Transmission Media
CIS748 Class Notes

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1 Introduction

Signals need something to travel though. The electromagnetic spectrum is filled with many different kinds of energies. The low frequencies are mostly used for power transmission, and voice (0-3kHz). Mid-range frequencies are used for radio (TV), microwaves, satellite. At around 300Ghz, energy becomes infrared light. Visible light is 430-750THz. That is then followed by Ultraviolet light, X rays, Gamma rays, etc.

In any case, the important thing is that we have different things to worry about depending on which frequencies we are dealing with.

There are two primary ways of getting signals from place to place, by using the *guided* or *unguided* media.

1.1 Guided Media

Guided media includes everything that 'guides' the transmission. That usually takes the form of some sort of a wire. Usually copper, but can also be optical fiber.

1.1.1 Twister-pair cable

One popular form of wire is the twisted pair. These are usually broken up into two major categories: Unshielded Twisted Pair (UTP), and Shielded Twisted Pair (STP).

The UTP wire is the cheapest and most common wire, which would explain why most LANs use UTP. There are several "categories" of UTP cable that have been standardized.

1. Category 1: Basic twisted pair; used for the old telephone system. Unsuitable for data communications (unless very low-speed).

2. Category 2: Better than Category 1. Suitable for data communications up to 4Mbps.

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3. Category 3: Required to have at least 3 twists per foot, and can be used for data communications up to 10Mbps. Modern telephone wire.

4. Category 4: Improved version of Category 3, can be used for data communications up to 16Mbps.

5. Category 5: Can be used for data transmission of up to 100Mbps.

The STP cable has a foil of metal mesh covering the pair of wires, eliminating crosstalk, etc.

1.1.2 Coaxial cable

Commonly known as *coax* carries a signal at much higher frequencies than twisted pair. Instead of having two wires, there is a primary 'core' wire in the center, with an insulator, and an outer conductor that serves as a shield and insulator. Cable TV uses Coaxial Cable. There are a few standards:

1. RG-8: Used in Thick Ethernet.

2. RG-9: Used in Thick Ethernet.

3. RG-11: Used in Thick Ethernet.

4. RG-58: Used for Thin Ethernet.

5. RG-59: Used for TV.

The standards generally describe different thickness of the wire. The usual wire used for cable TV would be considered 'thin'.

1.1.3 Fiber-Optic cable

There are many different kinds of fiber wires, as well as many different ways of sending data through them. The whole concept is that light tends to bend or reflect when hitting something of different density. For example, light tends to refract when hitting a pool of water; the same light, if hitting the pool at a different angle, might make the water appear like a mirror (will reflect instead of refract).

The same thing happens if you have two glass (or plastic) layers of different densities. In fiber optic cable, you have an inner 'core' of glass (or plastic) of higher density, and an outer layer (cladding) of lower density glass (or plastic).

Propagation Modes: There are several ways of arranging the wire:

- Multimode, step-index: The thick inner core of glass of constant density is surrounded by cladding of lower density. When the beam hits the cladding, it is reflected.

- Multimode, graded-index: Instead of just having high density and low density, the graded-index has many 'steps' of densities. The effect is more of bending the light beam as opposed to a sudden reflection of light.
- Singlemode: Thin high density fiber surrounded by lower density cladding. Angle of incidence is such that the transmission travels in nearly a straight line.

1.2 Unguided Media

Unguided media is still 'media' (stuff that signal travels though). The trick is that the media is usually not directional, like air, space, etc. Because the effect is usually much wider than with guided media, there have been a lot of regulation, licensing, and standardization of transmissions via unguided media. The range spans:

1. VLF, 3kHz-30kHz, Very Low Frequency. Used for surface propagation.
2. LF, 30kHz-300kHz, Low Frequency. Used for surface propagation.
3. MF, 300kHz-3MHz, Middle Frequency. Used for Tropospheric propagation.
4. HF, 3MHz-30MHz, High Frequency. Used for Ionospheric propagation.
5. VHF, 30MHz-300MHz, Very High Frequency. Used for Space and Line-of-sight propagation.
6. UHF, 300Mhz-3GHz, Ultra High Frequency. Used for Space and Line-of-sight propagation.
7. SHF, 3GHz-30GHz, Super High Frequency. Used for Space propagation.
8. EHF, 30GHz-300GHz, Extremely High Frequency. Used for Space propagation.

Depending on the frequency used, there are different propagation modes.

- Surface Propagation: The transmission travels near the ground, hugging the earth.
- Tropospheric Propagation: Either line of sight, or bounding off the signal via Ionosphere.
- Ionospheric Propagation: Bouncing off the signal off Ionosphere.
- Line-of-sight Propagation.
- Space Propagation: signals are sent from ground to satellites, which then relay them back to earth.

1.2.1 Terrestrial Microwave

One can arrange a series of directional microwave receivers/transmitters (transceivers) to send signals over long distances (longer than line of sight).

1.2.2 Satellite Communication

To overcome to the issue of sending signals around the earth (line-of-sight), a satellite can be used to relay signals. The signal is sent to the satellite, which then transmits it to other satellites or the earth.

The most common (or useful) satellites are Geosynchronous satellites. Those orbit the earth in the same synch as the rotation of the earth—they appear to hover (very high; 22,000 miles) above the earth at the same point.

2 Distortions

There are a few distortions that can cause problems with the transmission. These were discussed in notes on signals; mentioned here just for review purposes.

2.1 Attenuation

The longer the signal travels, the more energy it loses. If not amplified (or repeated), the signal will eventually become meaningless.

We can use the decibel (dB) to calculate the loss (or gain) of power during the transmission

$$dB = 10 \log_{10}(P_r/P_s)$$

where P_r is received signal power, while P_s is the sent signal power. Note that dB will be negative if we lost power, and positive if we gained power (and exactly the same if there was no change). When a signal is amplified, dB becomes positive.

2.2 Distortion

Different frequencies travel through the medium at different speeds. A signal consisting of several different frequencies will have all of its frequencies arrive at different speeds—causing distortion of the original signal.

2.3 Noise

There are several different types of noise. Thermal noise is the 'white noise' that effects all systems all the time. Crosstalk is noise that is caused by other wires or devices in the system (like two wires next to each other). Impulse noise is a spike in the system—usually hard to eliminate.

3 Performance

3.1 Throughput

Throughput is the measure of how quickly bits travel over the media. It can be viewed as a counter on a certain point of the wire that counts number of bits that pass it per second.

3.2 Propagation Speed

Propagation Speed is the distance a bit can travel through the media in one second. For example, light can travel at 3×10^8 meters per second in a vacuum. Similar for electricity in wires. Signals travel at about 2×10^8 meters per second in coaxial cable and fiber optic cables.

3.3 Propagation Time

Propagation Time is the time required for a bit to travel through a certain distance of the medium. Obviously, it is related to Propagation Speed:

$$PropagationTime = Distance/PropagationSpeed$$