Wires and Optics

CS158a
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Outline

- Maximum Data Rate of a Channel
- Guided Transmission Media (wires and optics)

Maximum Data Rate of a Channel

- Nyquist in the 1920s derived an equation expressing the maximum data rate for a finite bandwidth noiseless channel.
- He showed if the bandwidth is H, then the filtered signal can be completely reconstructed by making 2H samples/second.
- Sampling at a higher rate won't get you any more information.
- Nyquist's Theorem says if the signal has V discrete levels then the maximum data rate is:

  maximum data rate = $2H \log_2 V$ bits/sec

- So a 3kHz channel cannot transmit binary signals at a rate exceeding 6kbps.

The Effects of Noise

- The maximum data rate gets worse if noise is present.
- The amount of noise present is measured as a ratio of the power of the signal divided by the power of the noise.
- This is called the **signal-to-noise ratio**.
- Usually, we'll use S for signal, N for noise; so this ratio is S/N.
- Typically, people quote the value $10 \log_{10} (S/N)$, rather than S/N. This values units are then given as decibels (dB).
- Shannon proved that the maximum data rate of a noisy channel of bandwidth H, signal-to-noise ratio S/N is given by: maximum number of bits/sec = $H\log_2(1+S/N)$.
- So a 3kHz bandwidth channel with a signal-to-noise ratio of 30dB (typical of the phone system), can never transmit much more than 30 kbps no matter how many signal levels are used.

Guided Transmission Media

- The purpose of the physical layer is to transport a raw bit stream from one machine to another.
- We now look various transmission media for doing this.
- Each has its own niche based on speed, price, installation cost, maintainability, etc.
- These media can be grouped into two types: **guided** (wires, fiber optics, etc) and **unguided** (radio, lasers, etc).

Magnetic Media

- One way to transport data from one machine to another is to save the data to disk, tape, flash memory, etc and then carry it between the two machines.
- This mode of transport is sometimes called **SneakerNet**.
- The book gives an example based on an Ultrium tape, which can store 200Gb.
- You could but 1000 such tapes in a box that could easily fit in the trunk of a car, giving a total capacity of 200terabytes (1.6 petabits).
- This box could be delivered anywhere in the U.S. within 24hours.
- This gives a bandwidth of 1.6x 10^{15}/86400 bit/sec, about 1.9 Gbps.
- It is also very cheap and easy to do. (Netflix for instances uses this idea)
- The main problem is the **delay** until the first bit arrives. This is 24hours.

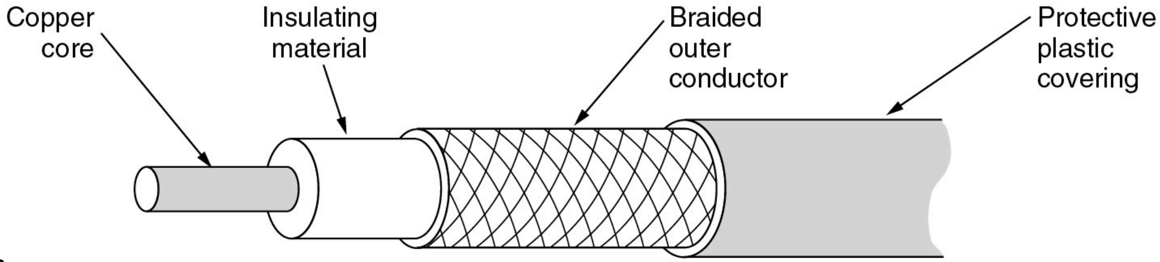
Twisted Pair

- Twisted pair wire consists of two insulated copper wires typically about 1mm thick which are twisted together.
- As a charge travels down a wire it gives off EM radiation, which is power lost.
- Twisting causes the waves that are radiated to cancel preventing the wires from radiating as effectively.
- Most telephones are connected to the phone company by twisted pair wires.
- A signal sent can be down such a wire without amplification for several kilometers. For longer distances a repeater is necessary.
- The bandwidth of these wires is on the order of megabits/sec, and they are very cheap.

Types of Twisted Pair Wires

- Category 3 - two insulated wires gentry twisted together, four such pairs grouped in a plastic sheath.
- Before 1988, most offices had one category 3 cable from a **central wiring closet** to each floor into each office.
- Category 5 - is like category 3 except the wires are more tightly twisted, giving a better signal to noice ratio.
- Category 6 and 7 cables are up and coming and offer bandwidths of 250 to 600 MHz.
- All these kinds of wires are called **UTP** (unshielded twisted pair) to distinguish them from the bulking kinds of twisted pair wires used by IBM.

Coaxial Cable



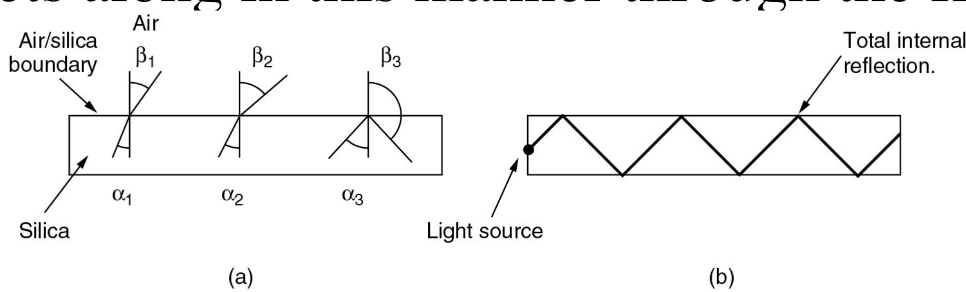
- This kind of wire has better shielding then twisted pair wires, so it can span wider distances at higher speeds.
- It is often called **coax**.
- There are two types of coax cables 50 and 75 ohm.
- 50 ohm was intended for digital transmission; whereas, 75 ohm was intended for both digital as well as analog tramsmission such as TV.
- Modern cables are capable of bandwidth around 1GHz.
- In addition to cable TV use, these cables used to be used by the phone company over long distances before fibre optics became more popular.

Fiber Optics

- This is the largest bandwidth transmission technology.
- Currently systems can operate at 10Gbps, with lab examples running at 100Gbps over a single fibre.
- Optical transmission has three components: the light source, the medium, and the detector.
- A pulse of light is used to indicate a 1, the absence of a pulse a 0.
- The transmission medium is an ultra-thin fibre of glass.
- A detector generates electrical pulses when light fall on it.

More on Fibre Optics

- Light does not leak out of the fiber because it get reflect off the sides of the fibre back into the fibre
- It ricochets along in this manner through the fiber



- Angles of incident light at which this ricochet effect will work are called **modes** of the fiber.
- You can have single as well as multi-mode fiber.
- Currently, single mode fiber can be used to get rates of up to 50 Gbps over 100km.