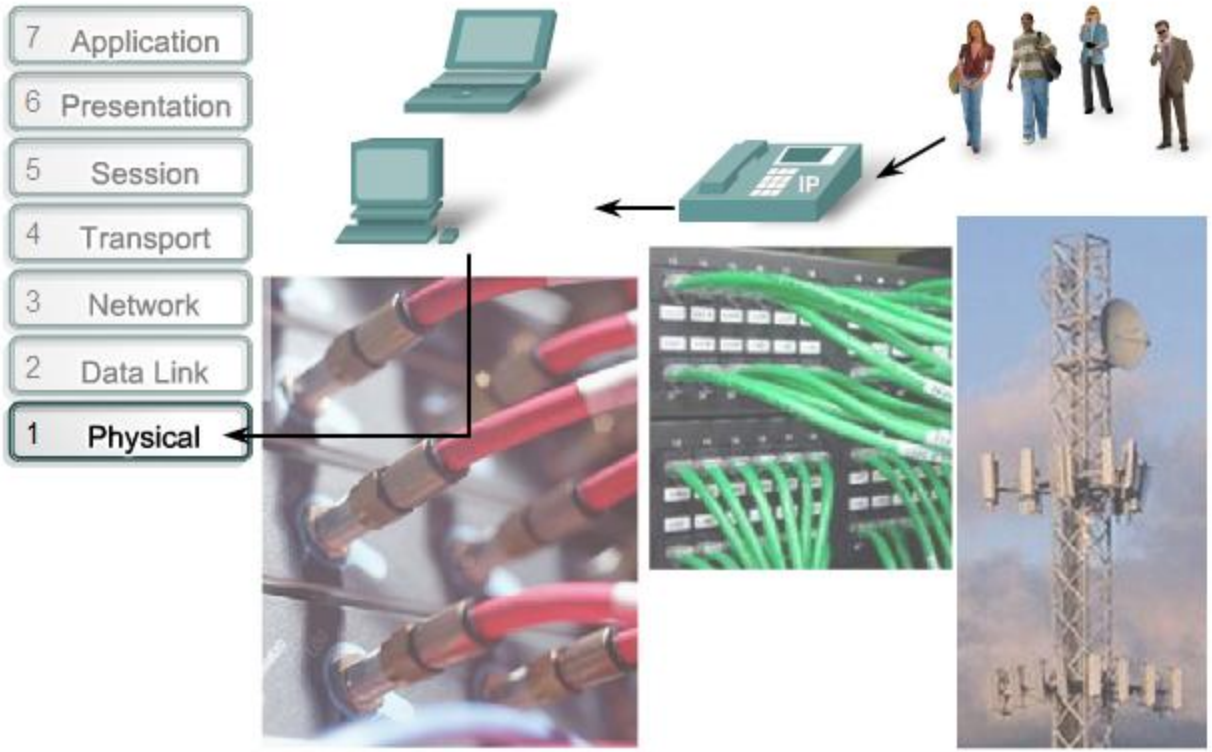
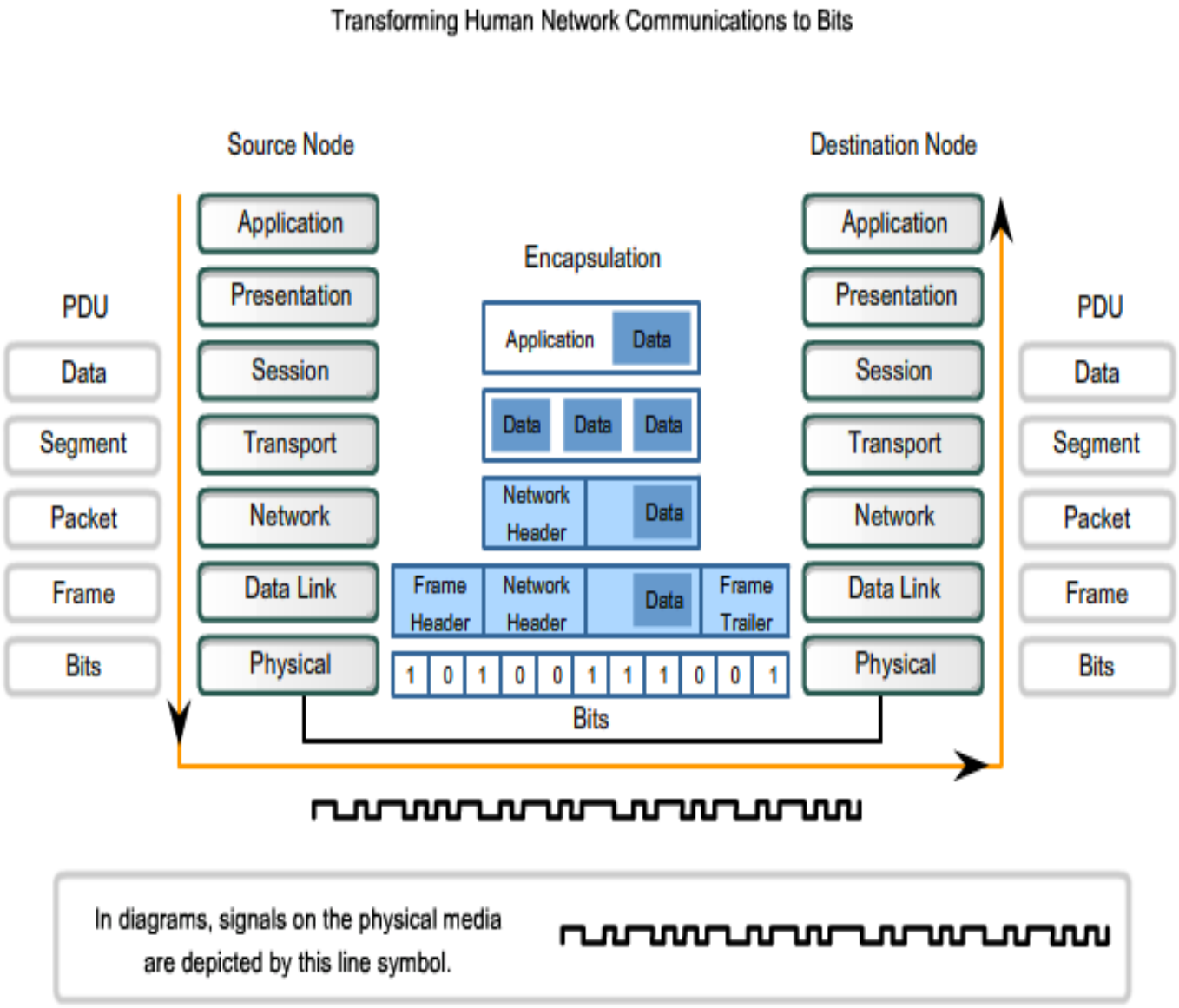
8.0.1 Chapter 8 Introduction



The Physical layer interconnects our data networks.

- **Physical layer protocols and services**
- **Physical layer signaling and encoding.**
- **Role of signals used to represent bits as a frame is transported across the local media.**
- **Basic characteristics of copper, fiber, and wireless network media.**
- **Common uses of copper, fiber, and wireless network media.**

8.1.1 Physical Layer Purpose

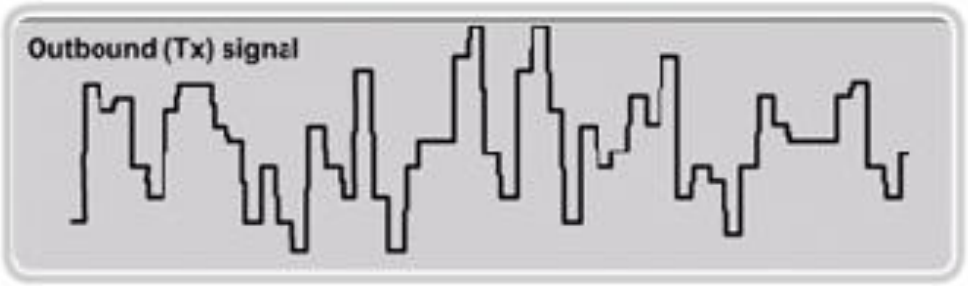


The delivery of frames across the local media requires the following Physical layer elements::

- Physical media and associated connectors
- Representation of bits on the media
- Encoding of data and control information
- Transmitter and receiver circuitry on the network devices

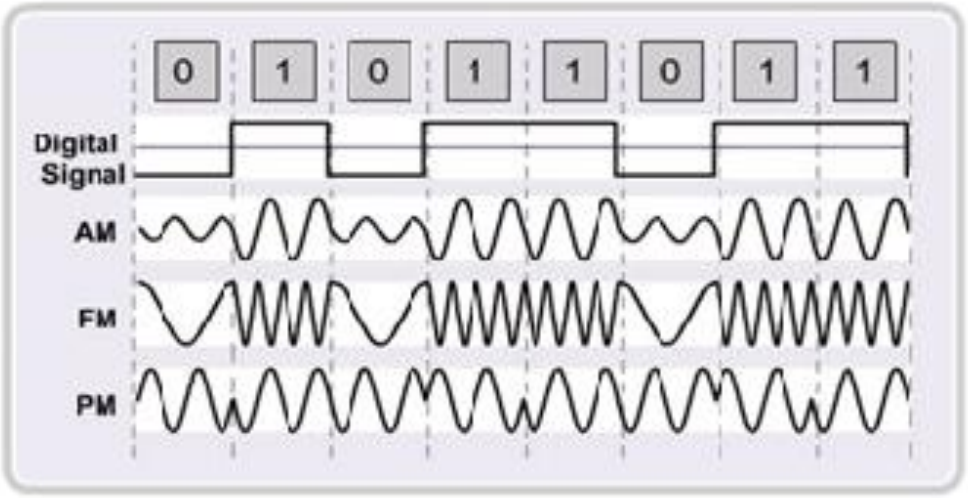
8.1.2 Physical Layer Operation

Representations of Signals on the Physical Media



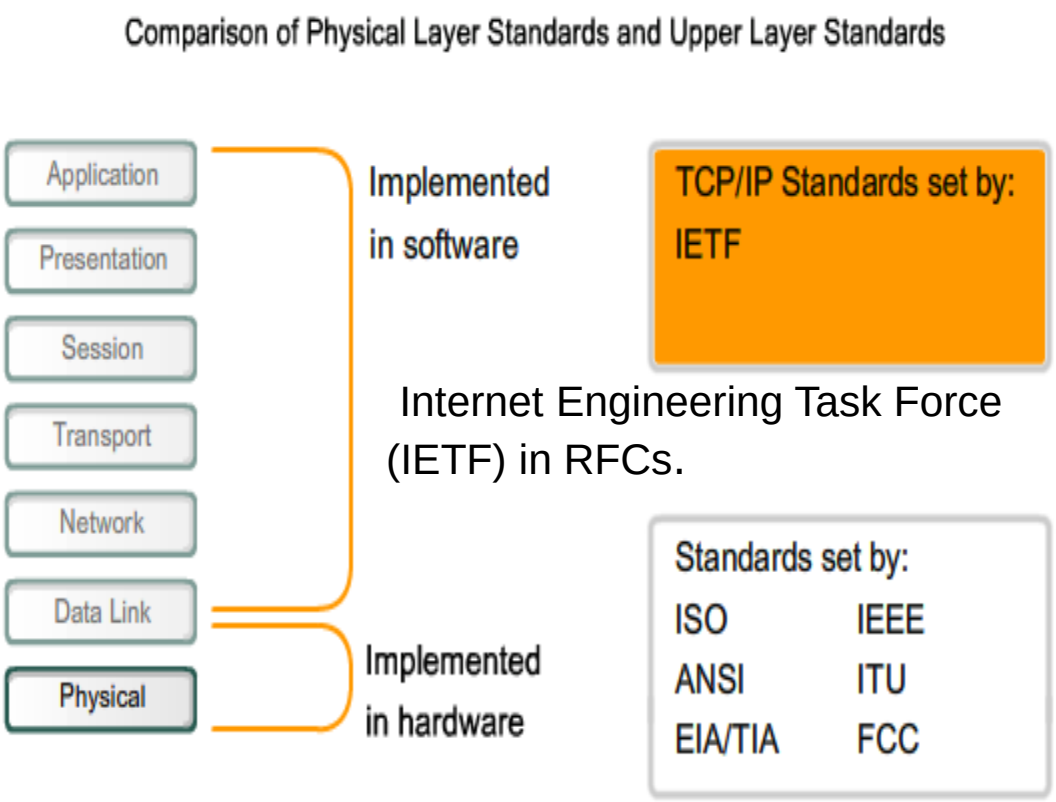
Sample electrical signals transmitted on copper cable

Representative light pulse fiber signals



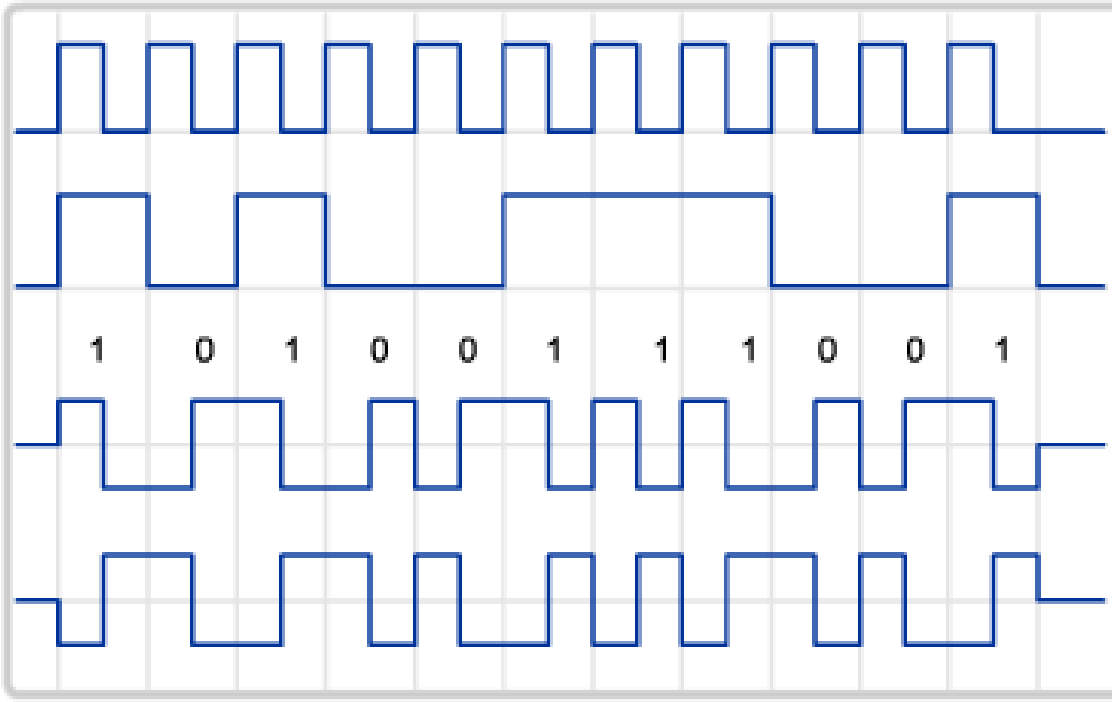
Microwave (wireless) signals

8.1.3 Physical Layer Standards



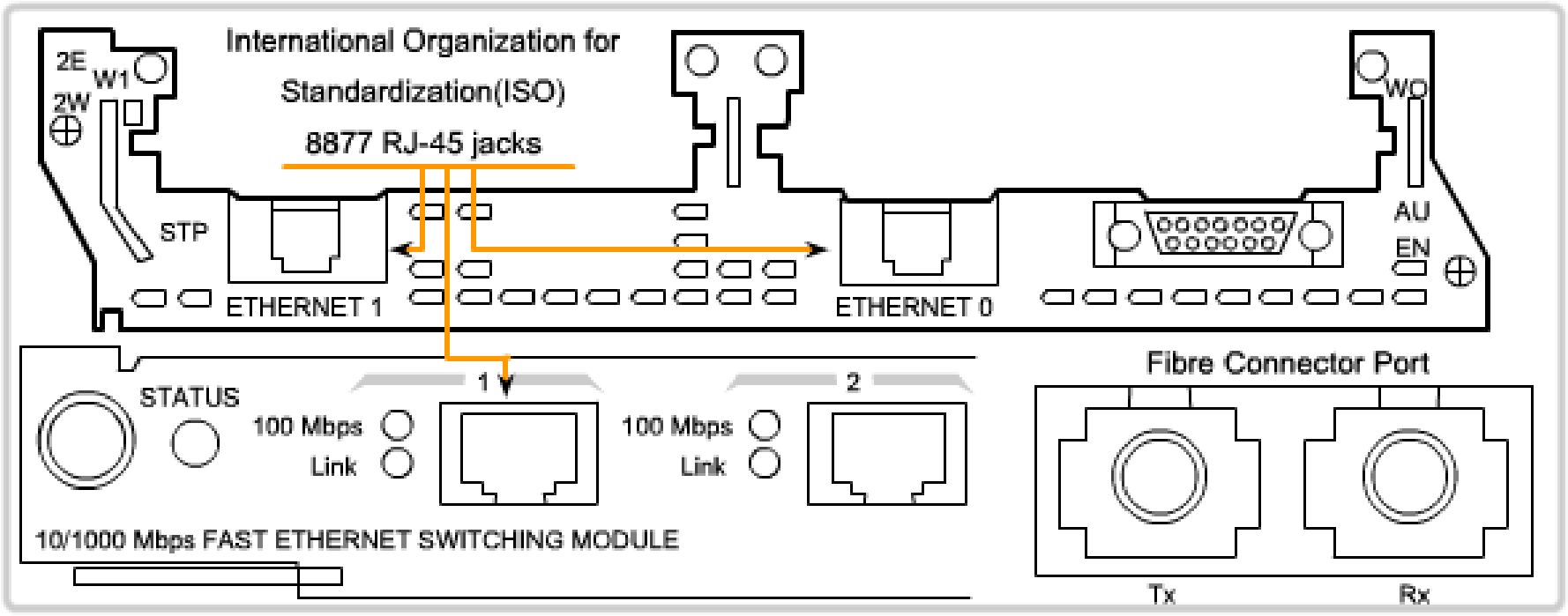
- The International Organization for Standardization (ISO)
- The Institute of Electrical and Electronics Engineers (IEEE)
- The American National Standards Institute (ANSI)
- The International Telecommunication Union (ITU)
- The Electronics Industry Alliance/Telecommunications Industry Association (EIA/TIA)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

8.1.3 Physical Signal Standards



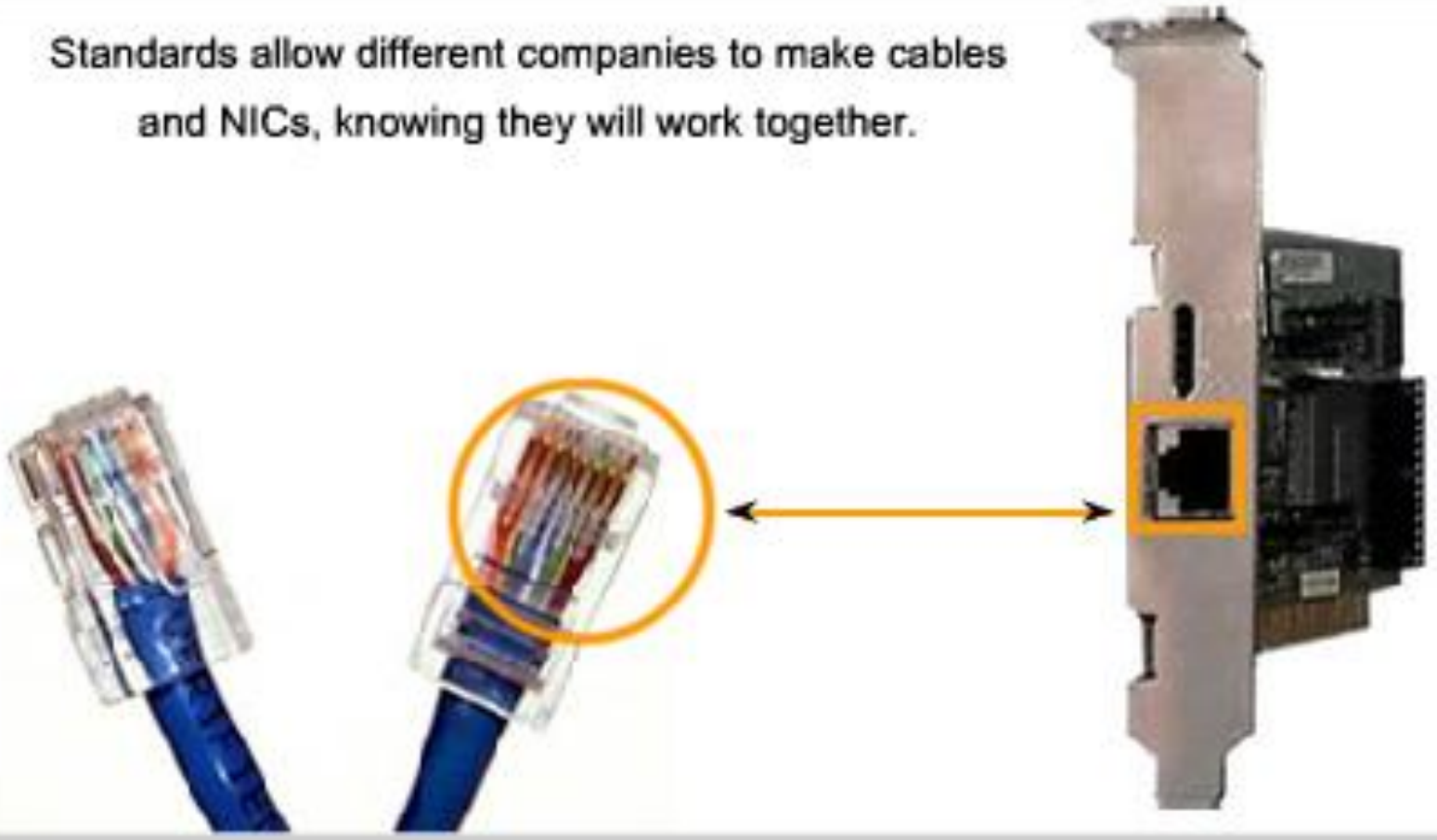
Signal standards allow a variety of devices to interoperate.

8.1.3 Physical Connection Standards

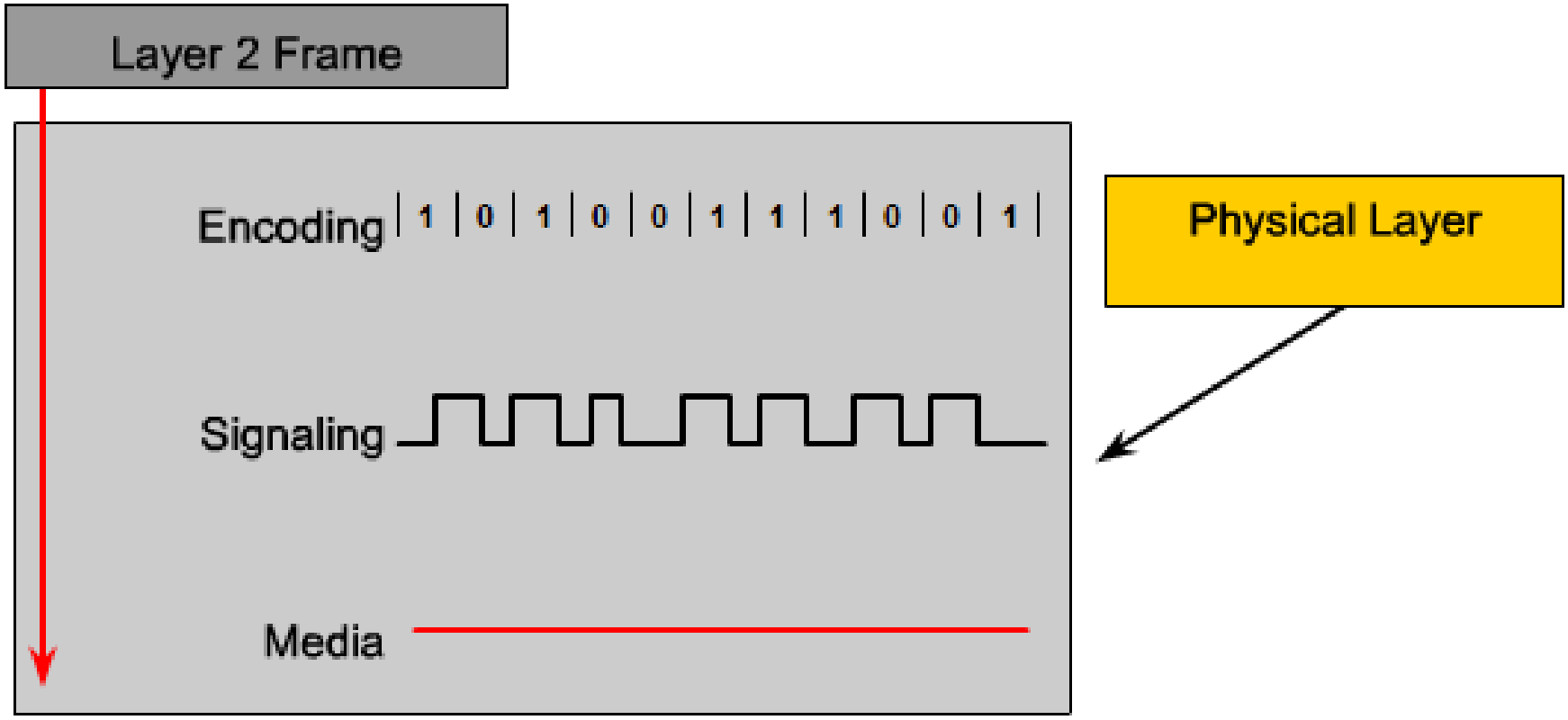


8.1.3 Physical Cable Standards

Standards allow different companies to make cables and NICs, knowing they will work together.



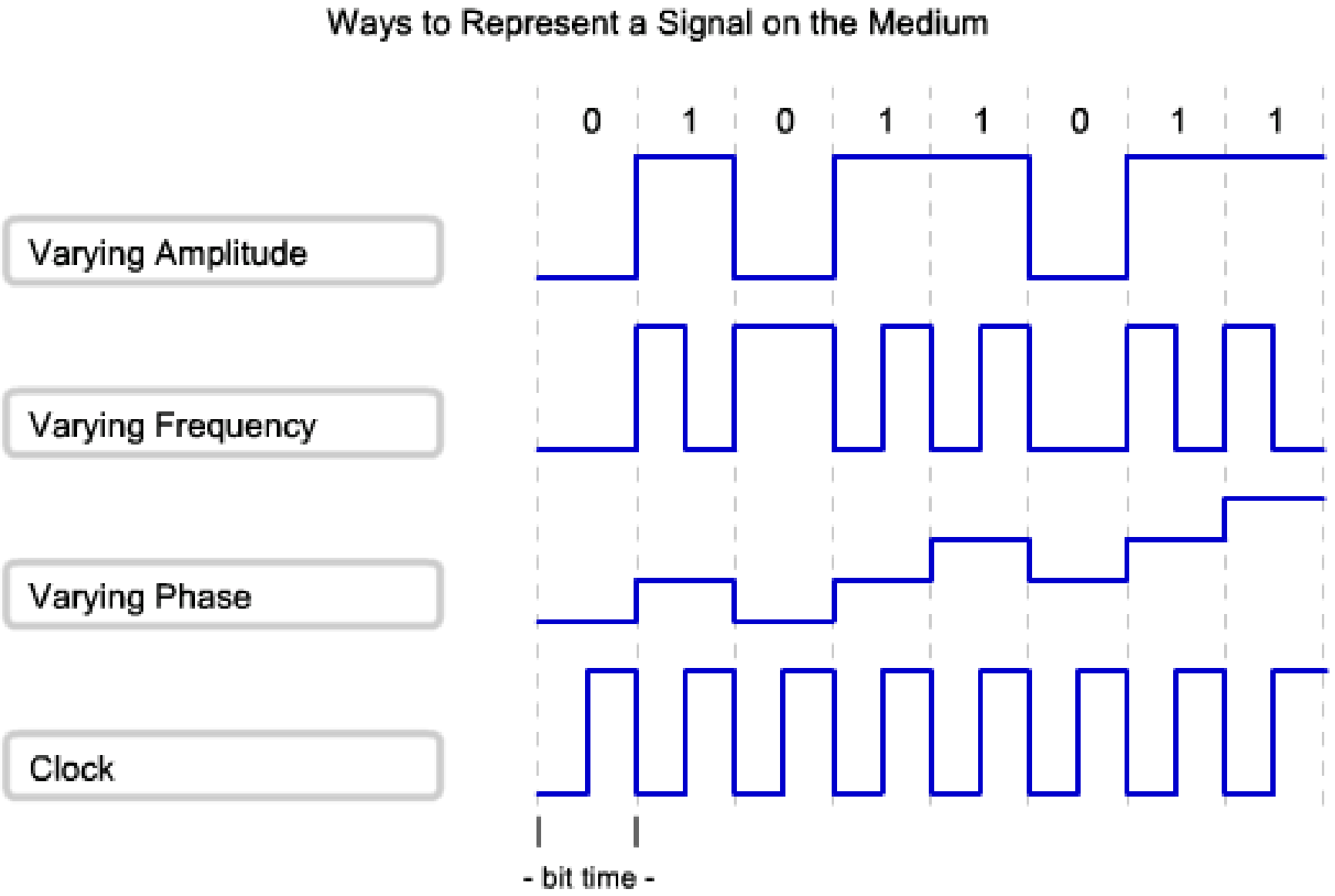
8.1.4 Physical Layer Principles



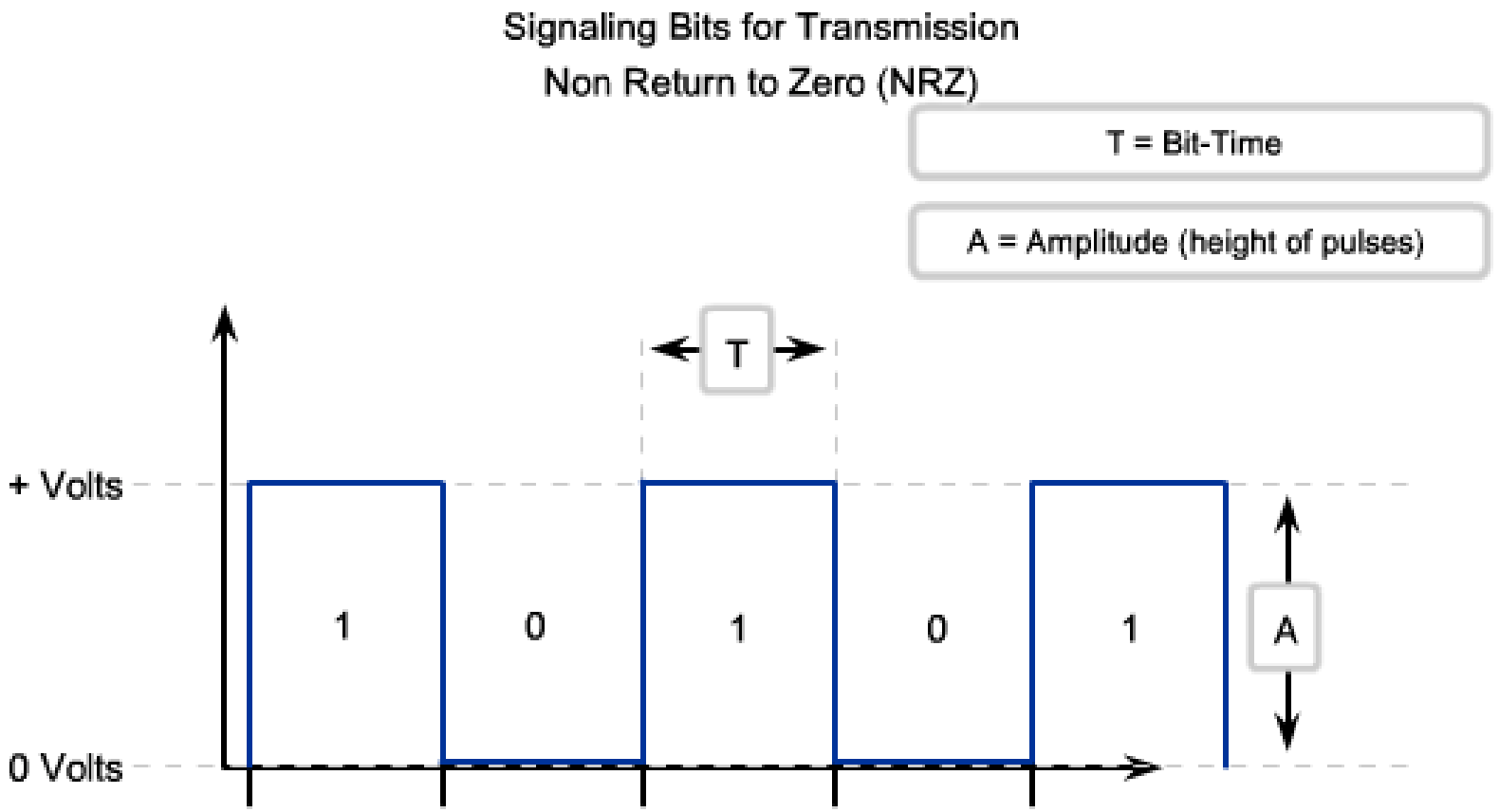
Encoding: Converting a stream of data bits into a predefined code.

Signaling: Electrical, optical, or wireless signals that represent the "1" and "0" on the media.

8.2.1 Signaling Bits on the Media



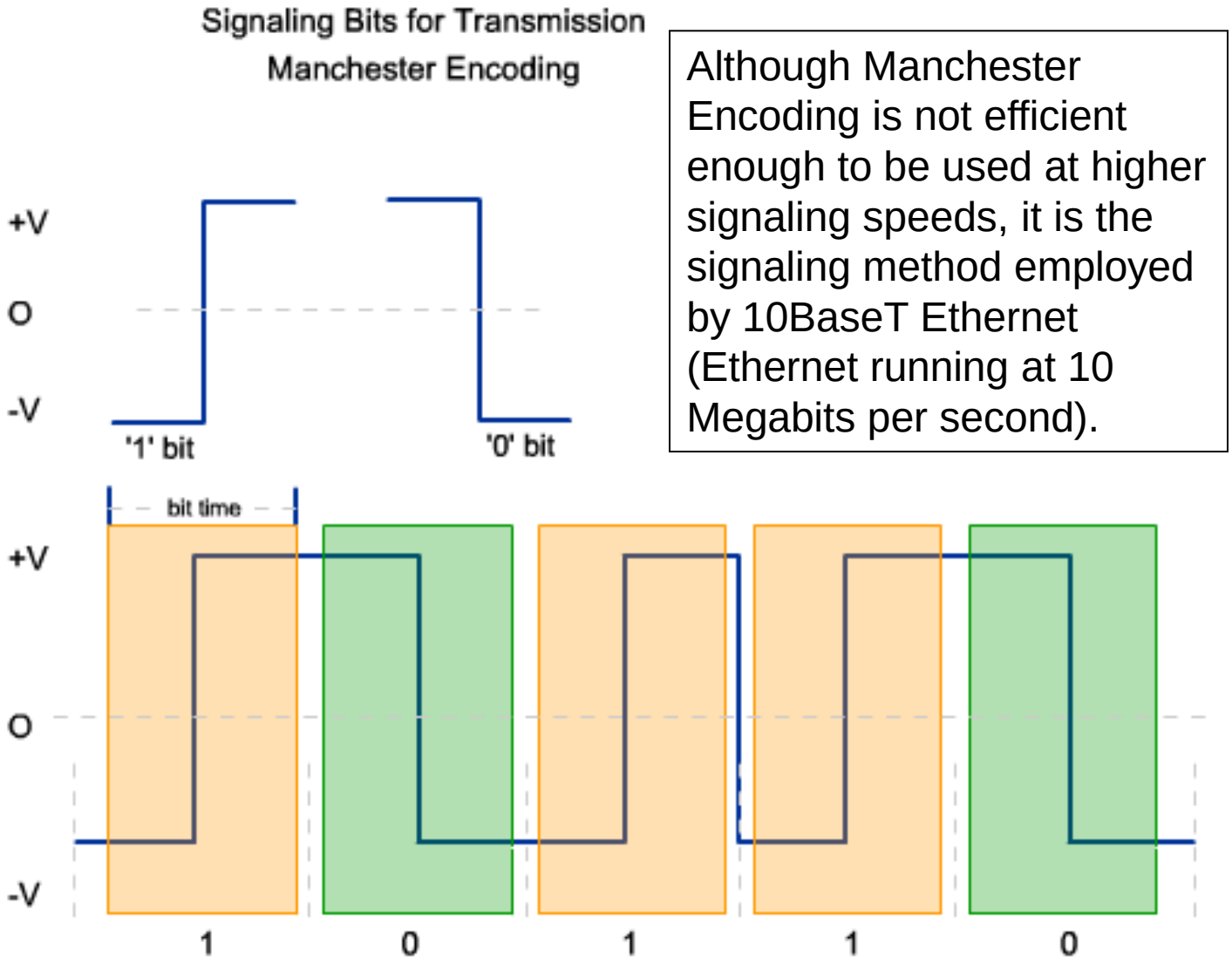
8.2.1 Signaling Bits for the Media



- Discrete pulses (not continuous)
- Can only have one of two states (1/0, on/off)
- Voltage jumps between levels

8.2.1 Signaling Bits for the Media

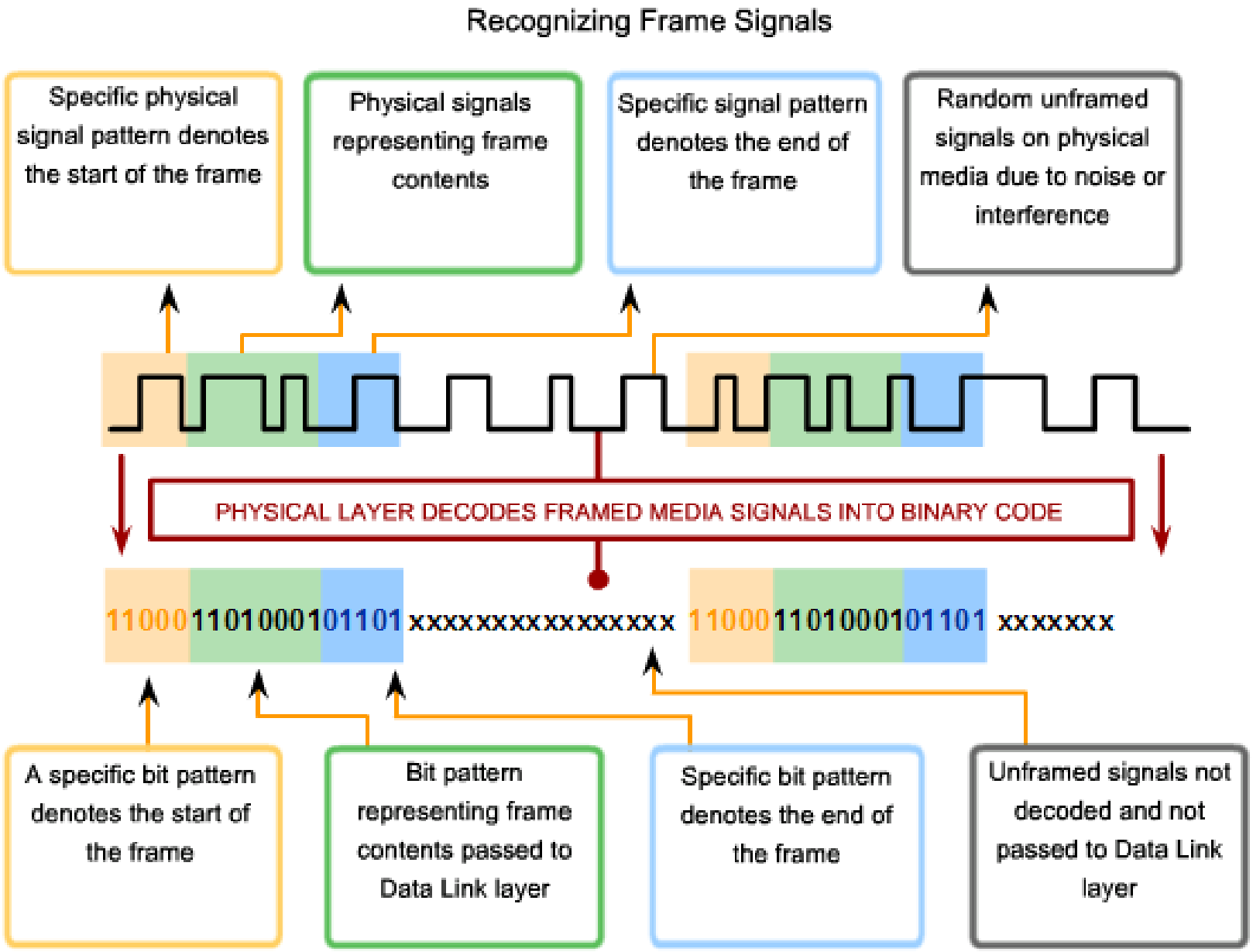
Manchester Encoding uses the **change in signal level** in the middle of the bit time to represent the bits.



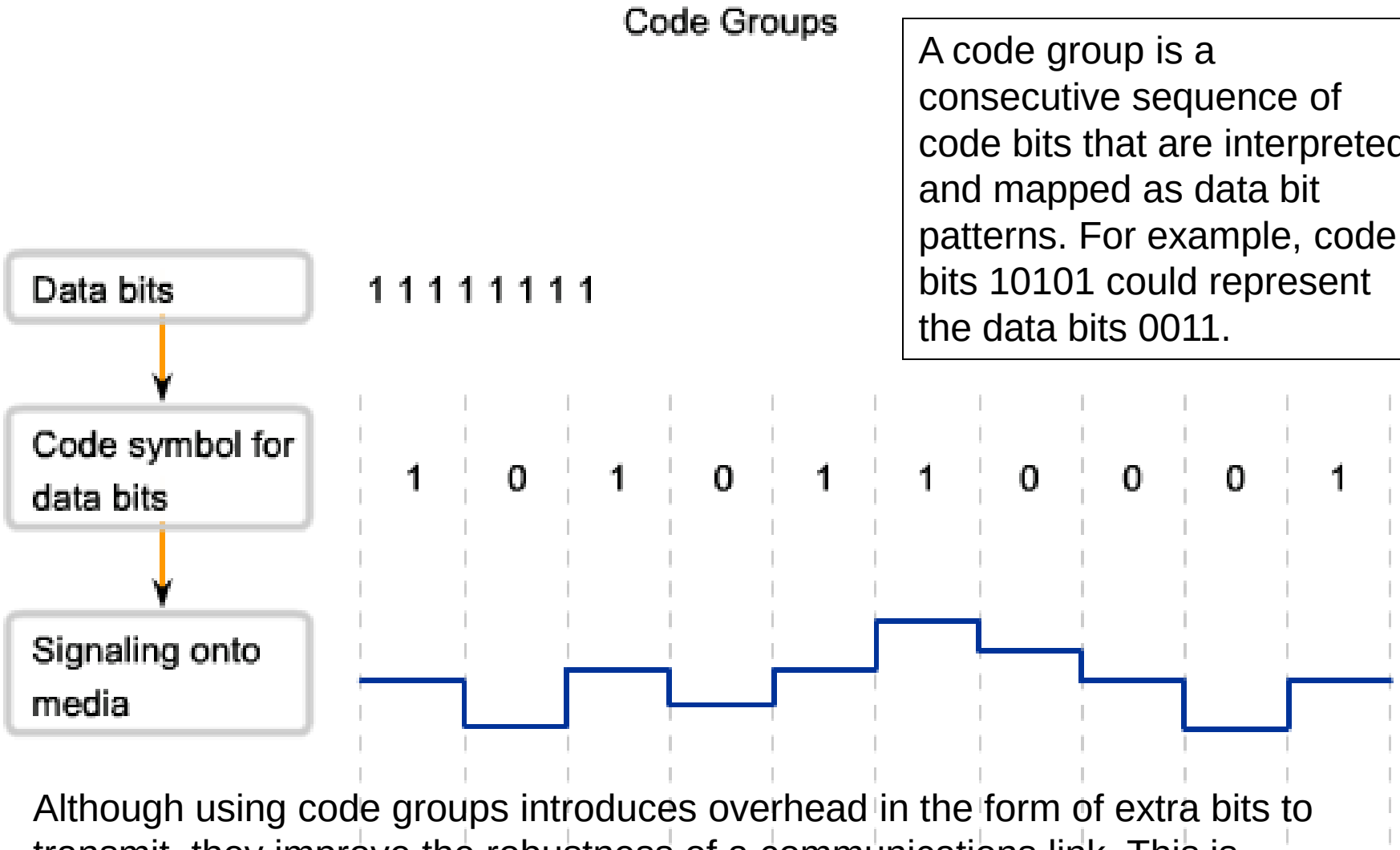
CHANGE!

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

8.2.2 Encoding - Grouping Bits



8.2.2 Encoding - Grouping Bits



A 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.

Although using code groups introduces overhead in the form of extra bits to transmit, they improve the robustness of a communications link. This is particularly true for higher speed data transmission.

8.2.2 Encoding - Grouping Bits

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

8.2.2 Encoding - Grouping Bits

4B/5B Encoding The encoding method used for encoding 4-bit data bytes to 5-bit Transmission Characters.

Data bytes are converted to Transmission Characters to improve the physical signal such that the following benefits are achieved:

- bit synchronization is more easily achieved,
- design of receivers and transmitters is simplified,
- error detection is improved, and
- control characters (i.e., the Special Character) can be distinguished from data characters.
- 4B/5B encoding prevent symbols with more than three 0's in succession from occurring in the stream.

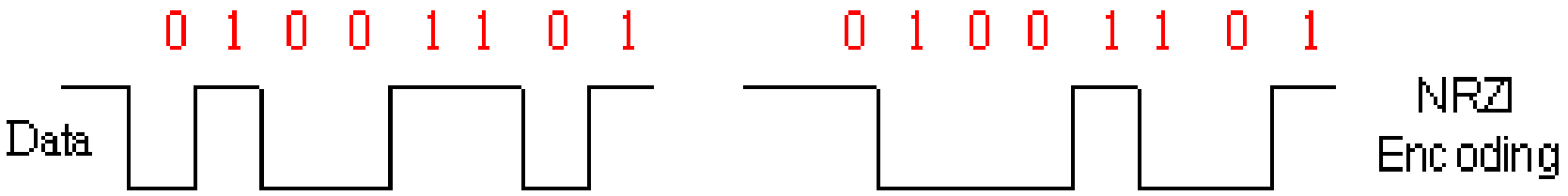
The encoding advantage is that it can use NRZ-I encoding without losing synchronization in case of long null sequences.
The disadvantage is the 25% overhead due to conversion from 4 to 5 bits.

Of the 32 different characters that the 4B/5B code can generate, only 16 characters are needed to transfer the payload, the remaining 16 are used as control characters

8.2.2 Non Return to Zero Encoding

NRZI [Non-Return-to-Zero-Inverted Encoding]: A '0' is encoded as no change in the level. However a '1' is encoded depending on the current state of the line. If the current state is '0' [low] the '1' will be encoded as a high, if the current state is '1' [high] the '1' will be encoded as a low. Used with FDDI and USB for example.

NRZI Encoding



8.2.3 Data Carrying Capacity

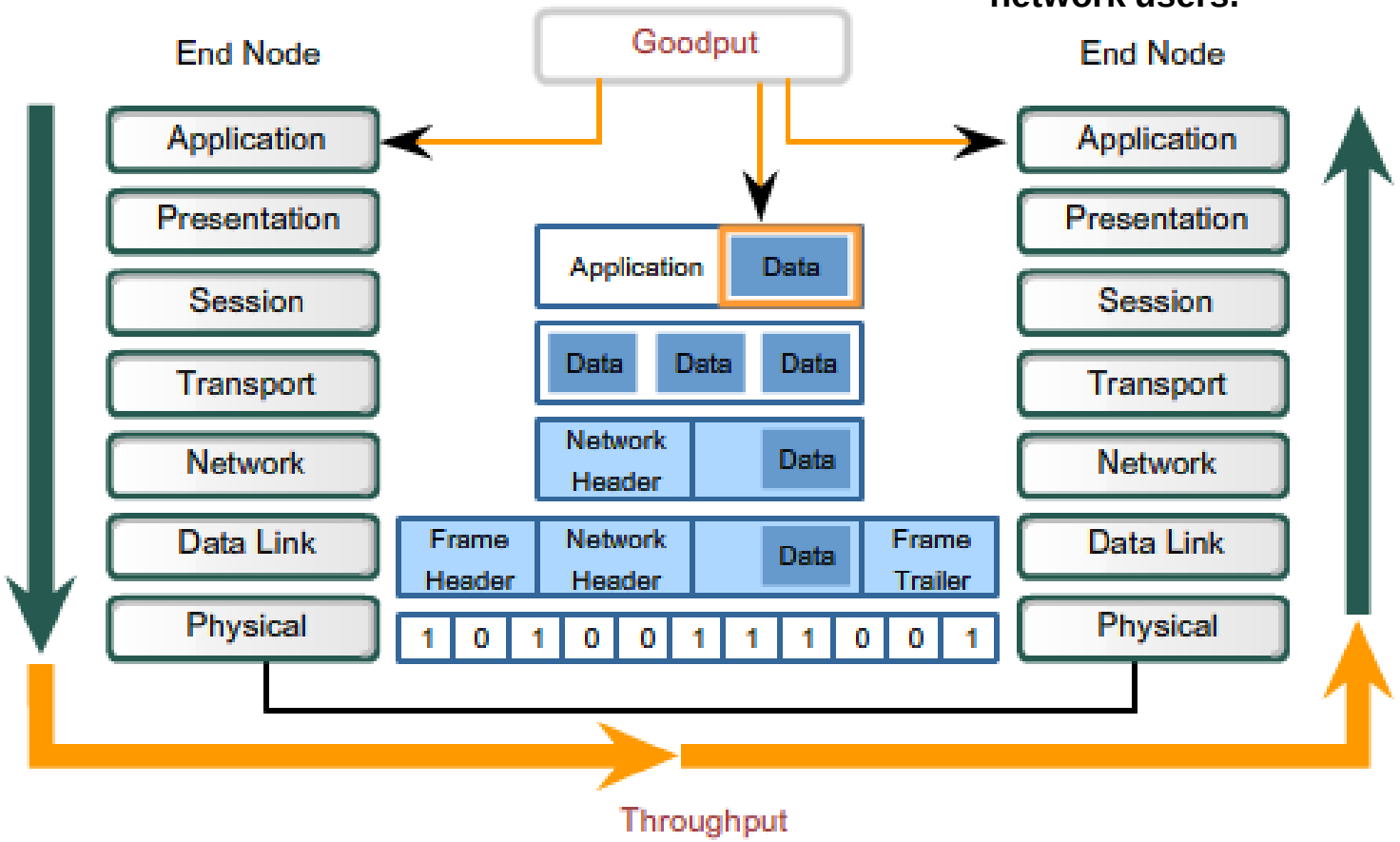
Units of Bandwidth, Throughput, and Goodput

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

8.2.3 Data Carrying Capacity

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

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.



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

8.3.1 Types of Physical 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 - four pair	EIA/TIA Category 5 UTP - two pair	50/62.5 mmulti mode fiber	STP	EIA/TIA Category 5 (or greater) UTP, four pair	50/62.5 micron multimode fiber	50/62.5 micron multimode fiber or 9 micron single mode fiber	9m single mode fiber	9m 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)				

Also 10Base2 and 10Base5 not mentioned above

8.3.1 Types of Physical Media

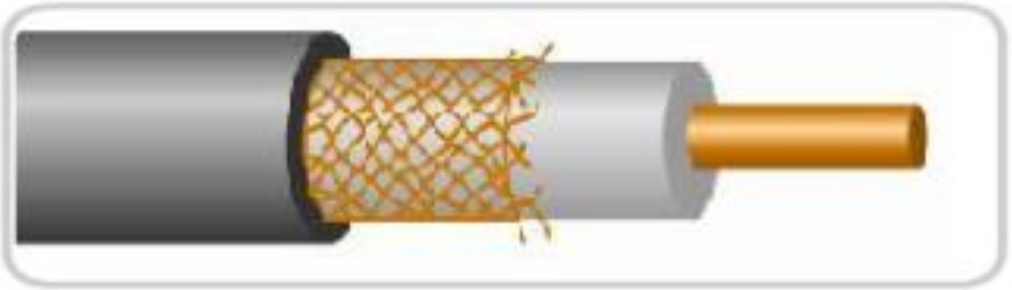
Physical Media - Characteristics

Wireless Media

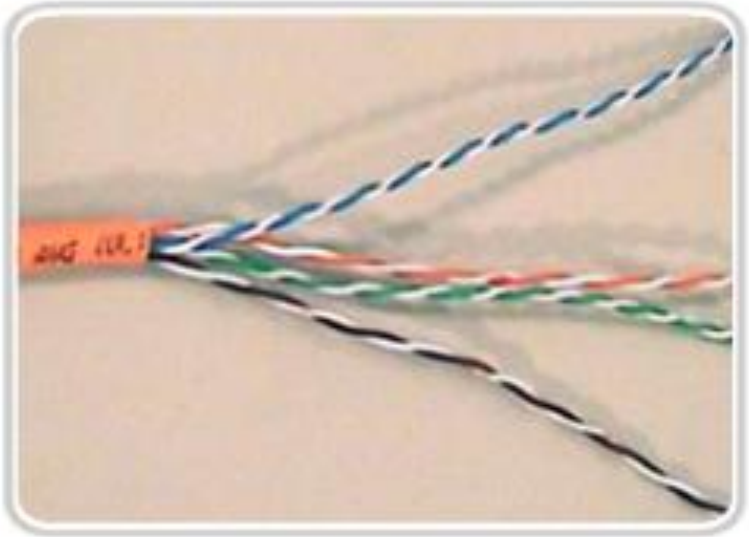
Standards	Bluetooth 802.15	802.11(a,b,g,n), HiperLAN 2	802, 11, MMDS, LMDS	GSM, GPRS, CDMA, 2.5- 3G
Speed	<1 Mbps	1 - 54 + Mbps	22 Mbps+	10- 384 Kbps
Range	Short	Medium	Medium- long	Long
Applications	Peer-to-peer device-to-device	Enterprise networks	Fixed, last mile access	PDAs, Mobile phones, Cellular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

8.3.2 Copper Media

Copper Media



Coaxial cable



Unshielded twisted-pair cable

RJ-45 connections

8.3.2 Copper Media

External Interference with Copper Media

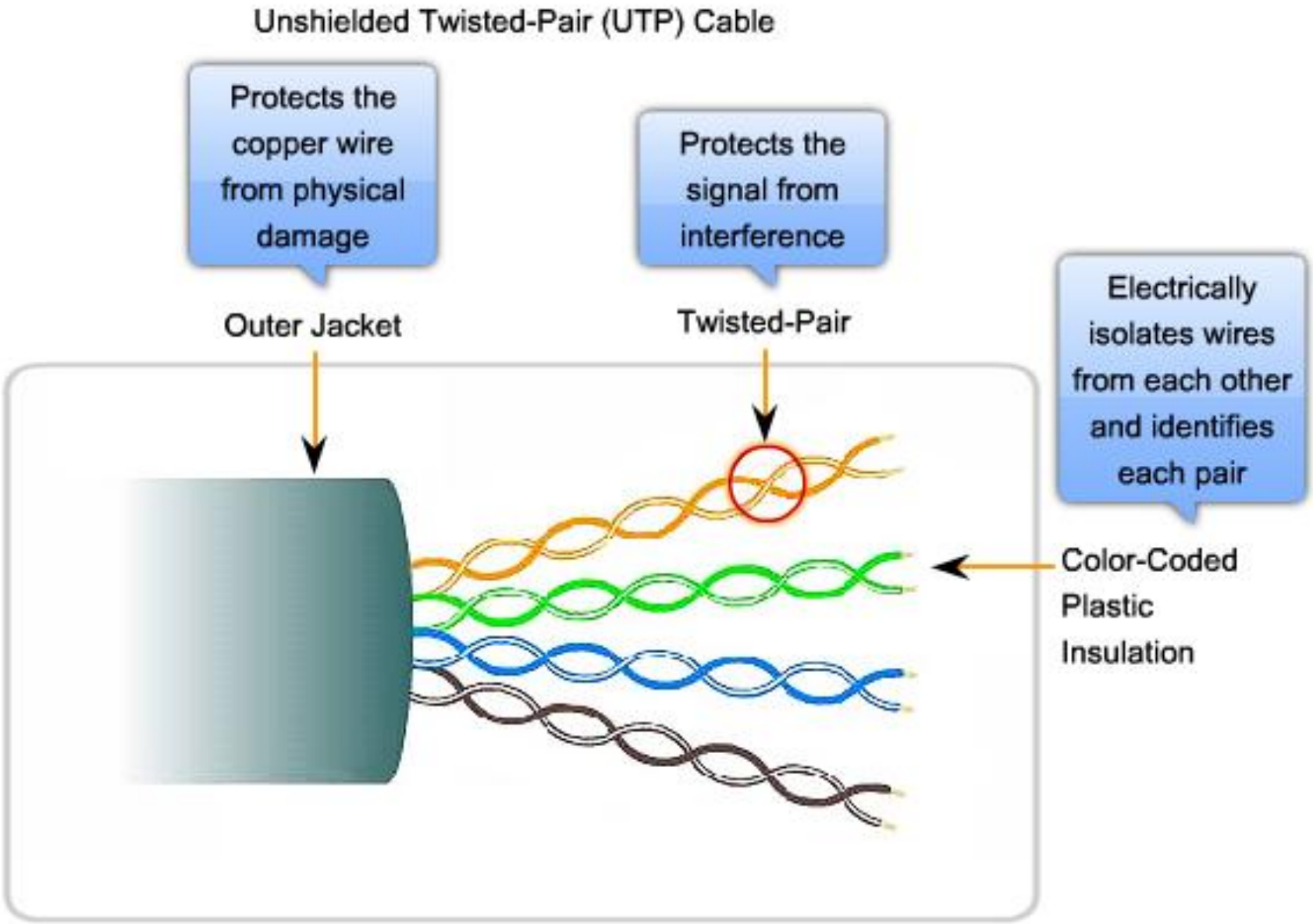
Sources of interference to data signals on copper media

Fluorescent lighting

Electric motors

Radio waves

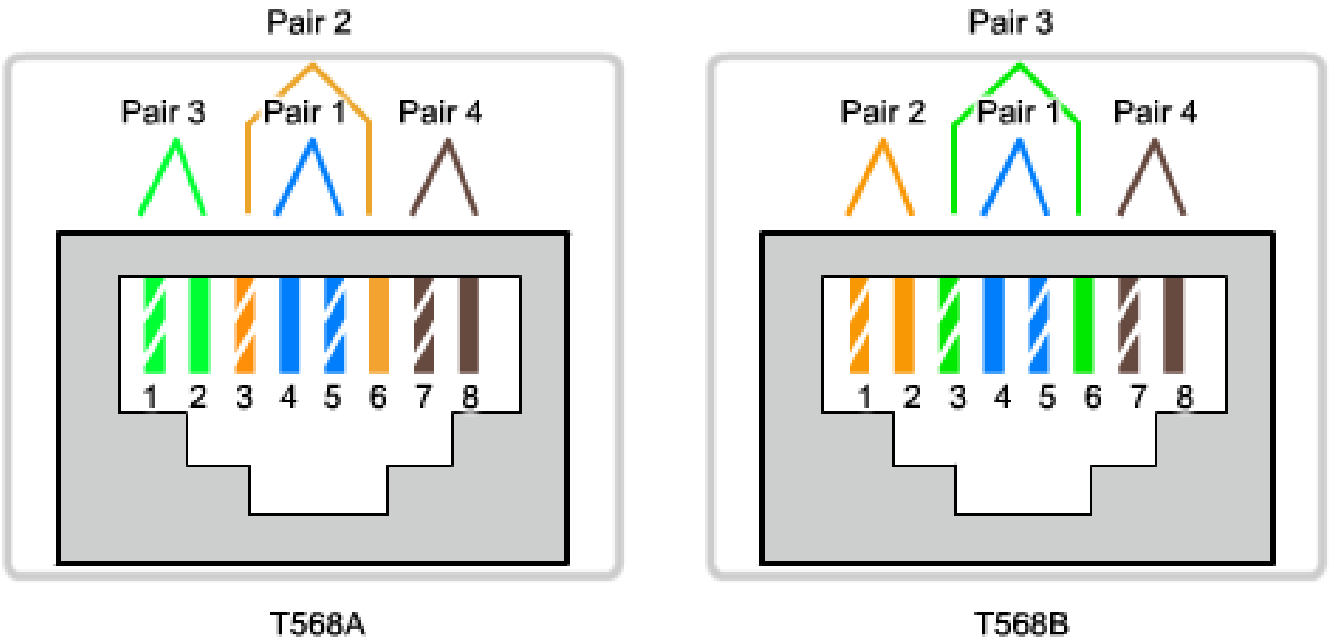
8.3.3 Unshielded Twisted Pair



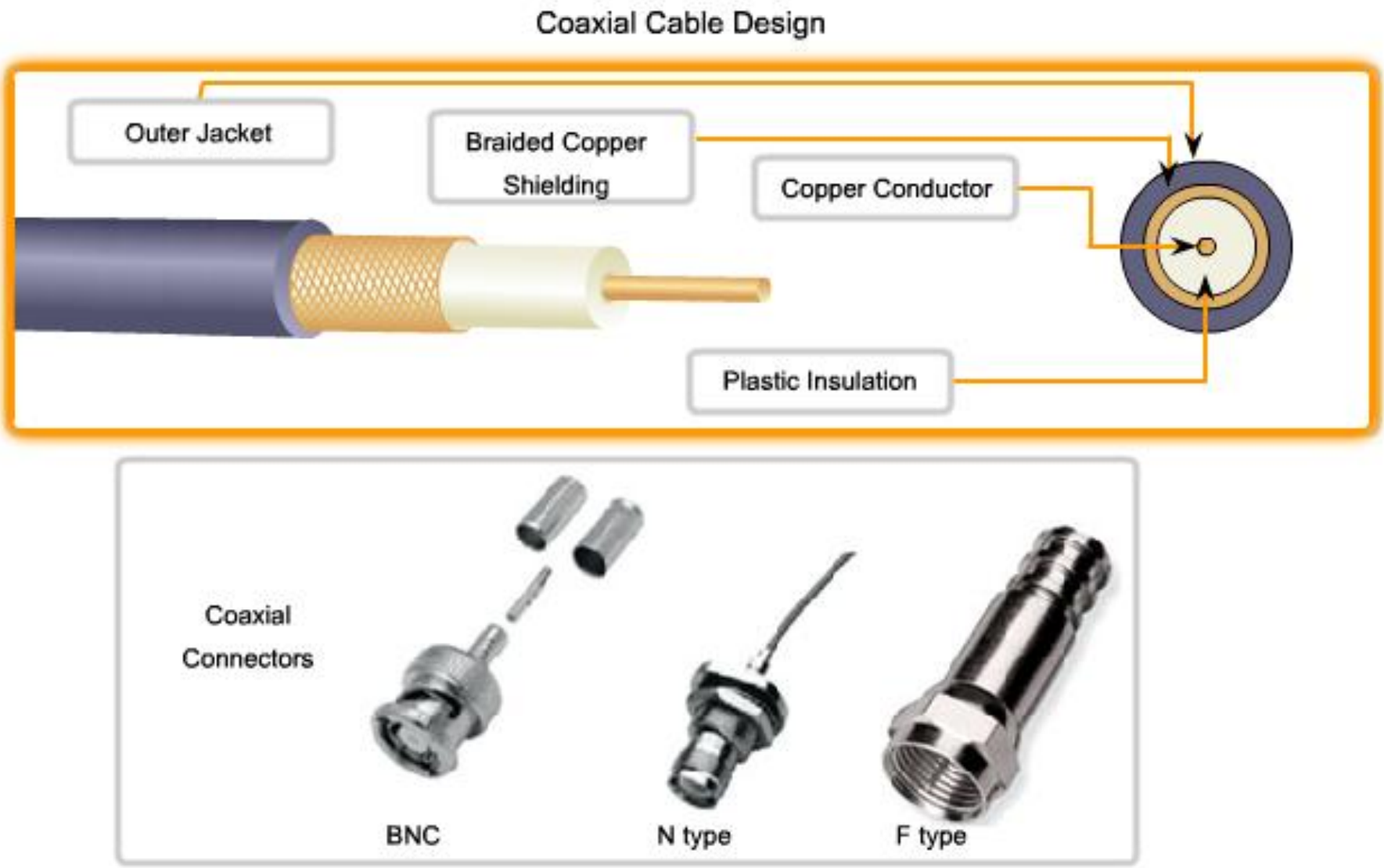
8.3.3 Unshielded Twisted Pair

Straight-through, Crossover, and Rollover Cable Types

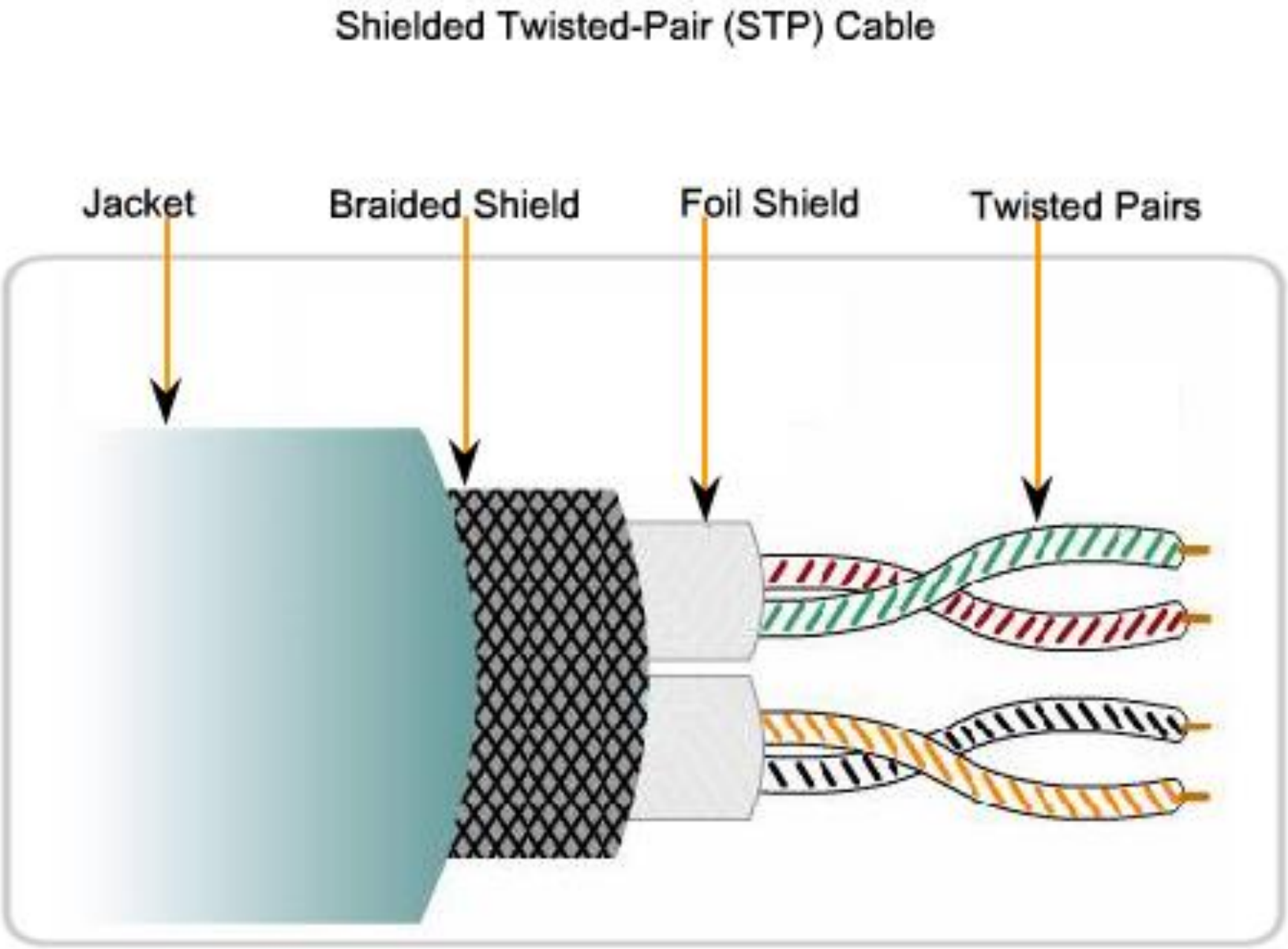
Cable Type	Standard	Application
Ethernet Straight-through	Both end T568A or both end T568B	Connecting a network host to a network device such as a switch or hub.
Ethernet Crossover	One end T568A, other end T568B	Connecting two network hosts. Connecting two network intermediary devices (switch to switch,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



8.3.4 Other Copper Media



8.3.4 Other Copper Media



8.3.5 Copper Media Safety

Copper Media Safety

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

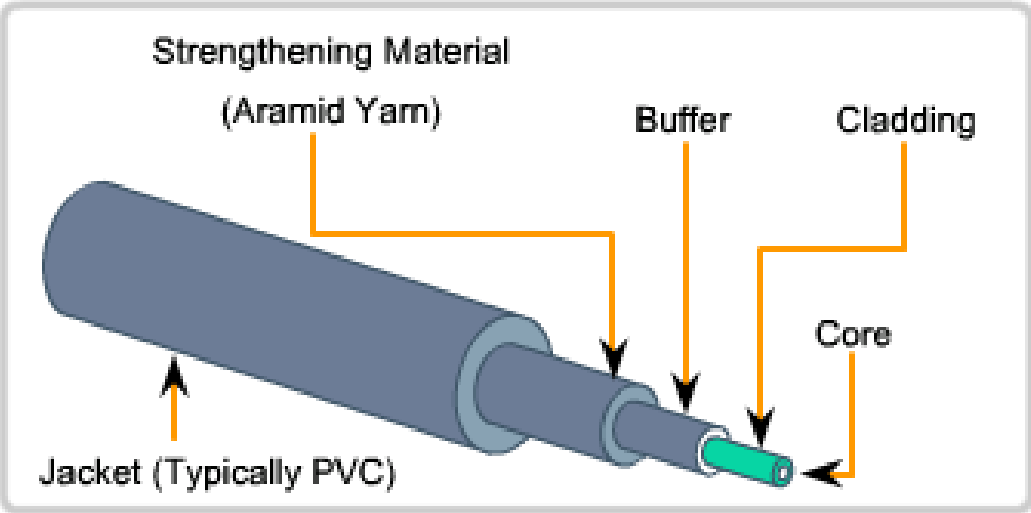
Cables must be connected correctly.

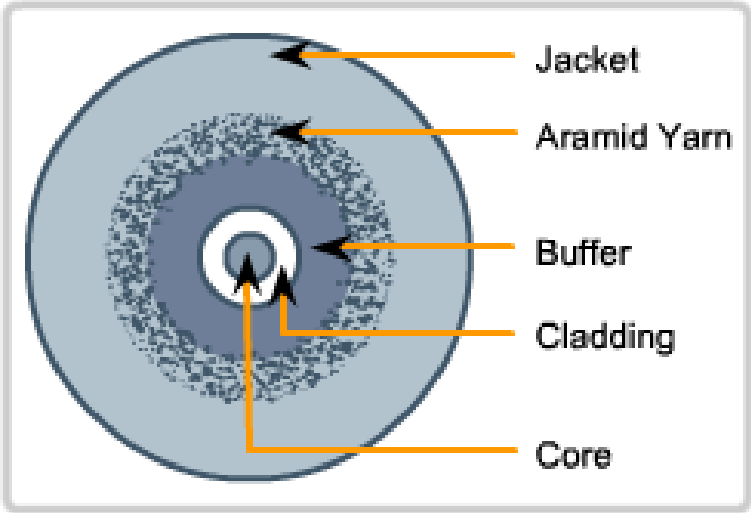
Installations must be inspected for damage.

Equipment must be grounded correctly.

8.3.6 Fiber Media

Fiber Media Cable Design





Fiber Connectors

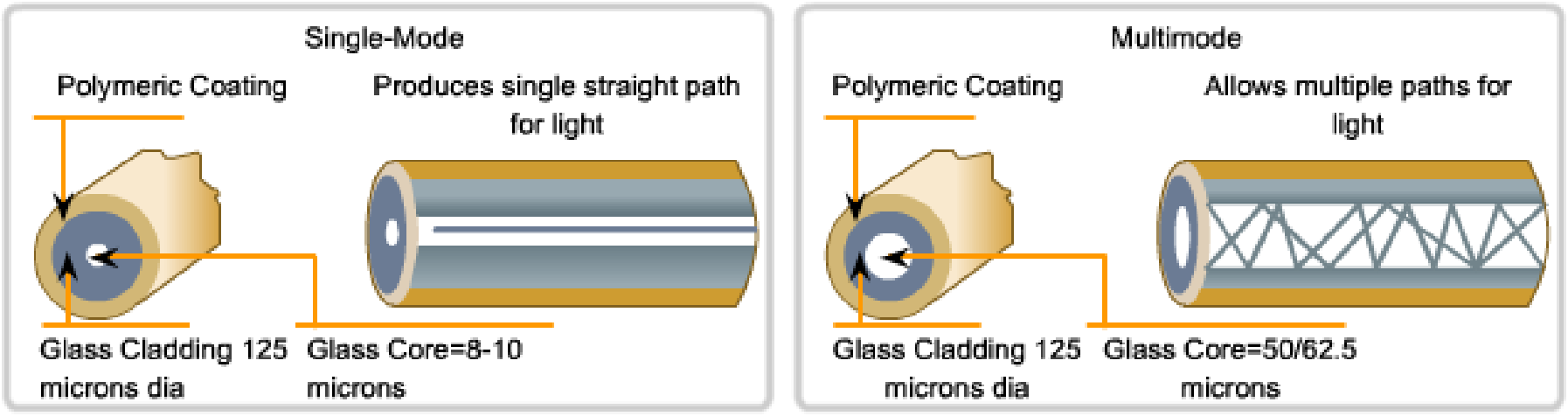
8.3.6 Fiber Media

Fiber Media Cable Design

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

8.3.6 Fiber Media

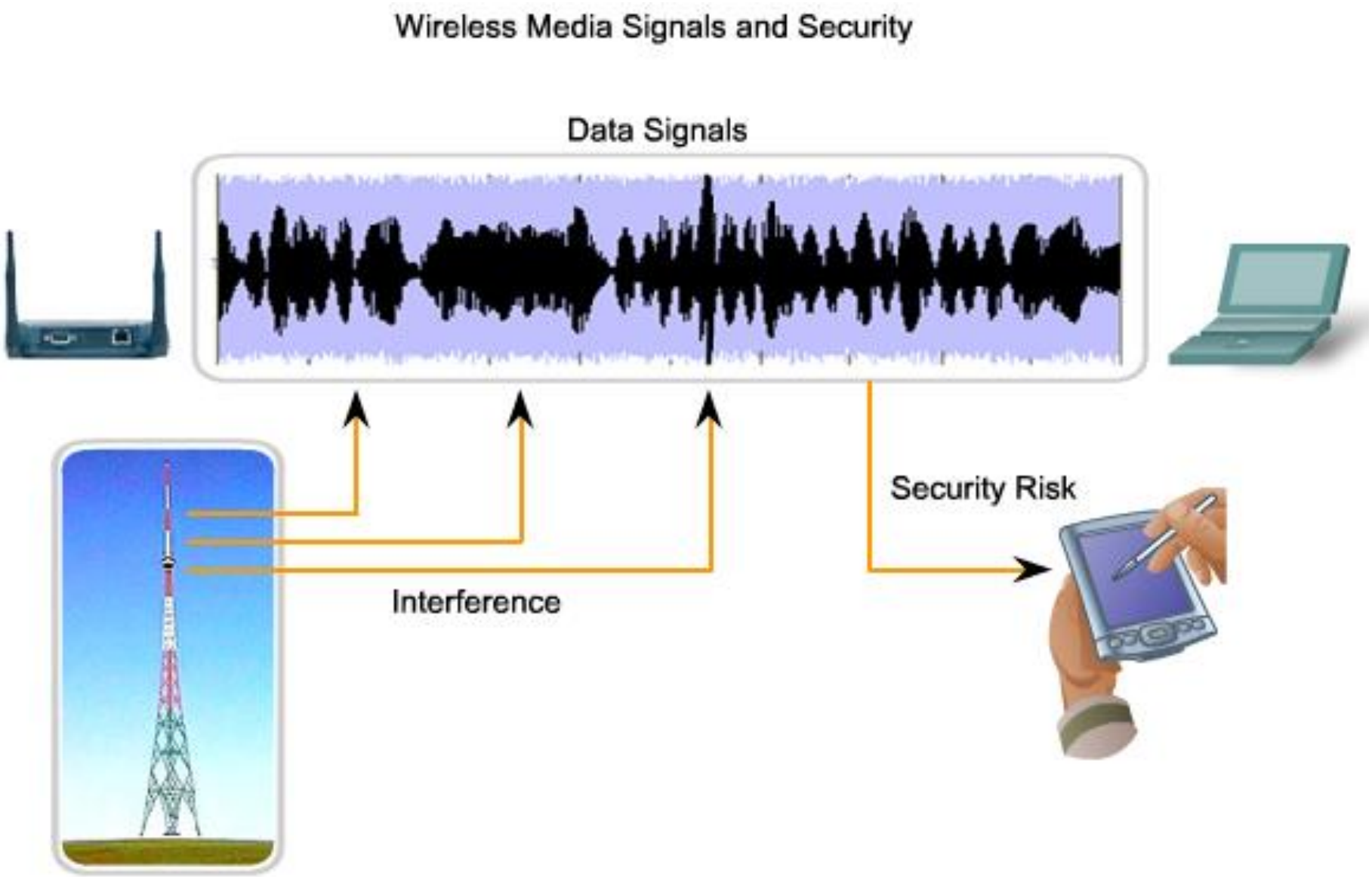
Fiber Media Modes



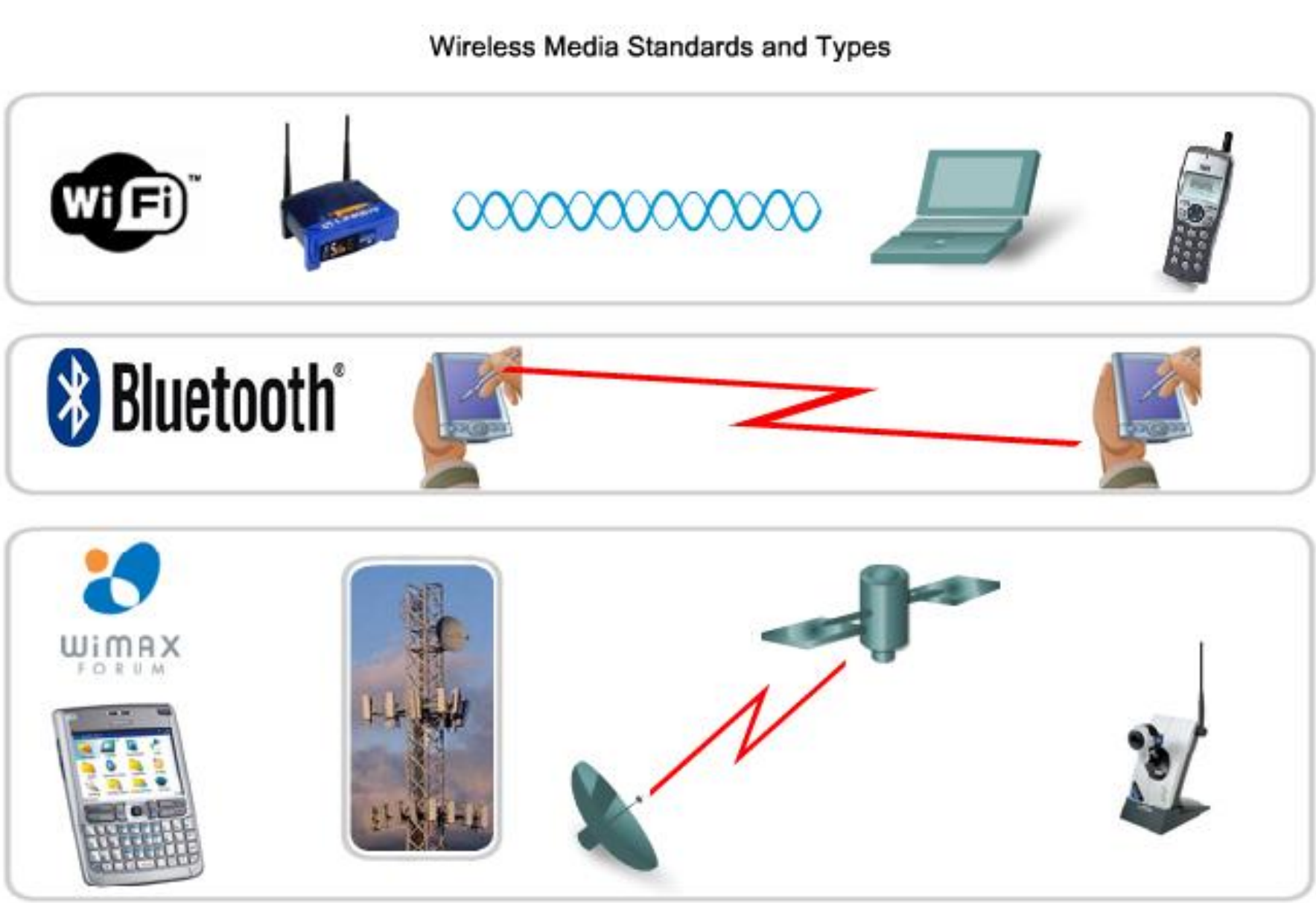
- Small Core
- Less Despersion
- Suited for long distance applications (up to 100 km, 62,14 mi.)
- Uses lasers as the light source often within campus backbones for distance of several thousand meters

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

8.3.7 Wireless Media



8.3.7 Wireless Media



8.3.7 Wireless Media

WLAN Access Points and Adapters

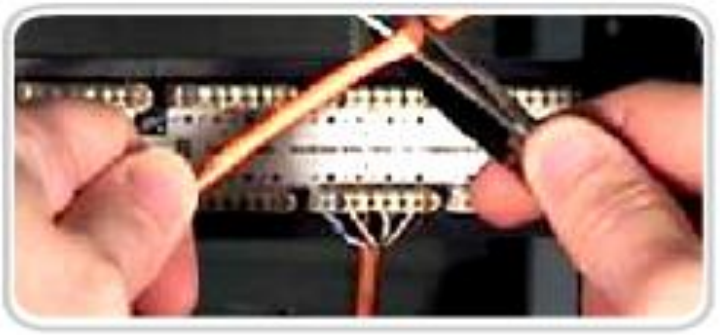
Wireless Access Point

Wireless Adapters

8.3.8 Media Connectors

Copper Media Connectors

110 punch block



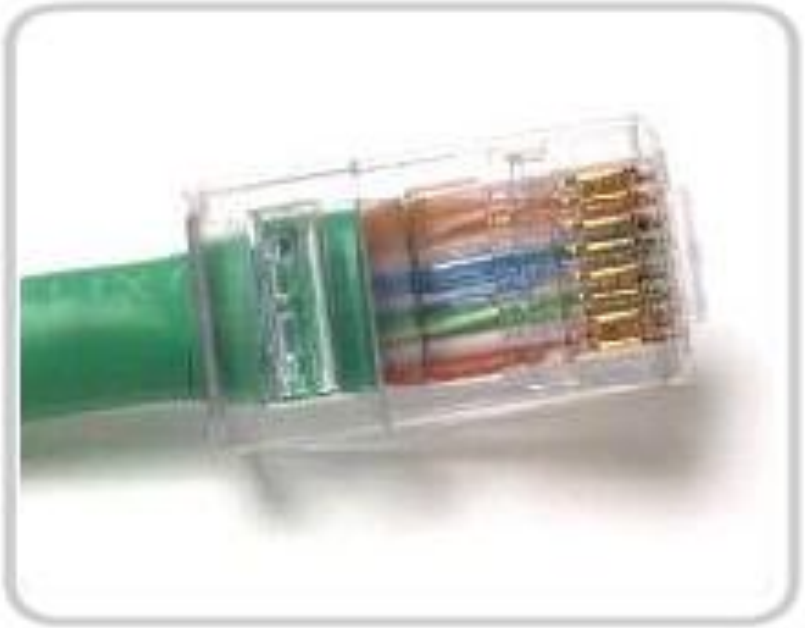
RJ-45 UTP
Plugs

RJ-45 UTP
Socket

8.3.8 Media Connectors

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.

8.3.8 Media 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

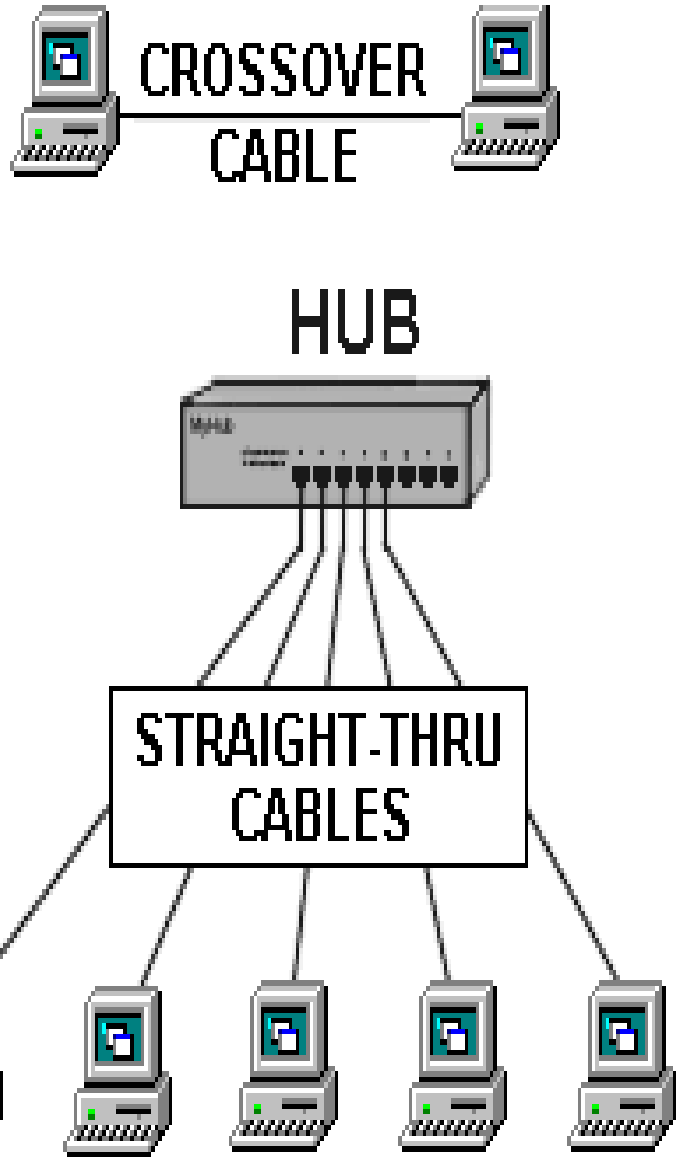
8.5.1 Summary and Review

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.

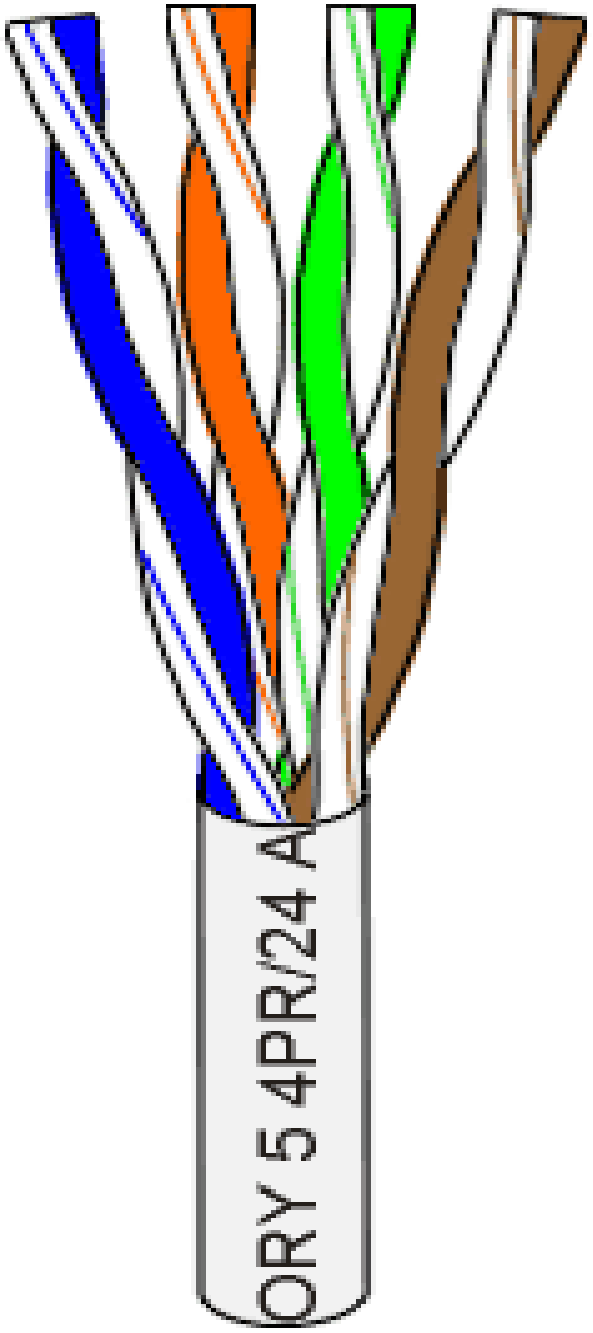
A LAN can be as simple as two computers, each having a network interface card (NIC) or network adapter and running network software, connected together with a **crossover cable**.

The next step up would be a network consisting of three or more computers and a hub. Each of the computers is plugged into the hub with a **straight-thru cable** (the crossover function is performed by the hub).



NETWORK CABLE AND CONNECTORS

CAT 5 wire is available in reel-in-box packaging. This is very handy for pulling the wire without putting twists in it. Without this kind of package or a cable reel stand, pulling wire is a two-person job. Before the advent of the reel-in-box, we used to put a reel of wire on a broom handle to pull it. One person would hold the broom handle and the other would pull and measure the cable. You will produce a tangled mess, if you pull the wire off the end of the reel.

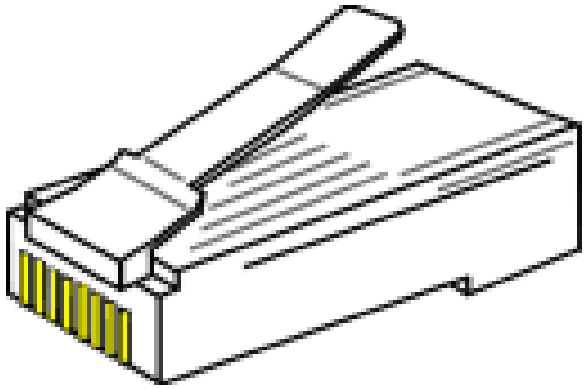


CAT 5 cable has four twisted pairs of wire for a total of eight individually insulated wires. Each pair is color coded with one wire having a solid color (blue, orange, green, or brown) twisted around a second wire with a white background and a stripe of the same color. The solid colors may have a white stripe in some cables. Cable colors are commonly described using the background color followed by the color of the stripe; e.g., white-orange is a cable with a white background and an orange stripe

CONNECTORS. The straight through and cross-over patch cables are terminated with CAT 5 RJ-45 modular plugs.

RJ-45 plugs are similar to those you'll see on the end of your telephone cable except they have eight versus four or six contacts on the end of the plug and they are about twice as big.

Make sure they are rated for CAT 5 wiring. (RJ means "Registered Jack"). Also, there are RJ-45 plugs designed for both solid core wire and stranded wire. Others are designed specifically for one kind of wire or the other



NETWORK CABLE TOOLS

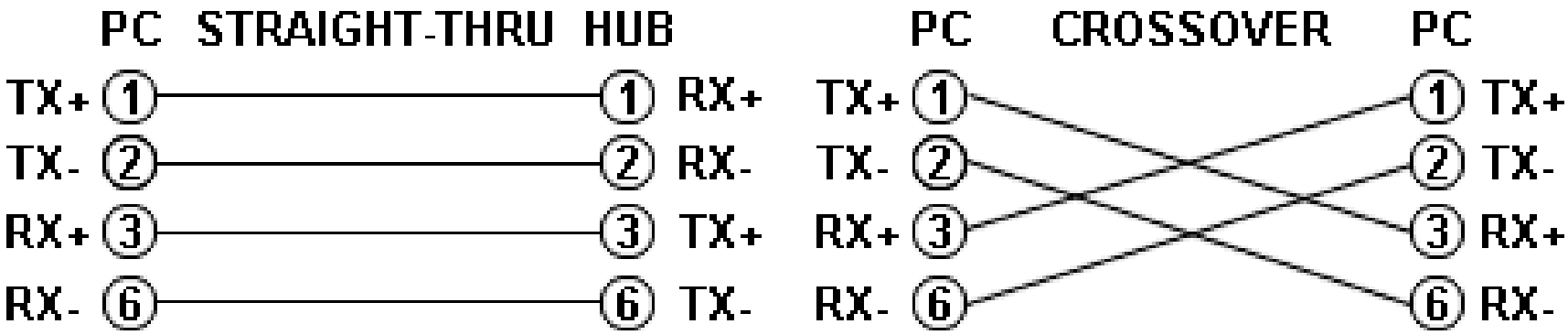
Last updated: 2/11/2000

Modular Plug Crimp Tool.

You will need a modular crimp tool. This one is very similar to the one I have been using for many years for all kinds of telephone cable work and it works just fine for Ethernet cables. You don't need a lot of bells and whistles, just a tool which will securely crimp RJ-45 connectors. This one is made by **Eclipse Enterprises, Inc.** Even though the crimper has cutters which can be used to cut the cable and individual wires, and possibly stripping the outer jacket, I find that the following tools are better for stripping and cutting the cable...

Universal UTP Stripping Tool (Eclipse). I recently bought one of these tools and it works slick, and it makes a much neater cut. I recommend that you purchase one if you will be making many cables.

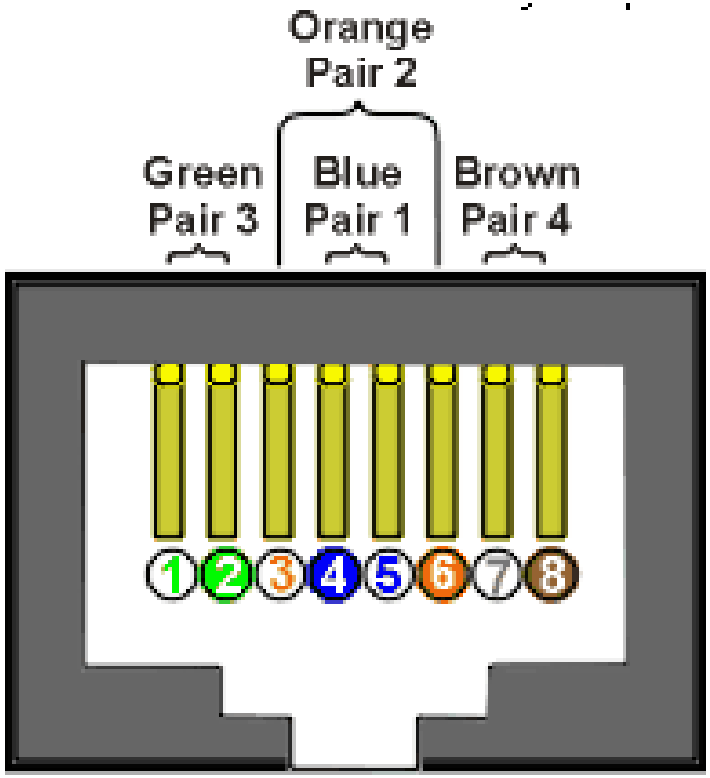
COLOR-CODE STANDARDS



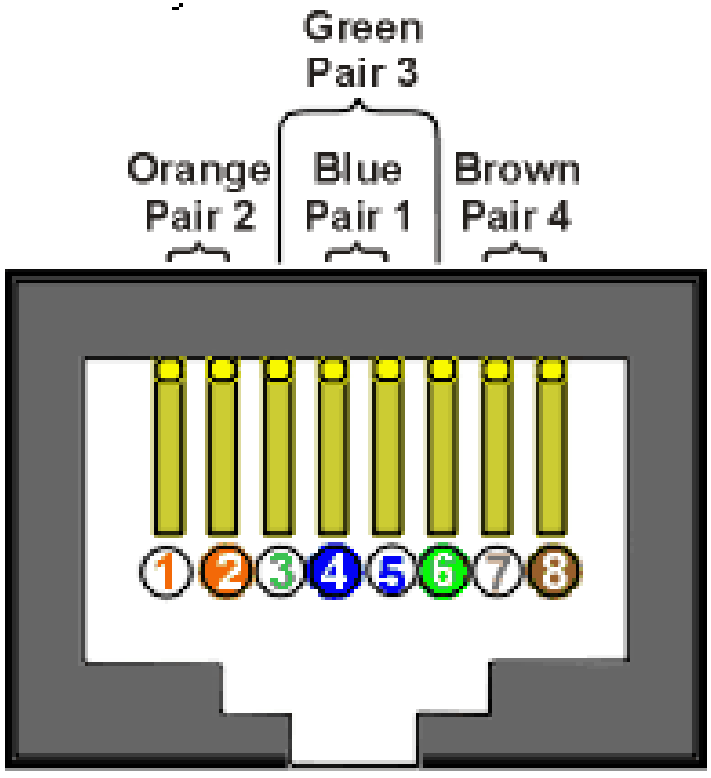
Note that the TX (transmitter) pins are connected to corresponding RX (receiver) pins, plus to plus and minus to minus.

And that you must use a cossover cable to connect units with identical interfaces. If you use a straight-through cable, one of the two units must, in effect, perform the cross-over function.

Two wire color-code standards apply: EIA/TIA 568A and EIA/TIA 568B. The codes are commonly depicted with RJ-45 jacks as follows

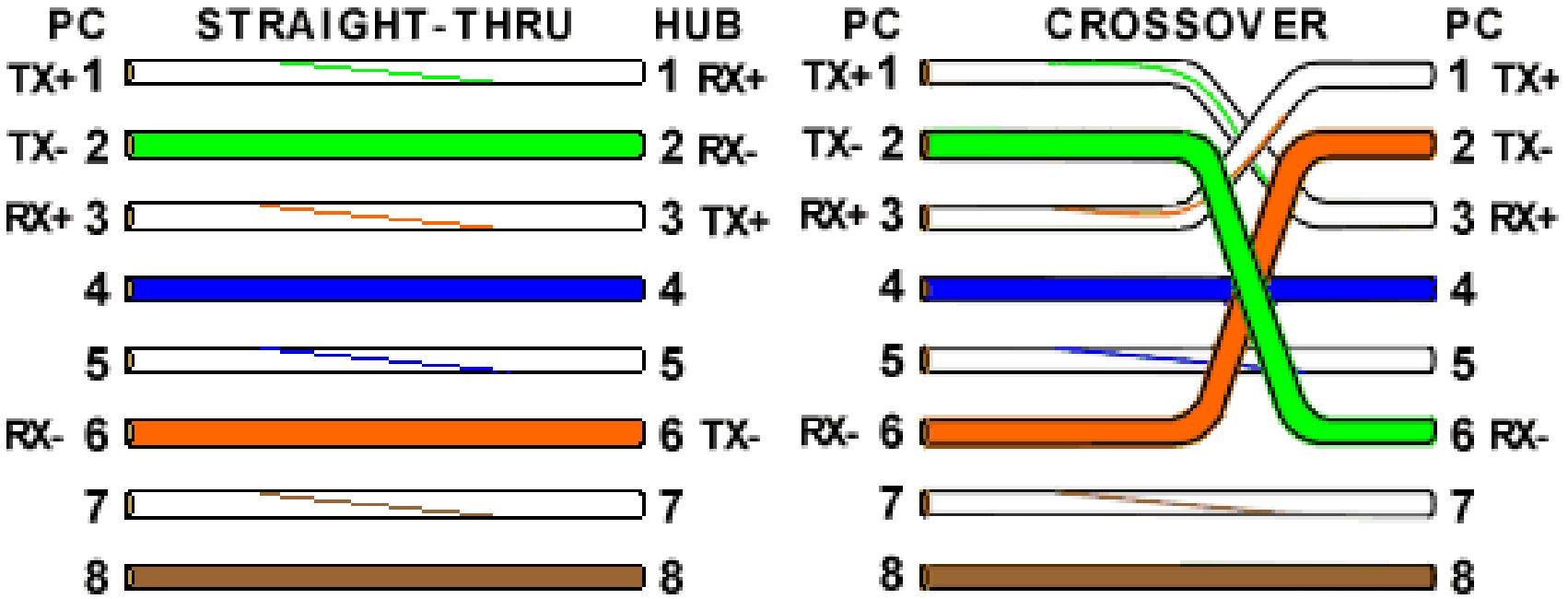


RJ-45 JACK
EIA/TIA 568A STANDARD



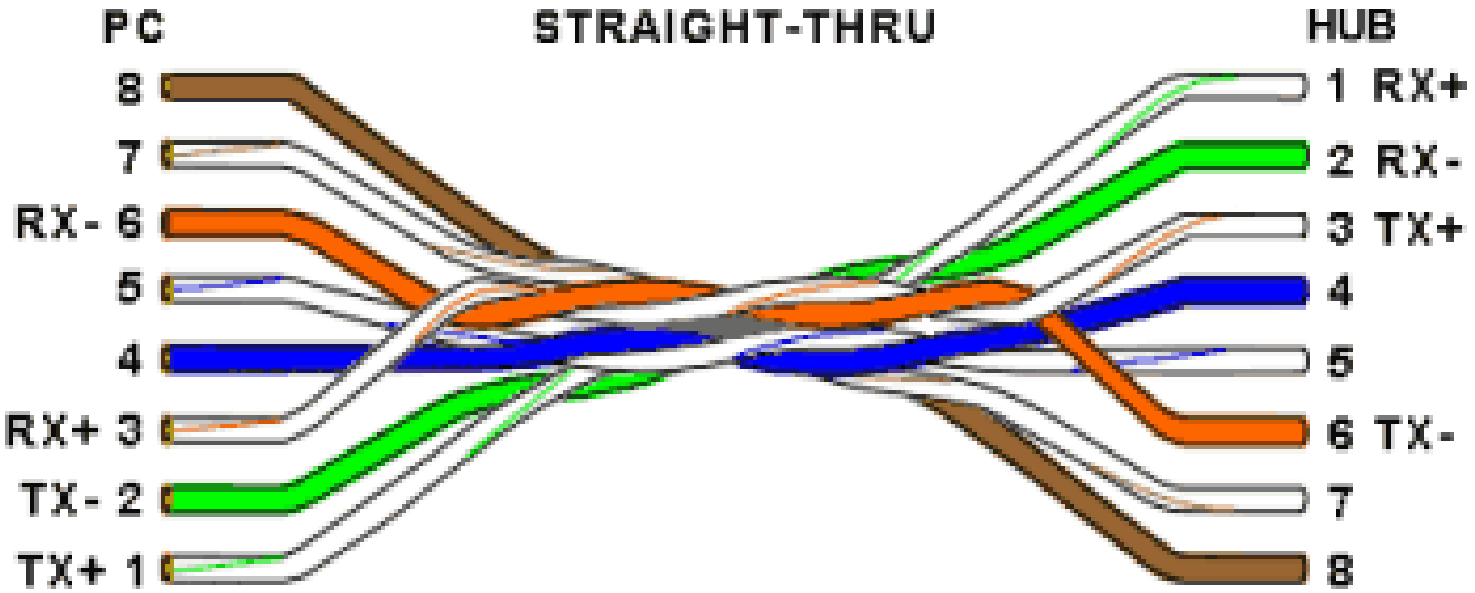
RJ-45 JACK
EIA/TIA 568B STANDARD

If we apply the 586A color code and show all eight wires, our pin-out looks like this



Note that pins 4, 5, 7, and 8 and the blue and brown pairs are not used in either standard. Quite contrary to what you may read elsewhere, these pins and wires are not used or required to implement 100BASE-TX duplexing--they are just plain wasted

the actual cables are not physically that simple. In the diagrams, the orange pair of wires are not adjacent. The blue pair is upside-down. The right ends match RJ-45 jacks and the left ends do not. If, for example, we invert the left side of the 586A "straight"-thru cable to match a 586A jack--put one 180° twist in the entire cable from end-to-end--and twist together and rearrange the appropriate pairs, we get the following can-of-worms



This further emphasizes, I hope, the importance of the word "twist" in making network cables which will work.

You cannot use an flat-untwisted telephone cable for a network cable.

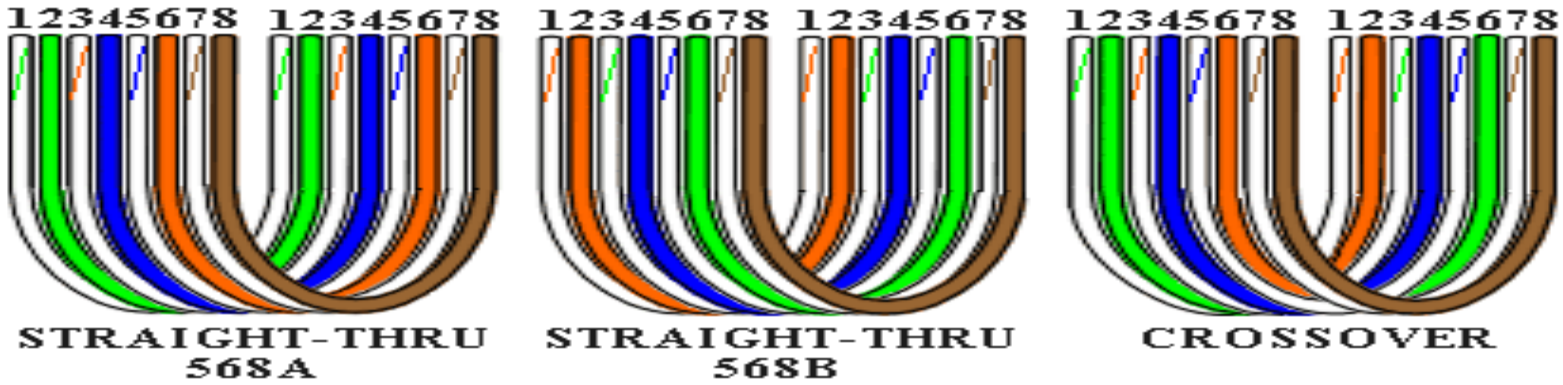
Furthermore, you must use a pair of twisted wires to connect a set of transmitter pins to their corresponding receiver pins.

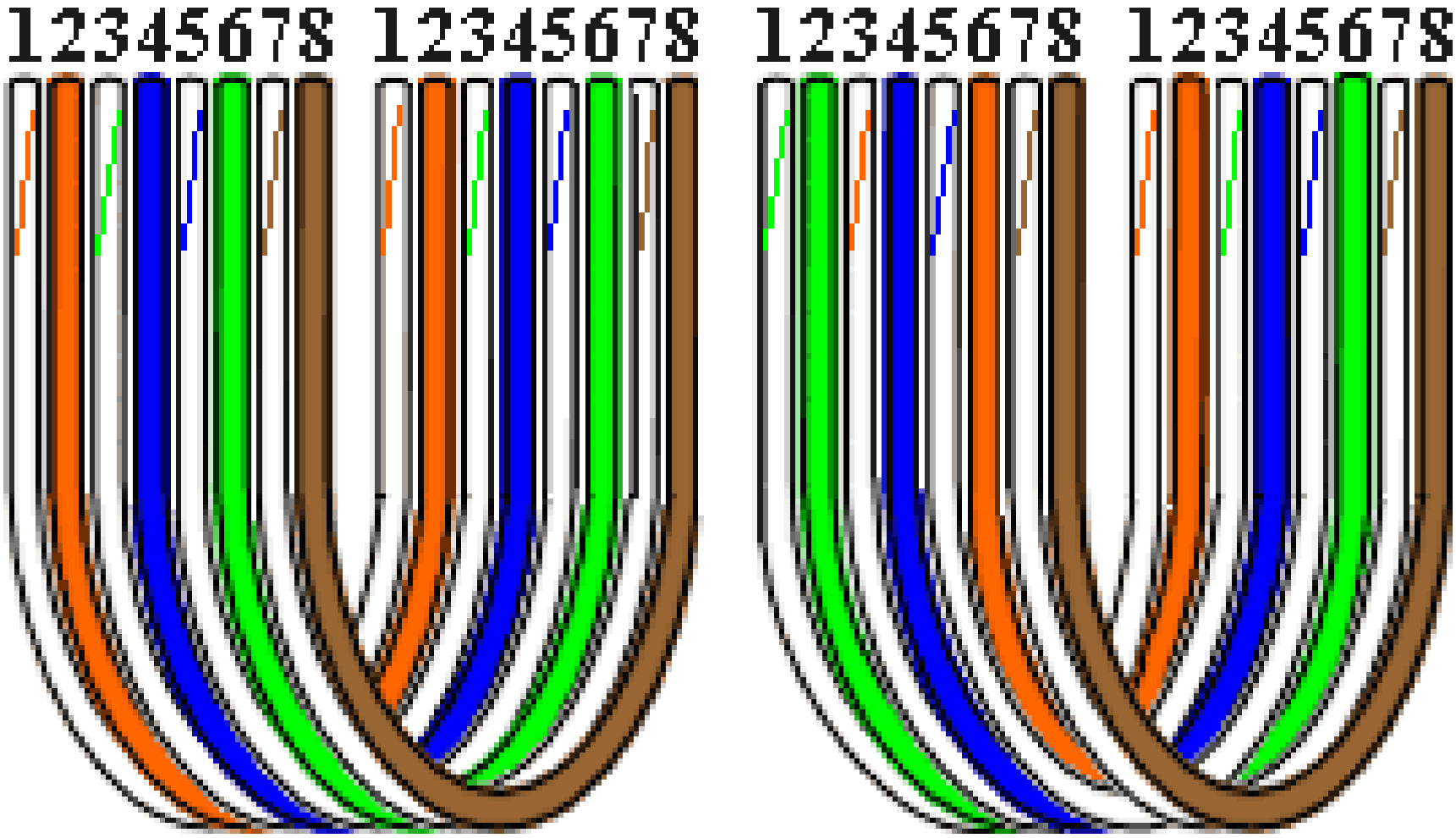
You cannot use a wire from one pair and another wire from a different pair

Keeping the above principles in mind, we can simplify the diagram for a 568A straight-thru cable by untwisting the wires, except the 180° twist in the entire cable, and bending the ends upward.

Likewise, if we exchange the green and orange pairs in the 568A diagram we will get a simplified diagram for a 568B straight-thru cable.

If we cross the green and orange pairs in the 568A diagram we will arrive at a simplified diagram for a crossover cable

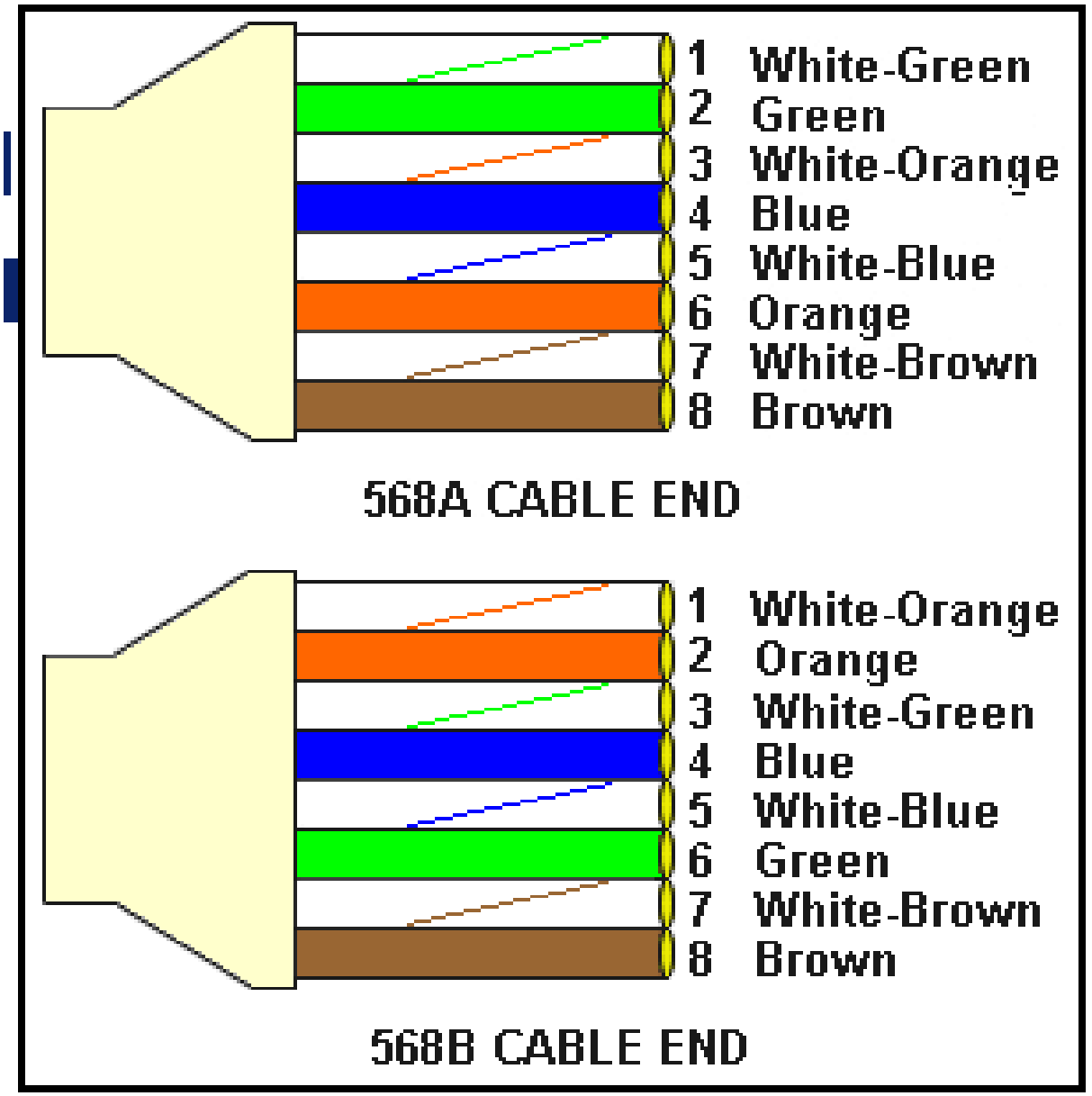




STRAIGHT-THRU
568B

CROSSOVER

There are only two unique cable ends in the preceding diagrams. They correspond to the 568A and 568B RJ-45 jacks and are shown to the right



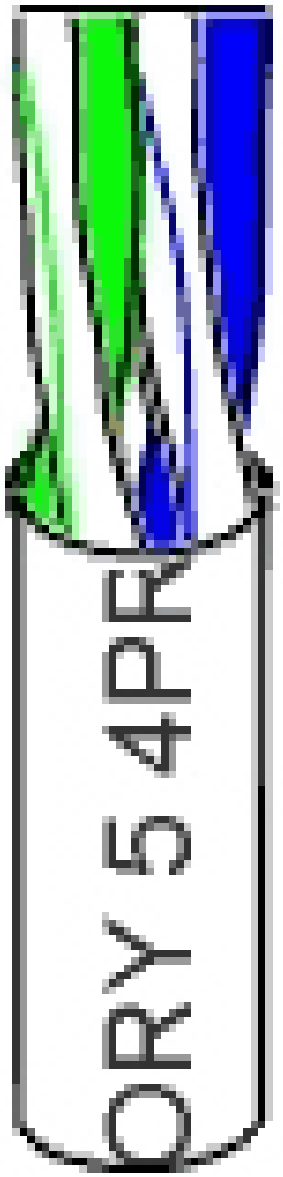
Now, all you need to remember, to properly configure the cables, are the diagrams for the two cable ends and the following rules:

- **A straight-thru cable has identical ends.**
- **A crossover cable has different ends.**

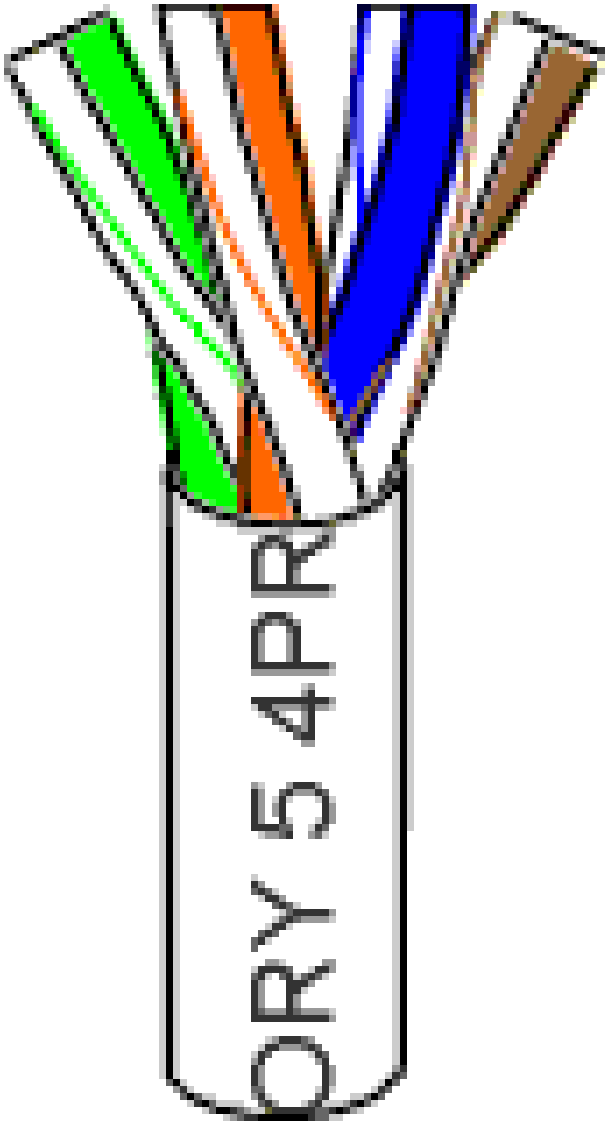
It makes no functional difference which standard you use for a straight-thru cable. You can start a crossover cable with either standard as long as the other end is the other standard. It makes no functional difference which end is which. Despite what you may have read elsewhere, a 568A patch cable will work in a network with 568B wiring and 568B patch cable will work in a 568A network. The electrons couldn't care less.

LET'S MAKE SOME CABLES

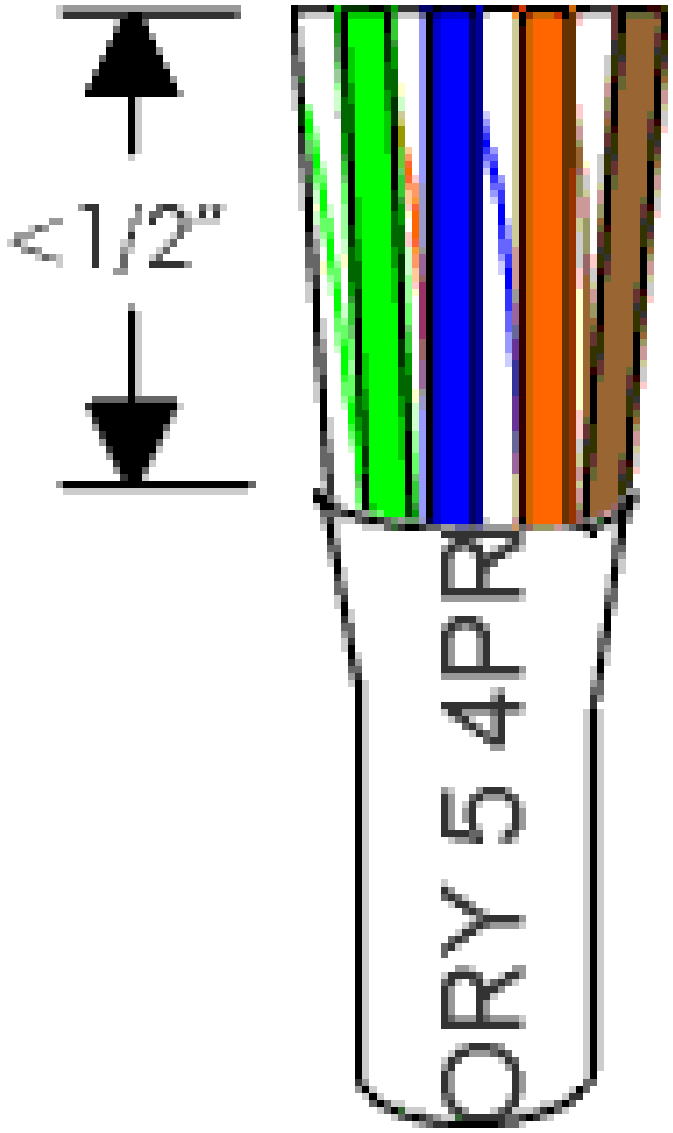
Strip one end of the cable with the stripper or a knife and diags. If you are using the stripper, place the cable in the groove on the blade (left) side of the stripper and align the end of the cable with the right side of the stripper. This will strip about 1/2" of the jacket off the cable. Turn the stripper about 1 1/4 turns and pull. If you turn it more, you will probably nick the wires. If you are using a knife and diags, carefully slit the cable for about an inch or so and neatly trim around the circumference of the cable with diags to remove the jacket.



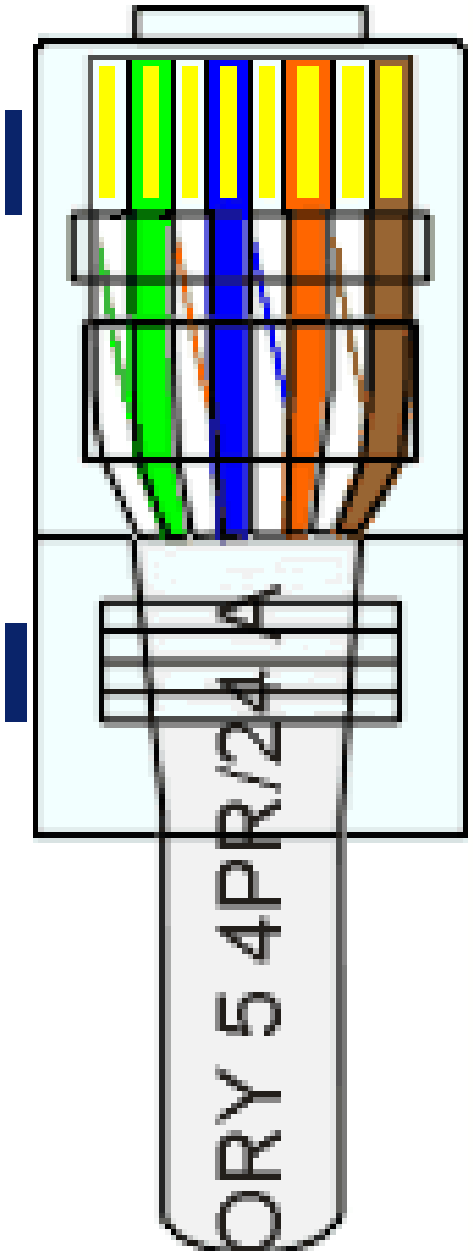
Spread and arrange the pairs roughly in the order of the desired cable end.



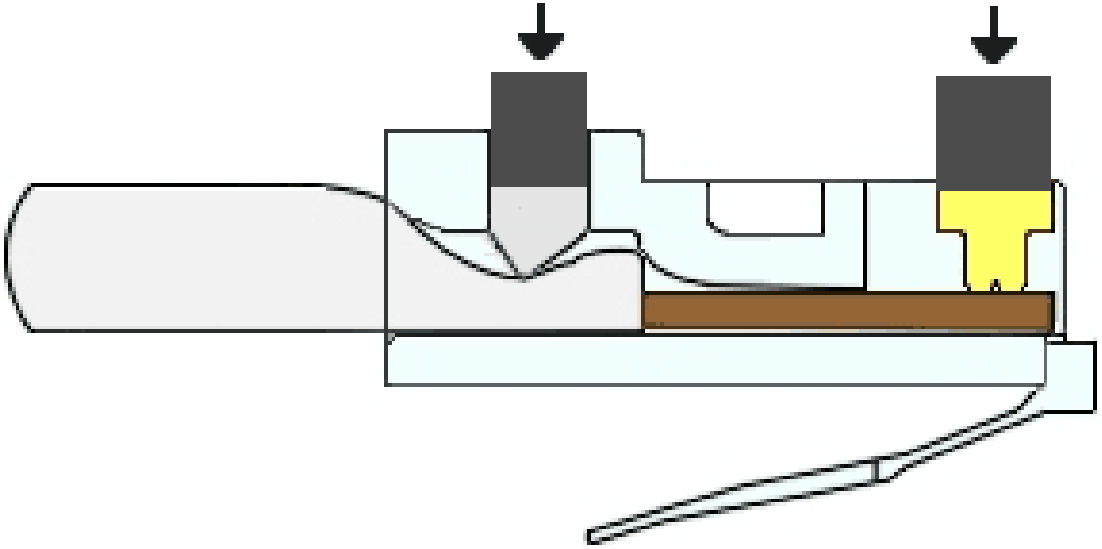
Untwist the pairs and arrange the wires in the order of the desired cable end. Flatten the end between your thumb and forefinger. Trim the ends of the wires so they are even with one another. **It is very important that the unstripped (untwisted) end be slightly less than 1/2" long.** If it is longer than 1/2" it will be out-of-spec and susceptible to crosstalk. If it less than slightly less than 1/2" it will not be properly clinched when RJ-45 plug is crimped on.. Flatten again. There should be little or no space between the wires.



Hold the RJ-45 plug with the clip facing down or away from you. Push the wire firmly into the plug. **Now**, **inspect the darn thing... before crimping and wasting the plug!** Looking through the bottom of the plug, the wire on the far left side will have a white background. The wires should alternate light and dark from left to right. The furthest right wire is brown. The wires should all end evenly at the front of the plug. The jacket should end just about where you see it in the diagram--right on the line.



Hold the wire near the RJ-45 plug with the clip down and firmly push it into the left side of the front of the crimper (it will only go in one way). Hold the wire in place squeeze the crimper handles quite firmly



CABLING RULES

1. Try to avoid running cables parallel to power cables.
2. Do not bend cables to less than four times the diameter of the cable.
3. If you bundle a group of cables together with cable ties (zip ties), do not over-cinch them. It's okay to snug them together firmly; but don't tighten them so much that you deform the cables.

4. Keep cables away from devices which can introduce noise into them. Here's a short list: copy machines, electric heaters, speakers, printers, TV sets, fluorescent lights, copiers, welding machines, microwave ovens, telephones, fans, elevators motors, electric ovens, dryers, washing machines, and shop equipment.

5. Avoid stretching UTP cables (the force should not exceed 25 LBS).
6. Do not run UTP cable outside of a building. It presents a very dangerous lightning hazard!
7. Do not use a stapler to secure UTP cables. Use telephone wire hangers which are available at most hardware stores.