Computer Networks and Internets, 5e
Chapter 7
Transmission Media

Modified from the lecture slides of Lami Kaya
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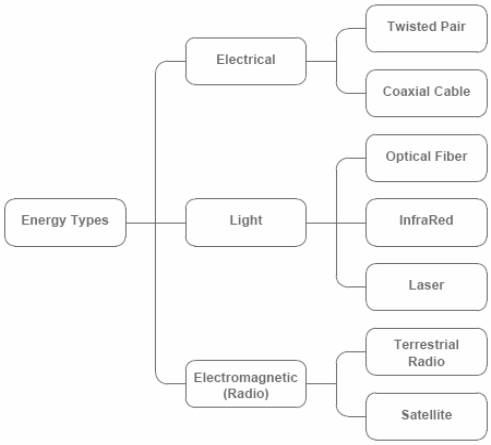
Guided and Unguided Transmission

- How should we categorize transmission media?
- Two broad approaches:
  - Type of path: communication can follow an exact path such as a wire, or can have no specific path, such as a radio transmission
  - Form of energy: electrical energy is used on wires, radio transmission is used for wireless, and light is used for optical fiber
- We use the terms guided (wired) and unguided (wireless) transmission to distinguish between physical media
  - Term wired is used even when the physical medium is an optical fiber

A Taxonomy by Forms of Energy

- Figure 7.1 illustrates how physical media can be classified according to the form of energy used to transmit data.
- Like most taxonomies, the categories are not perfect and exceptions exist.
  - For example: a space station in orbit around the earth might employ non-terrestrial communication that does not involve a satellite
- Nevertheless, our taxonomy covers most communications



Background Radiation and Electrical Noise

- Electrical current flows along a complete circuit
  - all transmissions of electrical energy need two wires to form a circuit; a wire to the receiver and a wire back to the sender
- The simplest form of wiring consists of a cable that contains two copper wires
- Each wire is wrapped in a plastic coating
  - it insulates the wires electrically
- The outer coating on the cable holds related wires together to make it easier for humans who connect equipment

Background Radiation and Electrical Noise

To understand the wiring used in Computer networks three facts must be understood:

1. Random electromagnetic radiation, called noise, permeates the environment
   - In fact, communication systems generate minor amounts of electrical noise as a side-effect of normal operation
2. When it hits metal, electromagnetic radiation produces a small signal
   - random noise can interfere with signals used for communication
3. Because it absorbs radiation, metal acts as a shield
   - Thus, placing enough metal between a source of noise and a communication medium can prevent noise from interfering

Twisted Pair Copper Wiring

There are three forms of wiring that help reduce interference from electrical noise

- Unshielded Twisted Pair (UTP)
  - also known as twisted pair wiring
- Coaxial Cable
- Shielded Twisted Pair (STP)

Twisted Pair Copper Wiring

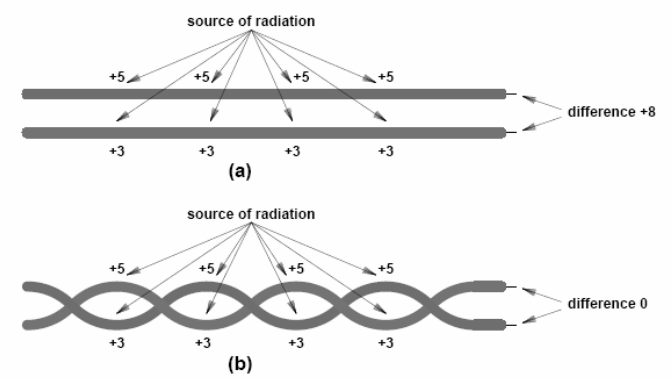


Figure 7.2 Unwanted electromagnetic radiation affecting (a) two parallel wires, and (b) twisted pair wiring.

Note: Twisting two wires makes them less susceptible to electrical noise than leaving them parallel

Twisted Pair Copper Wiring

- When two wires run in parallel:
  - there is a high probability that one of them is closer to the source of electromagnetic radiation than the other
  - one wire tends to act as a shield that absorbs some of the electromagnetic radiation
  - Thus, because it is hidden behind the first wire, the second wire receives less energy
- In the figure, a total of 32 units of radiation strikes each of the two cases
  - In Figure 7.2a,
    - the top wire absorbs 20 units, and the bottom wire absorbs 12, producing a difference of 8
  - In Figure 7.2b
    - each of the two wires is on top one-half of the time, which means each wire absorbs the same amount of radiation

Shielding: Coaxial Cable & STP

- Although it is immune to most background radiation, twisted pair wiring does not solve all problems
- Twisted pair tends to have problems with:
  - strong electrical noise, close physical proximity to the source of noise
  - high frequencies used for communication
- If the intensity is high or cables run close to the source of electrical noise, even twisted pair may not be sufficient
  - (e.g., in a factory that uses electric arc welding equipment)
  - if a twisted pair runs above the ceiling in an office building on top of a fluorescent light fixture, interference may result
- Sometimes, it is difficult to build equipment that can distinguish between valid signals and noise
  - means that even a small amount of noise can cause interference when high frequencies are used

Shielding: Coaxial Cable and STP

- Forms of wiring are available that have extra metal shielding
- The most familiar form is the wiring used for cable television
  - known as coaxial cable (coax)
  - the wiring has a thick metal shield formed from braided wires that completely surround a center (inner) wire that carries the signal
- A coaxial cable can be placed adjacent to sources of electrical noise and other cables, and can be used for high frequencies

Shielding: Coaxial Cable and STP

Figure 7.3 illustrates the concept

The shield in a coaxial cable forms a flexible cylinder around the inner wire

that provides a barrier to electromagnetic radiation from any direction

The barrier also prevents signals on the inner wire from radiating electromagnetic energy

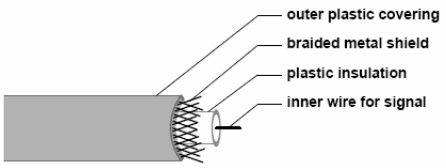


Figure 7.3 Illustration of coaxial cable with a shield surrounding the signal wire.

Shielding: Coaxial Cable and STP

- Using braided wire instead of a solid metal shield keeps coaxial cable flexible
  - but the heavy shield does make coaxial cable less flexible than twisted pair wiring
- Variations of shielding have been invented that provide a compromise
  - the cable is more flexible, but has slightly less immunity to electrical noise
- One popular variation is known as shielded twisted pair (STP)
  - The cable has a thinner, more flexible metal shield surrounding one or more twisted pairs of wires
  - In most versions of STP cable, the shield consists of metal foil, similar to the aluminum foil used in a kitchen

Categories of Twisted Pair Cable

- Standards organizations worked together to create standards for twisted pair cables used in computer networks
  - American National Standards Institute (ANSI)
  - Telecommunications Industry Association (TIA)
  - Electronic Industries Alliance (EIA)

Category	Description	Data Rate (in Mbps)
CAT 1	Unshielded twisted pair used for telephones	< 0.1
CAT 2	Unshielded twisted pair used for T1 data	2
CAT 3	Improved CAT2 used for computer networks	10
CAT 4	Improved CAT3 used for Token Ring networks	20
CAT 5	Unshielded twisted pair used for networks	100
CAT 5E	Extended CAT5 for more noise immunity	125
CAT 6	Unshielded twisted pair tested for 200 Mbps	200
CAT 7	Shielded twisted pair with a foil shield around the entire cable plus a shield around each twisted pair	600

Figure 7.4 Twisted pair wiring categories and a description of each.

Media Using Light Energy and Optical Fibers

- Three forms of media use light energy to carry information:
  - Optical fibers
  - InfraRed transmission
  - Point-to-point lasers
- Optical fiber (or fibre) is most important and widely used
- Each fiber consists of a thin strand of glass or transparent plastic encased in a plastic cover
  - Communication is uni-directional
  - One end of the fiber connects to a laser or LED used to transmit light
  - The other end of the fiber connects to a photosensitive device used to detect incoming light
- To provide two-way communication
  - two fibers are used; one to carry information in each direction

Media Using Light Energy and Optical Fibers

- Why does light travel around a bend in the fiber?
  - when light encounters the boundary between two substances
    - its behavior depends on the density of the two substances and the angle at which the light strikes the boundary
- For a given pair of substances:
  - There exists a critical angle, θ
    - measured with respect to a line that is perpendicular to the boundary
  - If the angle of incidence is exactly equal to the critical angle
    - light travels along the boundary
  - When the angle of incidence is less than θ
    - light crosses the boundary and is refracted
  - When the angle is greater than θ degrees
    - light is reflected as if the boundary were a mirror

Media Using Light Energy and Optical Fibers

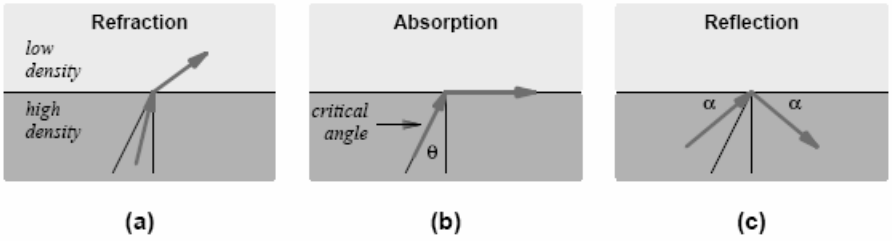


Figure 7.5 Behavior of light at a density boundary when the angle of incidence is (a) less than the critical angle θ, (b) equal to the critical angle, and (c) greater than the critical angle.

Media Using Light Energy and Optical Fibers

- Reflection in an optical fiber is not perfect
  - Reflection absorbs a small amount of energy
  - If a photon takes a zig-zag path that reflects from the walls of the fiber many times
    - the photon will travel a slightly longer distance than a photon that takes a straight path
  - The result is that a pulse of light sent at one end of a fiber emerges with less energy and is dispersed (i.e., stretched) over time
  - Dispersion is a serious problem for long optical fibers

Media Using Light Energy and Optical Fibers

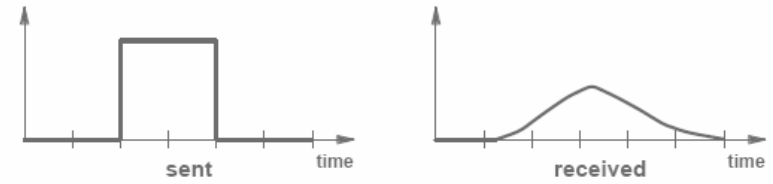


Figure 7.6 A light pulse as sent and received over an optical fiber.

Types of Fiber and Light Transmission

- Three forms of optical fibers have been invented that provide a choice between performance and cost:
  - Multimode, Stepped Index
    - the least expensive and used when performance is unimportant
    - the boundary between the fiber and the cladding is abrupt, which causes light to reflect frequently
    - dispersion is high
  - Multimode, Graded Index
    - fiber is slightly more expensive than the step index fiber
    - it has the advantage of making the density of the fiber increase near the edge, which reduces reflection and lowers dispersion
  - Single Mode
    - fiber is the most expensive, and provides the least dispersion
    - the fiber has a smaller diameter and other properties that help reduce reflection. Single mode is used for long distances and higher bit rates

Types of Fiber and Light Transmission

- Single mode fiber and the equipment used at each end are designed to focus light
  - A pulse of light can travel long distances without becoming dispersed
  - Minimal dispersion helps increase the rate at which bits can be sent
    - because a pulse corresponding to one bit does not disperse into the pulse that corresponds to a successive bit
- How is light sent and received on a fiber?
  - The key is that the devices used for transmission must match the fiber
- Transmission: LED or Injection Laser Diode (ILD)
- Reception: photo-sensitive cell or photodiode
  - LEDs and photo-sensitive cells are used for short distances and slower bit rates common with multimode fiber;
  - single mode fiber, used over long distance with high bit rates, generally requires ILDs and photodiodes

Optical Fiber Compared to Copper Wiring

- Optical fiber has several properties that make it more desirable than copper wiring
  - Optical fiber
    - is immune to electrical noise
    - has higher bandwidth
    - and light traveling across a fiber does not attenuate as much as electrical signals traveling across copper
    - Is harder to tap into
  - However, copper wiring is less expensive
  - Ends of an optical fiber must be polished before they can be used
  - Installation of copper wiring does not require as much special equipment or expertise as optical fiber
  - Copper wires are less likely to break if accidentally pulled or bent

Optical Fiber Compared to Copper Wiring

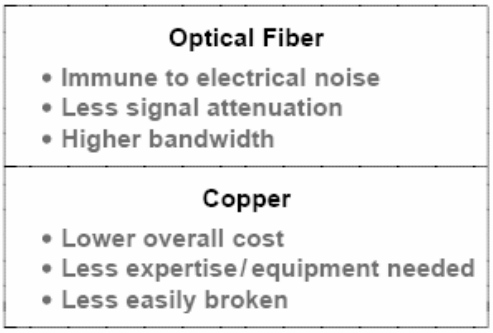


Figure 7.7 Advantages of optical fiber and copper wiring.

