Week 2 – Physical Layer

COMP nologies

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What is the Physical Layer ?

- Recall the layer hierarchy from network reference models
  - In OSI model, the physical layer is the lowest layer
  - In TCP/IP model, the physical layer's properties are in the "host-to-netw

- The physical l he **electrical, timing and mechanical inte** he network

  - Electrical: voltage levels, signal
  - Timing: data rate …
  - Mechanical: material, cable length …

Outline

- Timing aspect
  - Bandwidth and Latency
- Mechanical aspect: transmission media
  - Twisted pair
  - Co-axial
  - Fibre optics
  - Wireless: EM waves, satellites
- Electrical aspect
  - Data communication using signals
  - Digital modulation
- Capacity of a channel
  - Maximum data rate
  - Multiplexing

Link Model

- We can abstract the physical channel as a link
- Simplified Link Model: Consider the network as a connected link between computers

Link Model

- **Bandwidth** is usually treated as the rate of transmission in bits/second.

- **Delay** is the he first bit to travel from computer A ter B.

Example

- We need about 1 kbit/sec to transmit voice.
- Bandwidth of single mode fibre can reach 1 Tbit/sec.

- How many ansmitted through a Fibre Optic C

$10^{12} / 10^{3} = 1$ billion calls

Tbit/s kbit/s

Message Latency

- Latency is the time delay associated with sending a message over a link
- This is made of up two parts

  - **Transmiss**
    - T-delay =

ransmission
    - = M/R seconds

  - **Propagation delay**
    - P-delay= length of the channel/ speed of signals
    - = Length / Speed of signal (2/3 of speed of light for wire)
  - **Latency** = L = M/R + P-delay

Example-1

- A home computer is connected to an ISP server through 56 K bps modem. Assuming a frame size of 5600 bits, compute P-Delay and T-Delay for eed of signal = 2/3 C and length of th 5 K metres.

- T-delay = 5600 (bits)/ 56 0 100 m sec
- P-delay = 5 (km)/200000 (km/s) = 0.025 m sec
- Latency = 100.025 m sec

Example-2

- Now for the previous question, assume a countrywide optical broadband link of length 1000 kms of bandwidth 100 M bits/sec. Assuming a frame size of 5600 bits, compute P-Delay and T ssume speed of signal = C =
- T-delay = 5600 (bits)/ 100 its/s) = 0.056 m sec
- P-delay = 1000 (km) /300000 (km/s) = 3.33 m sec
- Latency = 3.386 m sec

The Growth of Bandwidth

- CPU speeds increase by a factor of ~20 per decade
  - 1981: PC 4.77MHz vs. 2020: PC 4GHz
  - Current CPU speed now approaching physical limits - constrained by physical properties pertaining to granularity of engraving on s

- Bandwidth incr 5 per decade
  - 1981: Modem 56kbps
  - Current bandwidth available up to 65 Tbps - vastly exceeding the rate at which we can convert electrical impulses to optical pulses

Outline

- Timing aspect
- Mechanical aspect: transmission media
- Electrical aspect
- Capacity of a c
  - Maximum data r
  - Multiplexing

Transmission Media

- How many different types of physical media can you think of?
  - Wired: twisted pair, co-axial, fibre optics
  - Wireless: el d satellites
- Various physical media can b ansmit data, but the performance is affected by physical properties.

Signal Attenuation

- The loss or reduction in the amplitude (strength) of a signal as it passes through a medium.
- Signal attenuation impacts how far and how much data a medium can c

Image source: https://www.signalintegrityjournal.com/articles/1734-how-to-reduce-attenuation-in-a-differential-channel

Wires – Twisted Pair

- Two insulated copper wires, twisted in helical (DNA) form.
- Twisting reduces interference: canceling out electromagnetic interference from external sources
- Distance up to 5km, repeaters can extend this distance

cable with four twisted pairs

Properties and Types of Twisted Pair

- Bandwidth depends on distance, wire quality/density
- Cat 3 - 2 wires, 4 pairs in sheath, 16MHz
- Cat 5 - 2 wires, 4 pair in sheath, more twists = less interference, higher quality over longer distance, 100 MHz
- Cat 8 – 2000 MHz

bout this unit for now, just higher value is better!

Coaxial Cable (Co-ax)

- Copper core with insulation, mesh, and sheath
- Better shielding than twisted pair = higher speeds over greater distances
- Bandwidth approaches 1GHz
- Still wide ernet

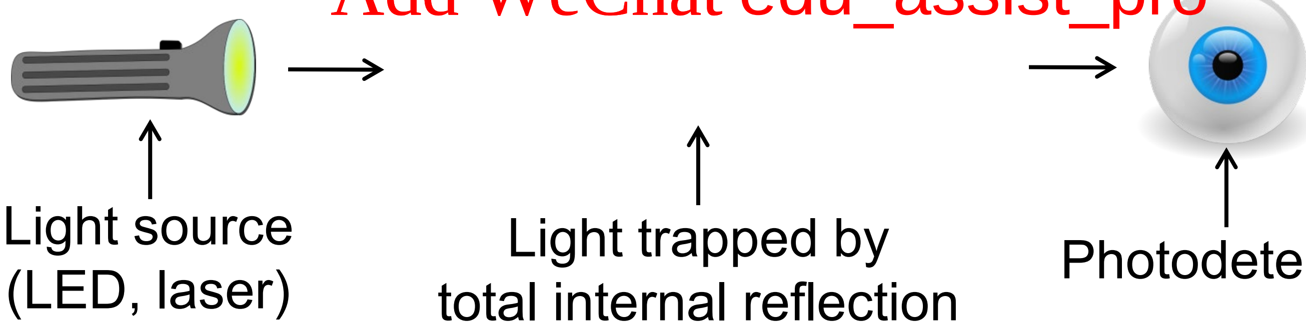
Fibre Optics

- Fibre has enormous bandwidth (THz) and tiny signal loss
- Data transmission over a fibre of glass
- Common for high rates and long distances

  - e.g. bac facilities, Fibre-to-the-H

Transmission of Light Through Fibre

- 3 components: light source, transmission medium, detector
- Semantics: light = 1, no light = 0 (basic binary system)
- Signalling using LED’s or semiconductor lasers
- A detector generates electrical pulse when light hits it
- Refraction bet mpensated for by design - total i



Fibre Optic Cables

Single-mode

- Narrow core (10um), light can't even bounce around
- Used with lasers for long distances, e.g., 100km

Multi-mode

- 50um core, light can bounce
- Used with LEDs for cheaper, shorter distance links

Fibre Optic Connections

- Connectors and Fibre Sockets (10-20% loss)
- Mechanical Splice (10% loss)
- Fusion (<1% loss)

Example: mechanical splice

Fibre Optic Networks

- Fibre optic cable is a scalable network media - LAN, WAN, long distances
- Fibre optic cable networks can be organised either as a ring or as a bu t-to-point connections)

Fibre Optic Ring

Comparison: Wires and Fibre

Comparison of the properties of wires (i.e. twisted pairs and co-ax cable) and fibre:

Property	**Wires**	**Fibre**
Distance		ong (tens of km)
Bandwidth		ery High
Security	Easy to tap	d to tap
Cost	Inexpensive	re Expensive
Convenience	Easy to use	Harder to use