Week 2 – Physical Layer

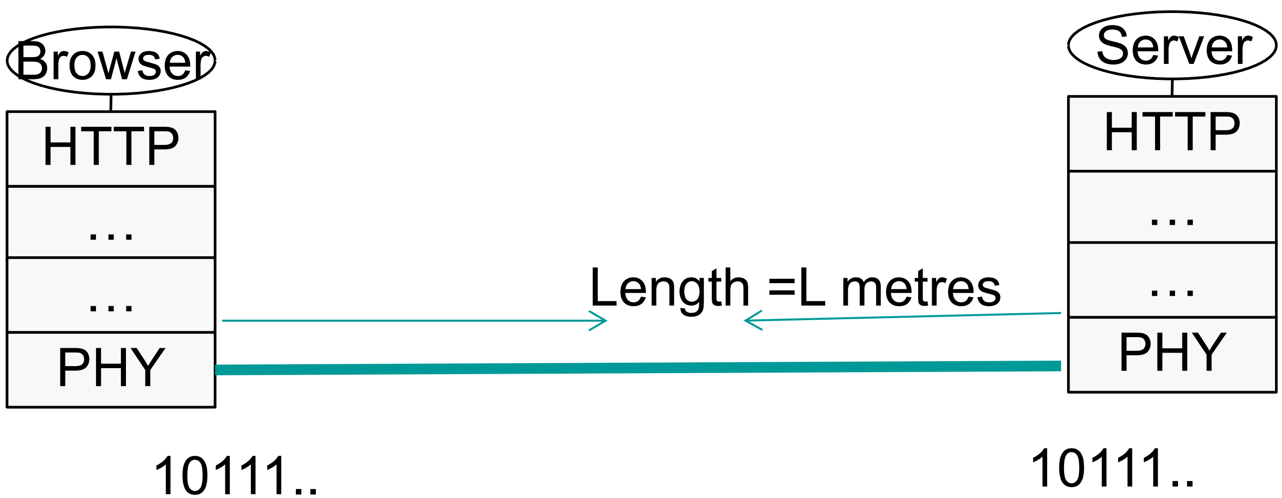
COMP90007
Internet Technologies

What is the Physical Layer

- Recall the layer hierarchy from network reference models
  - The **physical layer** is the lowest Layer in OSI model
  - The physical layer’s properties in TCP/IP model are in the **“host-to-network**” division
- The physical layer is concerned with the mechanical, electrical and timing interfaces of the network
- Various physical media can be used to transmit data, but all of them are affected by a range of physical properties and hence have distinct differences

First: What is a Link

- We can abstract a physical channel as a link
- We use a simplified link model: Considering the network has a connected link between two computers although reality may be more complex



Link Model Contd

- **Bandwidth** is usually treated as rate of transmission in bits/second
- **Delay** (in seconds) is the time required for the first bit to travel from the first computer A to the second, computer B

Examples

- We need about 1 kbit/sec to transmit voice.
- Bandwidth of single mode fibre can reach 1 Tbit/sec.
- How many voice calls can be transmitted through an Fiber Optic Cable?

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
- Made of up two parts related to the link model:
  - **Transmission delay**:
    - T-delay = Message in bits / Rate of transmission
    - = M/R seconds
  - **Propagation delay**
    - P-delay= length of the channel / speed of signals
    - Length / Speed of signal (e.g. 2/3 of speed of light for wire)
- **Latency** = L = T-delay + 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 the link. Assume speed of signal = 2/3 C and length of the link is 5 K metres.
- T-delay = 5600 (bits) / 56 000 (kbps) = 100 msec
- P-delay = 5 (km) / 200000 (km/s) = 0.025 msec
- Latency = 100.025 msec

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-Delay for the link. Assume speed of signal = C = 300000 km/sec.
- T-delay = 5600 (bits) / 100 000 000 (bits/s) = 0.056 msec
- P-delay = 1000 (km) / 300000 (km/s) = 3.33 msec
- Latency = 3.386 msec

Fun Fact: Thinking on Networks for Very Large Data Transfer

- While networks are increasingly becoming the default means by which data is transferred, there are other options for data transfer – consider removable media such as tapes, CD ROMs, DVDs, USBs
  - Cost-wise, such removable media are often more efficient on a per Mb/Gb basis
  - Why?

Fun Fact Contd.

- …using such media to transfer data introduces a significant delay but as they say “never underestimate the bandwidth of a car boot full of DVD’s”:
  - 1000 DVD’s x 4300Mb at 100km/h over distance of 100 kms = 4.3Tb / hr or 1.2 Gbps, not bad!
  - At $5/DVD, plus say $20,000 for the car, that’s $25,000 for a 1.2 Gbps data transfer over 100kms - to build a 1 Gbps network over 100km costs in the order of $1 million, so for a one time transfer, it’s better to use a car!

- Basically: Data transfer over a network is not always the most efficient method to use for extremely large data such as archival scientific data

The Bandwidth Revolution

- Evolutionary steps in available bandwidth:
  - CPU speeds increased by a factor of ~20 per decade
    - PC: 1981: 4.77Mhz vs 2001: 2 Ghz vs today: 5GHz
- Bandwidth speeds increase by a factor of ~125 per decade (1981: Modem 56kbps vs 2001: Net 1Gbps)
- Current CPU speed now at physical limits - constrained by physical properties pertaining to granularity of engraving on silicon. More power through more cores (e.g. GPU)
- Current bandwidth available up to 50Tbps - vastly exceeding the rate at which we can convert electrical impulses to optical pulses… thus bandwidth is no longer the bottleneck for many applications…

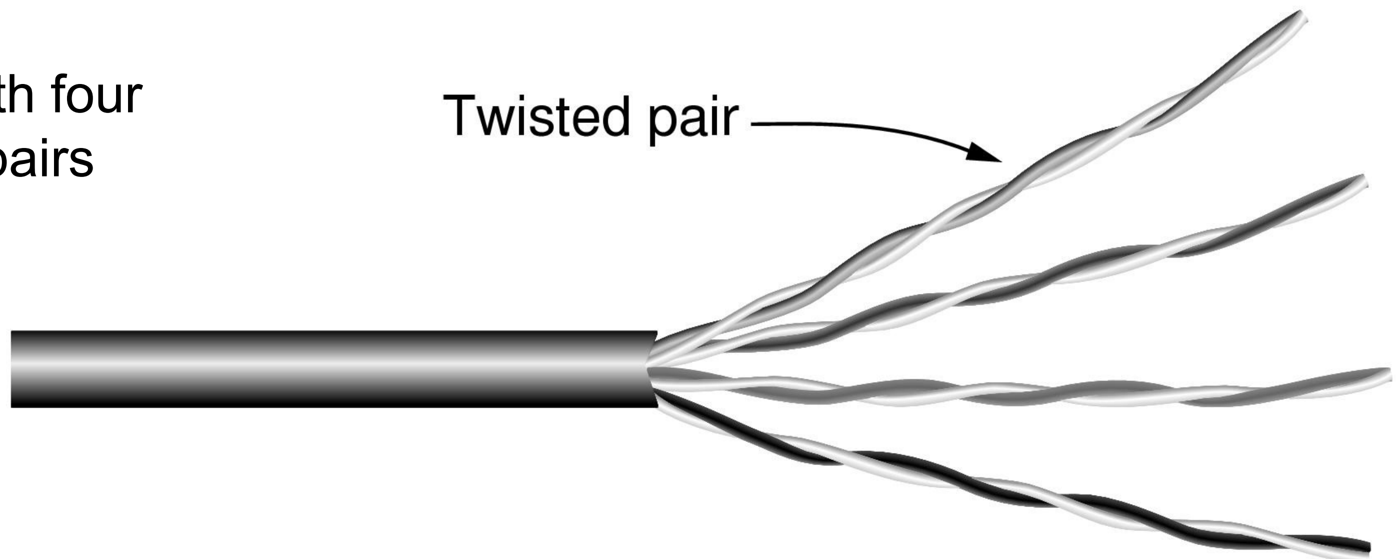
Lets start with simple concepts: Signal Attenuation

- How far and how much data a medium can carry has a lot to do with signal attenuation:
  - **Attenuation** is the loss or reduction in the amplitude (strength) of a signal as it passes through a medium.
  - Example is electricity over a simple cable.

Simplest of Wires – Twisted Pair

- Two insulated copper wires, twisted in helical (DNA) form.
- Twisting reduces radiance of waves from effectively parallel antennae
- Distance up to <5km, repeaters can extend this distance (large buildings often have km's of cabling)
- twisting reduces interference

cable with four twisted pairs



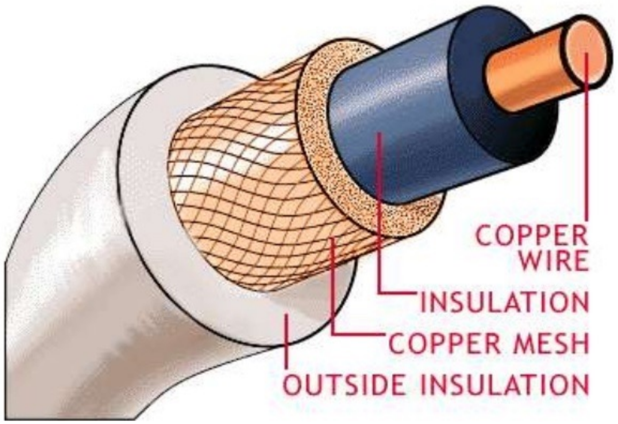
Properties and Types of Twisted Pair

- Bandwidth dependents 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 6 - 250 Mhz
- Cat 7…
- Note that bandwidth for cables is given with Mhz which we will come back to later…

Coaxial Cable (“Co-ax”)

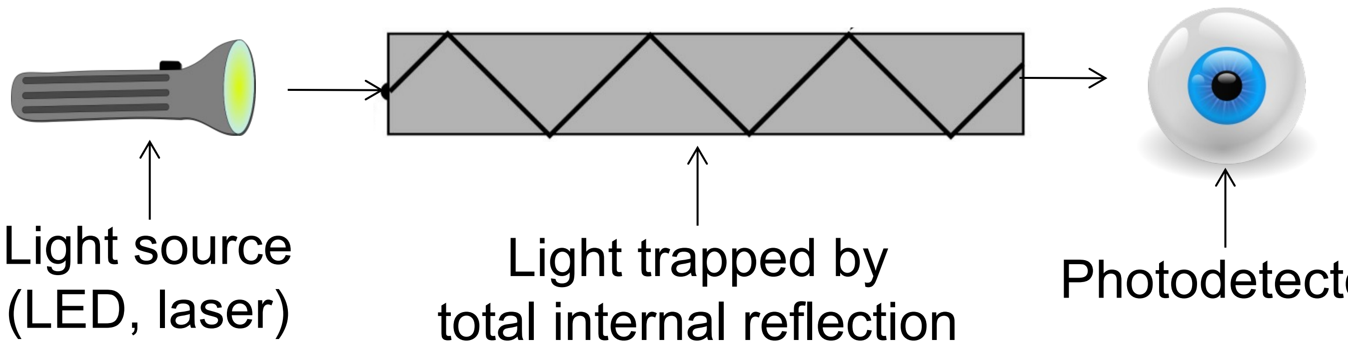
- Better shielding than twisted pair = higher speeds over greater distances
- Copper core with insulation, mesh, and sheath
- Bandwidth approaches **1Ghz**
- Still widely used for cable TV/Internet

A diagram of a coaxial cable



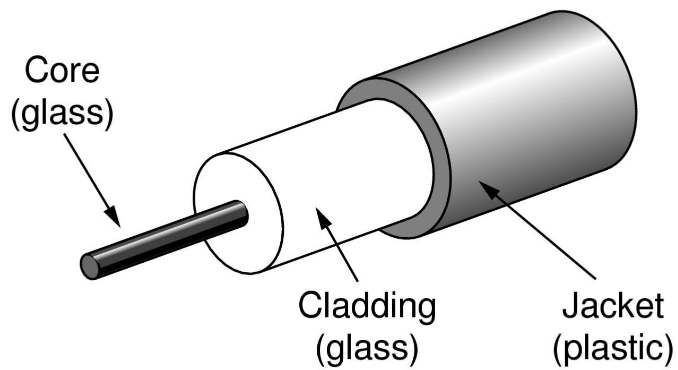
Fiber Optics

- Optical transmission has 3 components: light source, transmission medium, detector
- Base Semantics: light = 1, no light = 0 (basic binary system)
- Can also modulate the magnitude of the light
- Data transmission over a fibre of glass
- A detector generates electrical pulse when light hits it
- Common for high rates and long distances



Transmission of Light Through Fibre

Fiber has enormous bandwidth (**THz**) and tiny signal loss – *hence* high rates over long distances and increasingly a popular choice…



More on Fiber Optic Cables

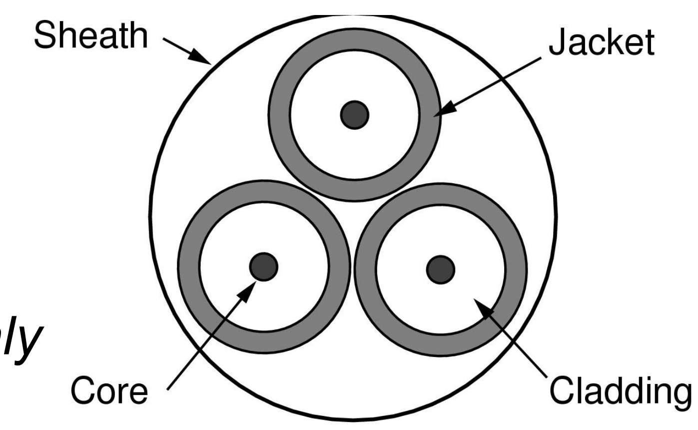
Single-mode

- Core so narrow light can't even bounce around
- Used with lasers for long distances, e.g., 100km

Multi-mode

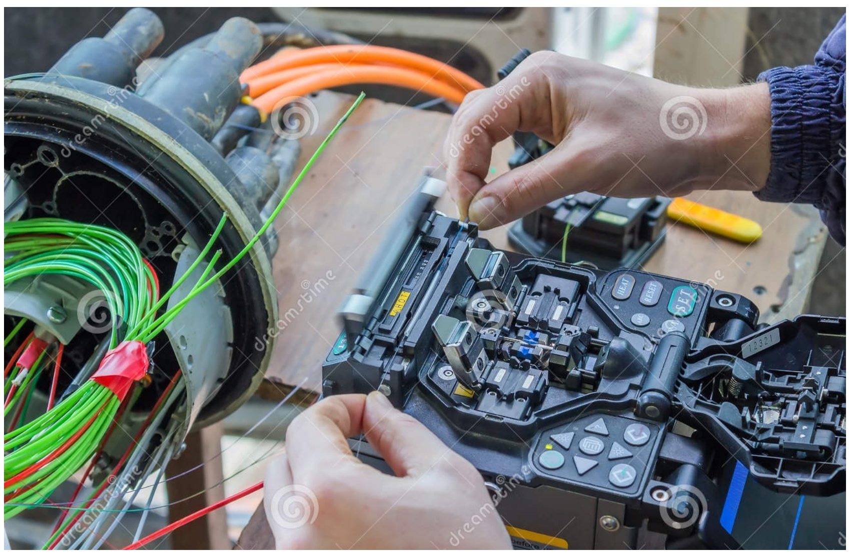
- Other main type of fiber
- Light can bounce
- Used with LEDs for cheaper, shorter distance links

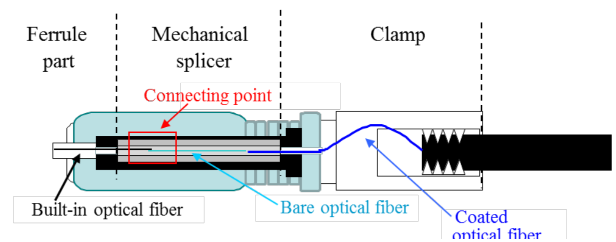
They come in bundles commonly



Fiber Optic Connections

- Connectors and Fiber Sockets (10-20% loss, but easy to configure)
- Mechanical Splice (10% loss, labour intensive)
- Fusion (<1% loss, but very specialised)

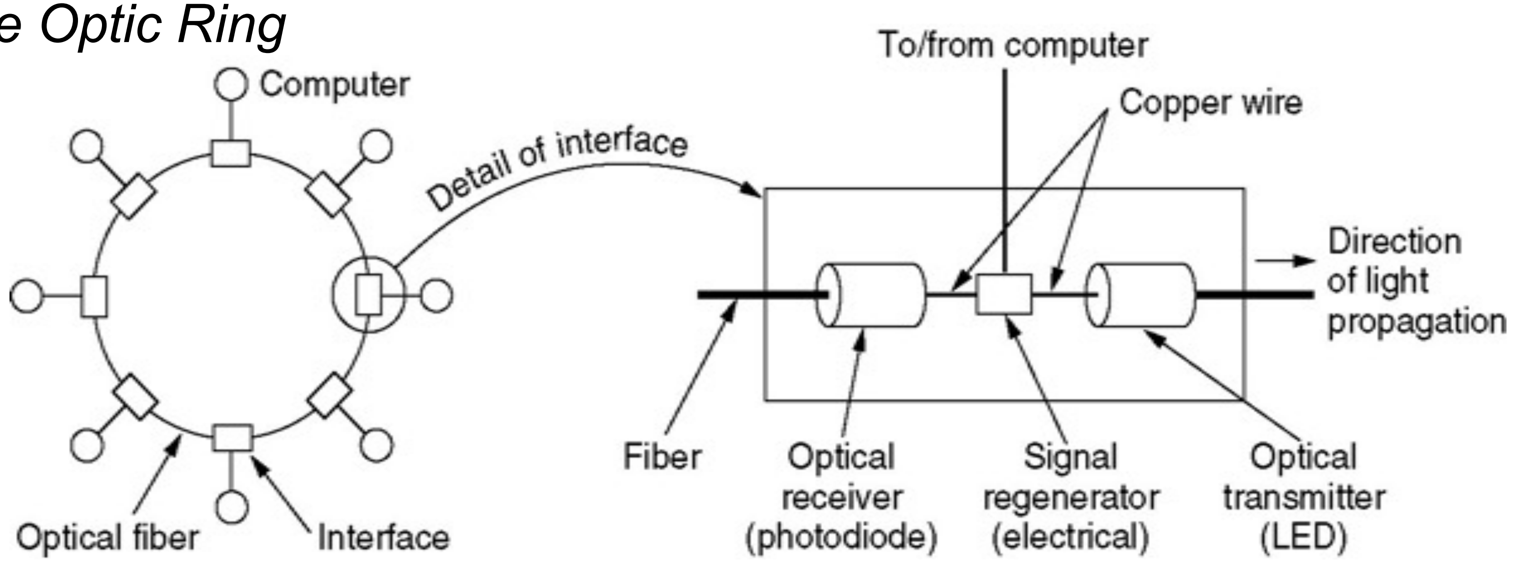




Fiber Optic Networks Contd.

- Fiber optic cable is a scalable network media - LAN, WAN, etc
- Fibre optic cable can be considered either as a ring or as a bus network type (series of point to point connections)

Fibre Optic Ring



Comparison: Wires and Fiber

Comparison of the properties of wires and fiber:

Property	Wires	Fiber
Distance	Short (100s of m)	Long (tens of km)
Bandwidth	Moderate	Very High
Cost	Inexpensive	More Expensive
Convenience	Easy to use	Harder to use
Security	Easy to tap	Hard to tap