstalk***
- UTP cabling standards are defined by Telecommunications Industry Association (TIA) and the Electronics Industries Alliance (EIA). E.g. stipulates the commercial cabling standards for LAN installations and is the standard most commonly used in LAN cabling environments
- Some the elements defined are:
  - Cable types
  - Cable lengths
  - Connectors
  - Cable termination
  - Methods of testing cable
- Cables are placed into categories according to their ability to carry higher bandwidth rates e.g. Cat5e and Cat6

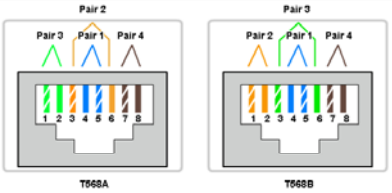


Unshielded Twisted Pair (UTP) Cable

- UTP cables terminated with RJ45 connectors
- UTP cables can be wired and terminated in different ways according to standards
- The following are main cable types that are obtained by using specific wiring conventions:
  - Ethernet Straight-through
  - Ethernet Crossover
  - Rollover

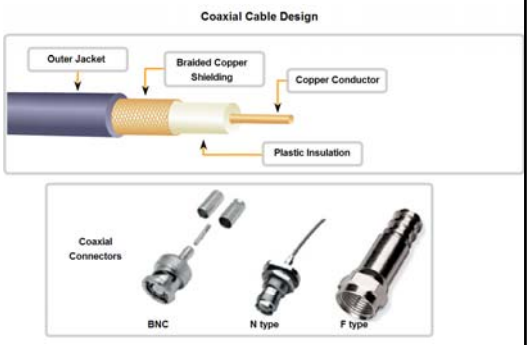
Straight-through, Crossover, and Rollover Cable Types

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.



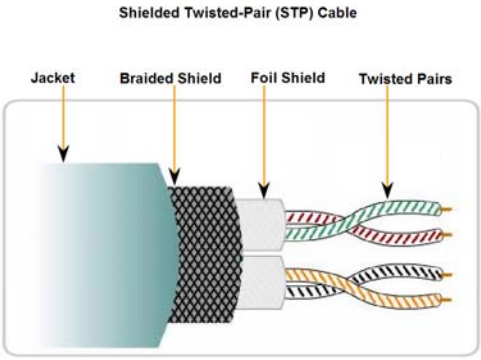
Other Types of Copper Media – Coaxial Cable (Coax)

- An important type of cable that is used in wireless and cable access technologies
- Used to attach antennas to wireless devices. It carries radio frequency (RF) energy between the antennas and the radio equipment
- Cables services (two-way system) provide Internet connectivity as well TV services (Hybrid Fiber Coax HFC)



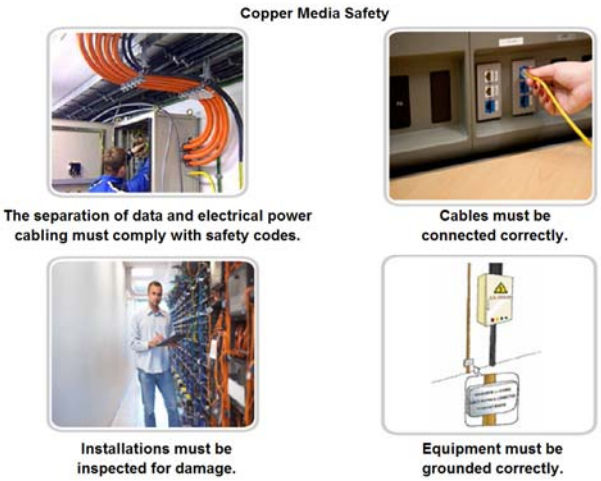
Other Types of Copper Media – Shielded Twisted Pair (STP) Cable

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



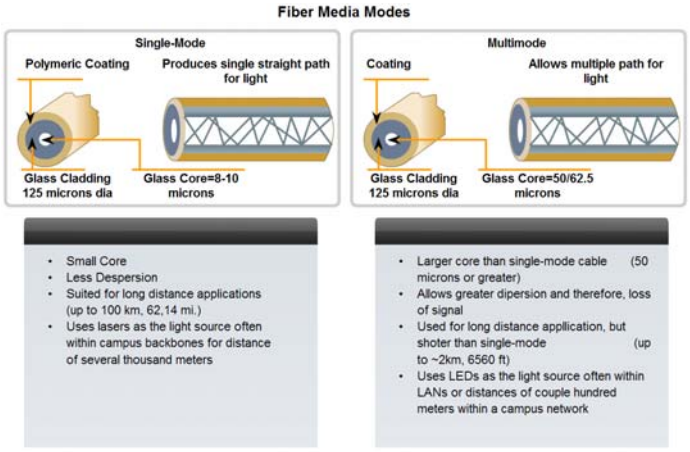
Characteristics & Uses of Network Media

- Identify types of safety issues when working with copper cabling



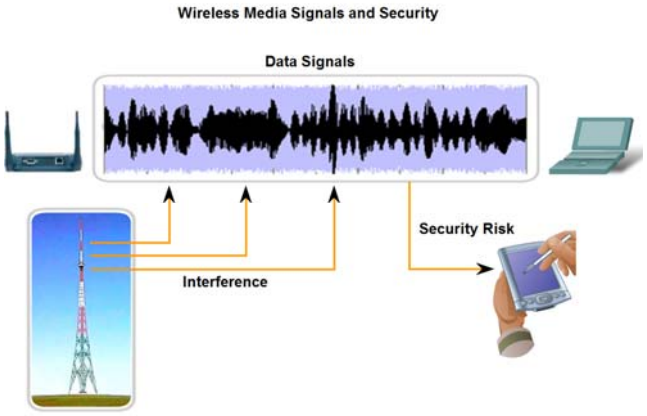
Characteristics & Uses of Network Media

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



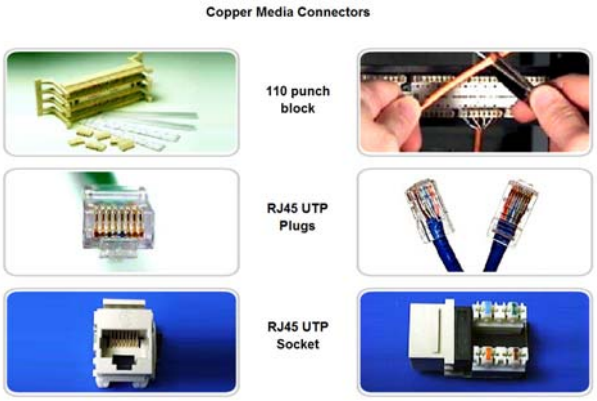
Characteristics & Uses of Network Media

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



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



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.