Week 2 – Physical Layer (1)

COMP90007

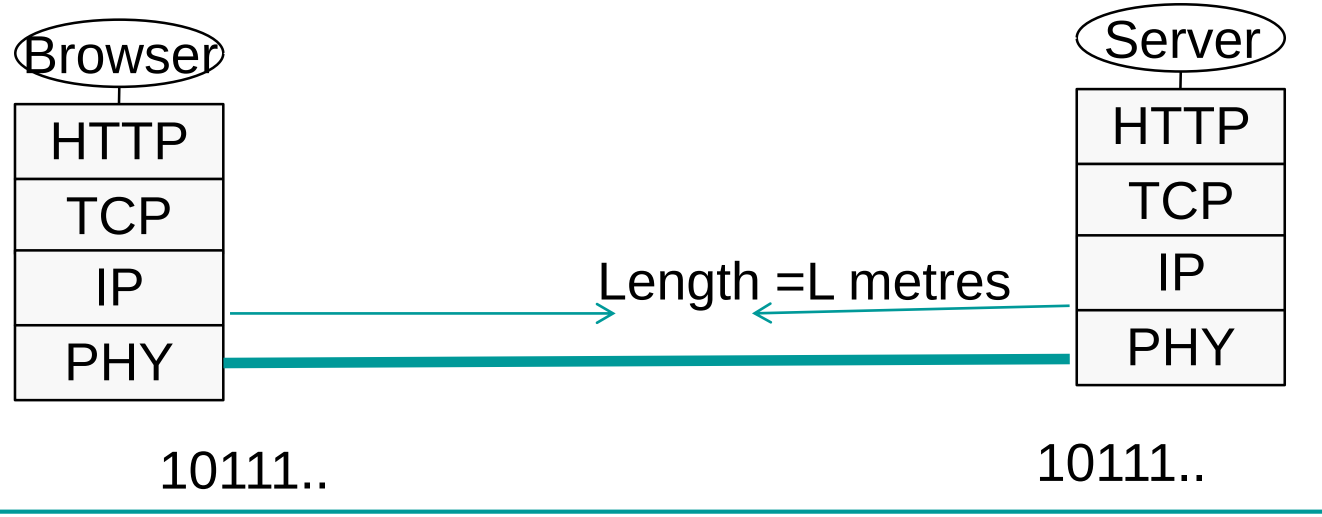
Internet Technologies

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
- How many different types of physical media can you think of?

Link Model

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



Link Model

- ***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 computer A to computer B.

Example

- 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 Fibre Optic Cable?

Message Latency

- Latency is the time delay associated with sending a message over a link
- This is made of up two parts
  - 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 (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 the link. Assume speed of signal = 2/3 C and length of the link is 5 K metres.
- T-delay =
- P-delay =
- Latency =

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 =
- P-delay =
- Latency =

Options for Data Transfer

- While networks are increasingly by default the means by which data is transferred, it is not always the most efficient method to use
- There are other options for data transfer – consider removable media such as CD ROMs, DVDs, portable hard drives
  - “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
  - Cost-wise, such removable media are often more efficient on a per Mb/Gb basis
    - 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
  - However, using such media to transfer data may introduce a significant delay

The Bandwidth Revolution?

- CPU speeds increase by a factor of ~20 per decade
  - 1981: PC 4.77MHz vs 2001: PC 2 GHz
- Current CPU speed now approaching physical limits - constrained by physical properties pertaining to granularity of engraving on silicon
- Evolutionary steps in available bandwidth:

  Bandwidth speeds increase by a factor of ~125 per decade (1981: Modem 56kbps vs 2001: Net 1Gbps)
- Current bandwidth available up to 50Tbps - vastly exceeding the rate at which we can convert electrical impulses to optical pulses

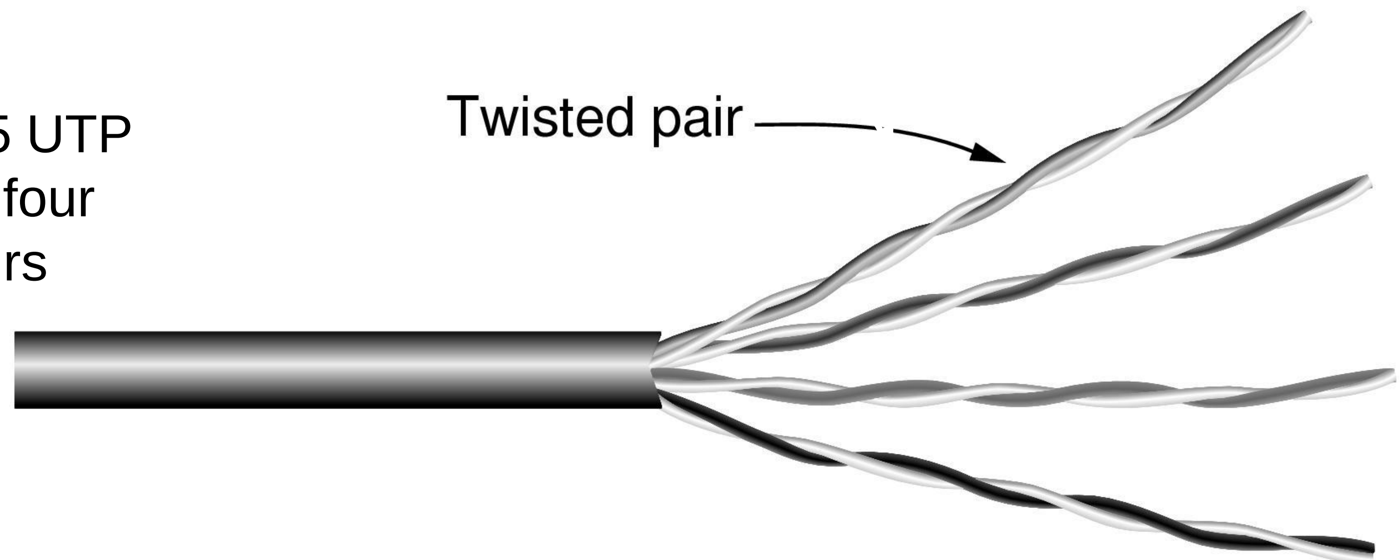
Signal Attenuation

- 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."

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 (large buildings often have km’s of cabling)

Category 5 UTP cable with four twisted pairs



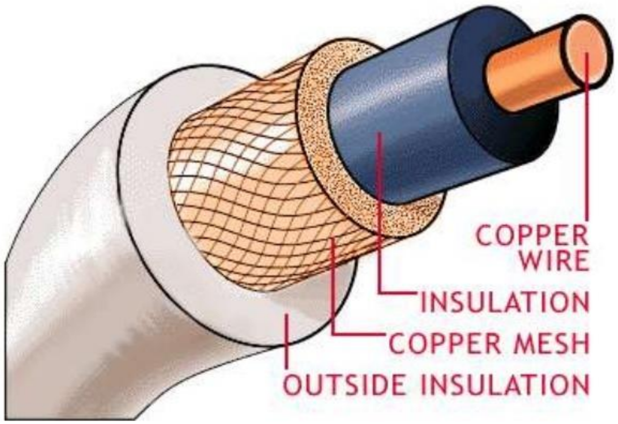
Properties and Types of Twisted Pair

- 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 6 - 250 MHz
- Cat 7 – 600 MHz

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

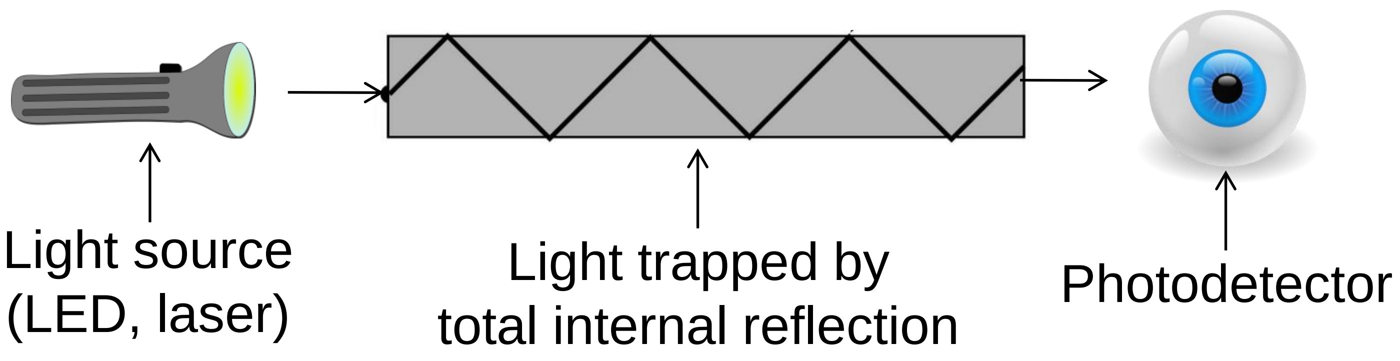


Fibre Optics

- Fibre has enormous bandwidth (THz) and tiny signal loss
- Common for high rates and long distances
  - e.g. backbone links between ISP facilities, Fibre-to-the-Home (FTTH)
- Data transmission over a fibre of glass

Transmission of Light Through Fibre

- Optical transmission has 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 between air/silica boundary is compensated for by design - total internal reflection



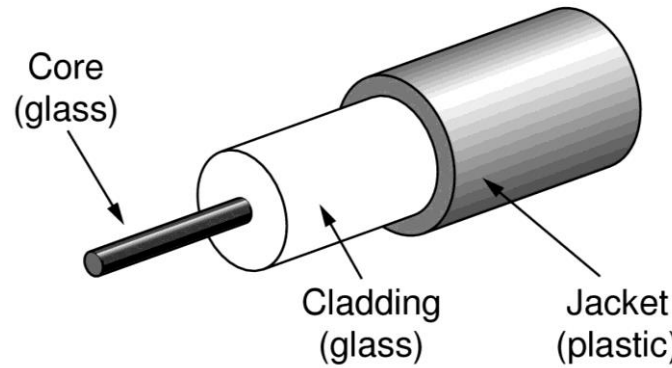
Fibre Optic Cables

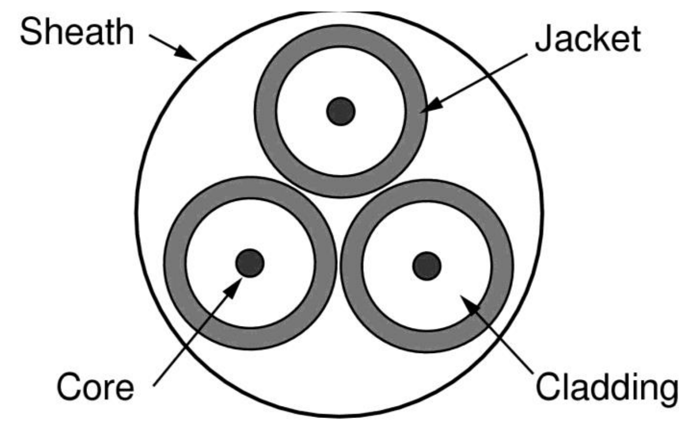
Single-mode

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

Multi-mode

- Other main type of fibre
- Light can bounce (50um core)
- Used with LEDs for cheaper, shorter distance links

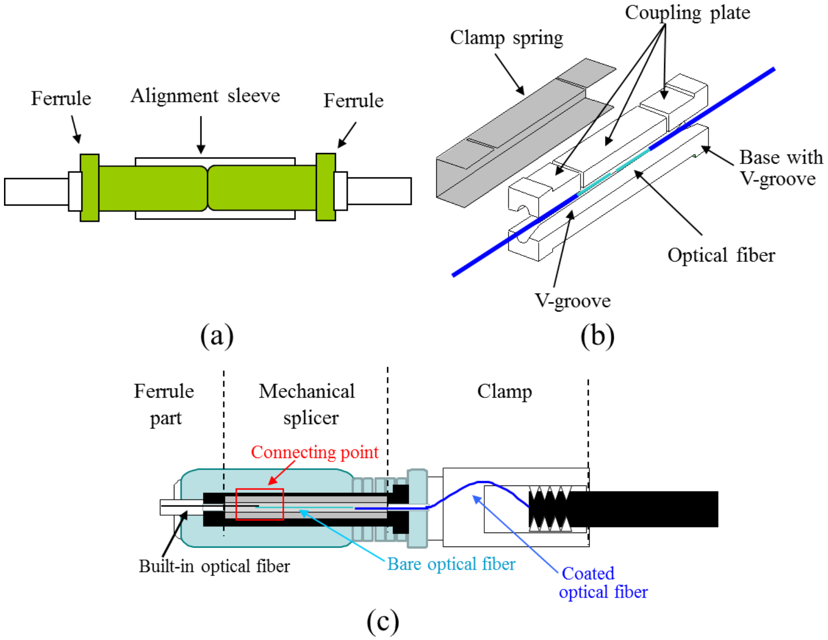




Fibres in a cable

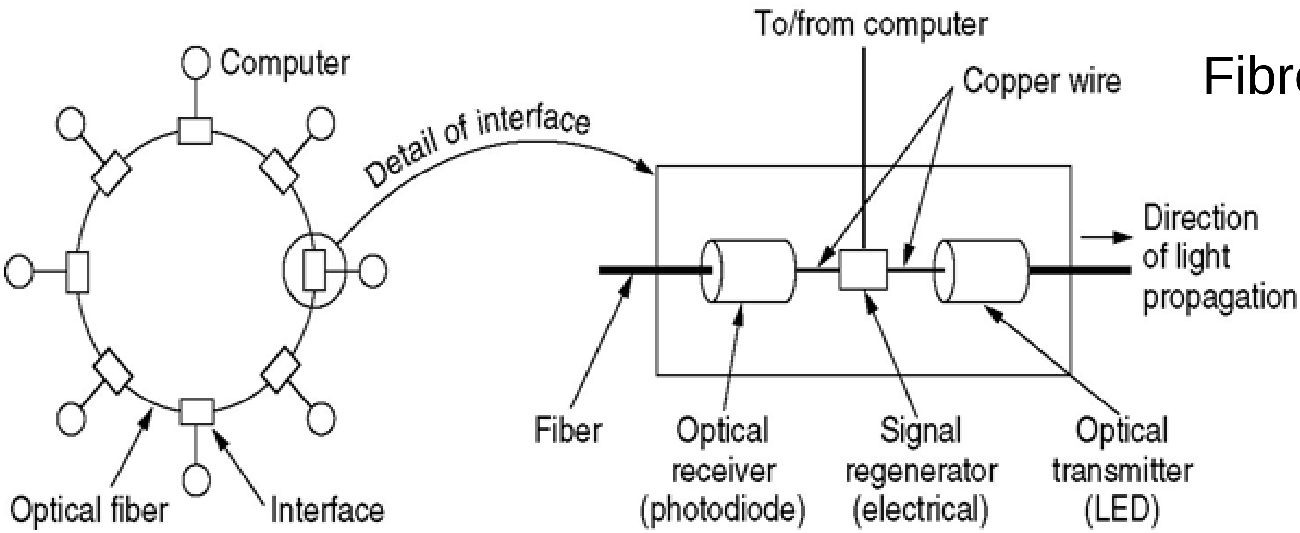
Fibre Optic Connections

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



Fibre Optic Networks

- Fibre optic cable is a scalable network media - LAN, WAN, long distance
- Fibre optic cable networks can be organised either as a ring or as a bus network (series of point to point connections)



Fibre Optic Ring

Comparison: Wires and Fibre

Comparison of the properties of wires and fibre:

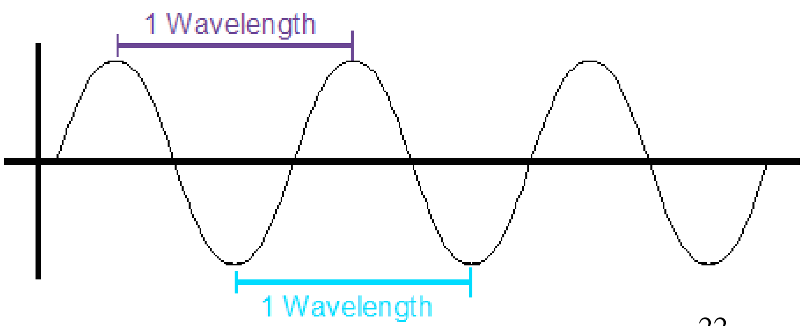
Property	**Wires**	**Fibre**
Distance	Short (100s of m)	Long (tens of km)
Bandwidth	Moderate	Very High
Security	Easy to tap	Hard to tap
Cost	Inexpensive	More Expensive
Convenience	Easy to use	Harder to use

Wireless Transmission

- Mobile users requires a **mobility enabled network** - contrast with the wired networks
- Wireless networks can provide advantages even in fixed location environments
- Wireless data transmission networks have a common basis - **electromegnatic wave propagation**
- Unlike previous media wireless signals are **broadcasted** over a region
- Potential **signal collisions** – Need regulations

Basics of Electromagnetic Waves

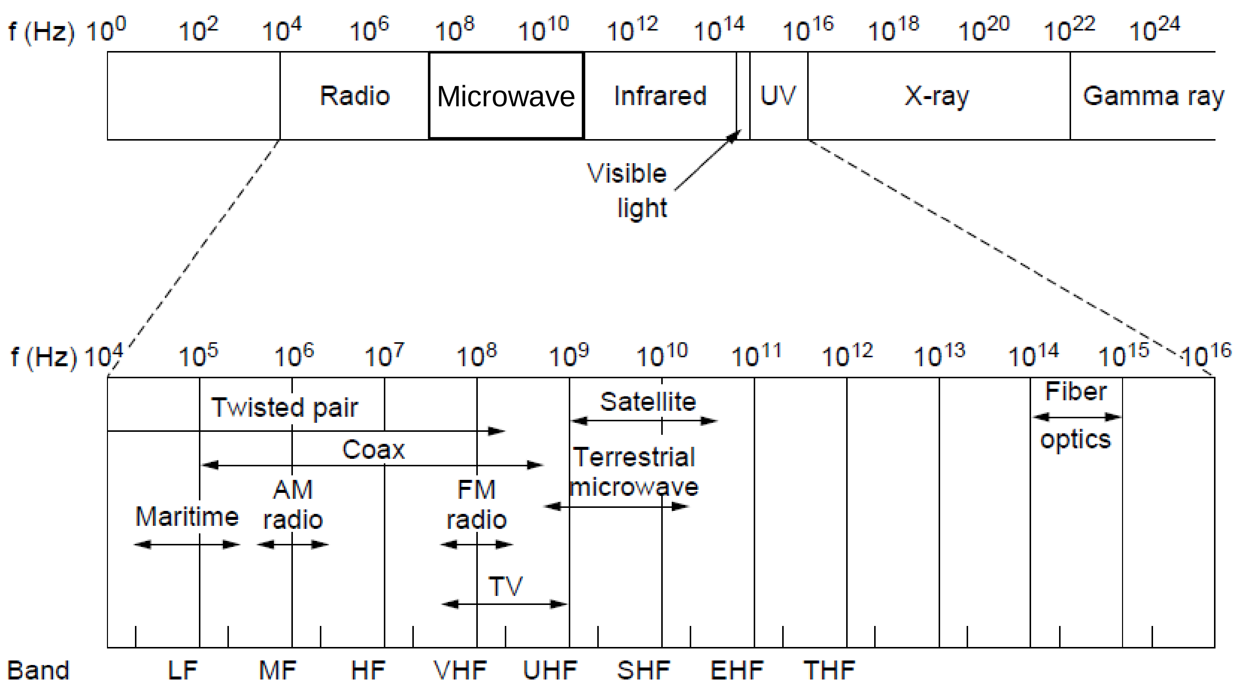
- **Frequency:** Number of oscillations per second of a wave, measured in Hertz (Hz).
- **Wavelength:** Distance between two consecutive minima or maxima.
- **Speed:** All EM waves travel at the same speed - the speed of light ~ $3*10^8$ m/s
- Fundamental relationship:
  - Wavelength x Frequency = Speed of Light
  - Units: (m) x (1/s) = (m/s)



Electromagnetic Spectrum

Different bands have different uses:

- Radio: wide-area broadcast;
- Microwave: LANs and 3G/4G;
- Infrared/Light: line-of-sight



Wireless vs. Wires/Fibre

Wireless:

- + Easy and inexpensive to deploy
- + Naturally supports mobility
- + Naturally supports broadcast
- Transmissions interfere and must be managed
- Signal strengths hence data rates vary greatly

Wires/Fibre:

- + Easy to engineer a fixed data rate over point-to-point links
- Can be expensive to deploy, esp. over distances
- Doesn’t readily support mobility or broadcast

Communication Satellites

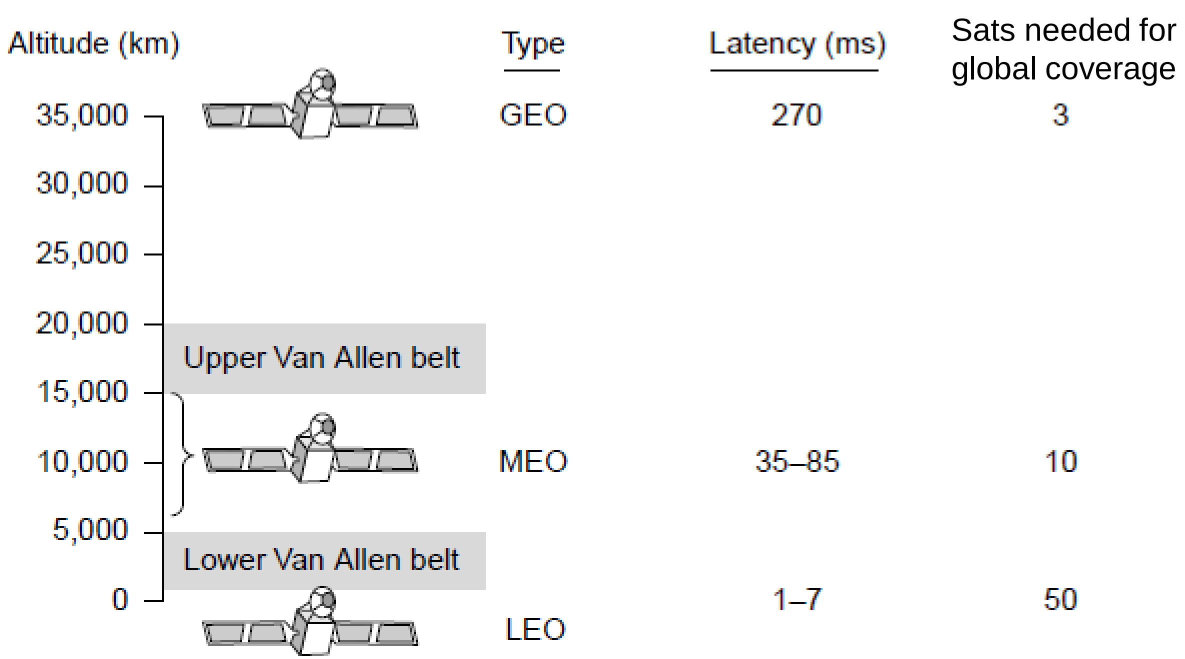
Satellites are effective for broadcast distribution and anywhere/anytime communications

- Types of satellites:
  - Geostationary (GEO) Satellites
  - Medium-Earth Orbit (MEO) Satellites
  - Low-Earth Orbit (LEO) Satellites
- Satellites vs. Fibre

Types of Satellites

Satellites and their properties vary by altitude:

- Geostationary (GEO), Medium-Earth Orbit

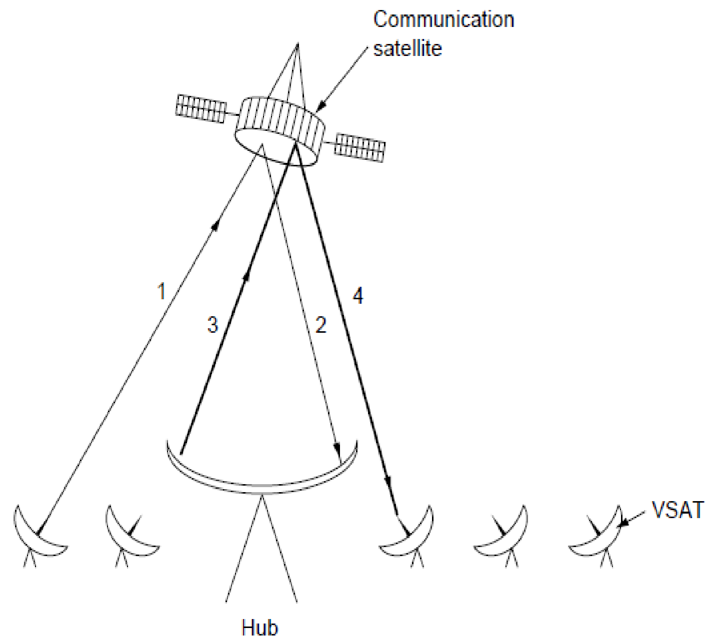


Geostationary Satellites

GEO satellites orbit 35,000 km above a fixed location

- VSAT (computers) can communicate with the help of a hub
- Different bands (L, S, C, Ku, Ka) in the GHz are in use but may be crowded or susceptible to rain.

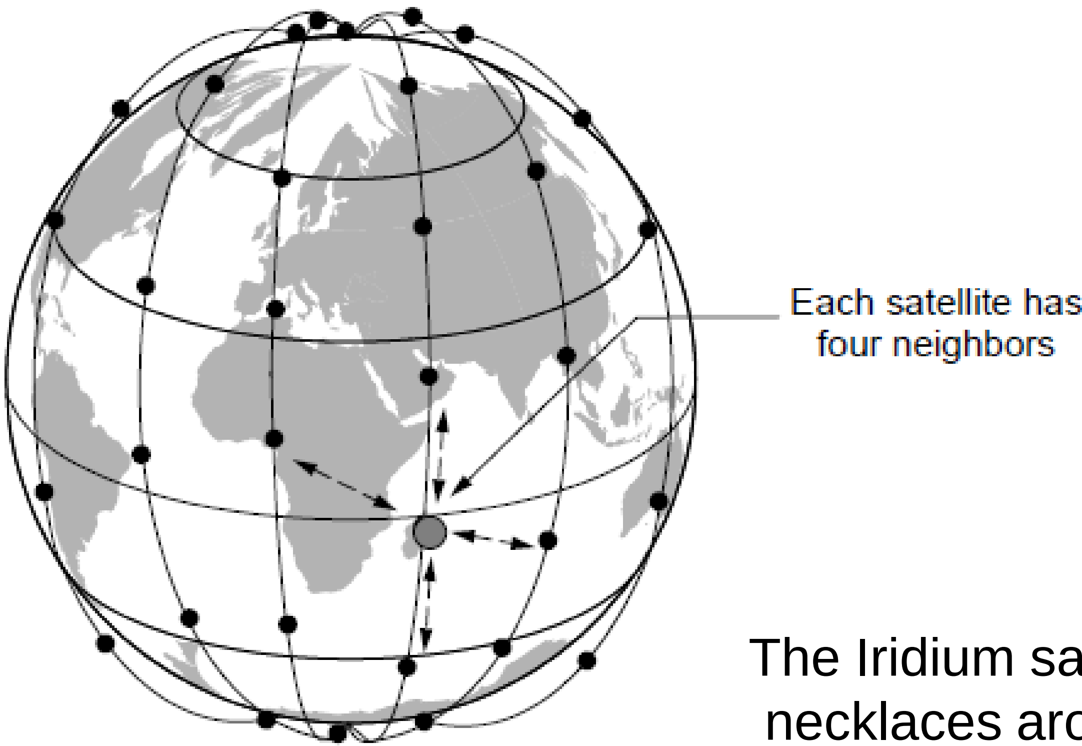
GEO satellite



VSAT
(Very Small Aperture Terminals)

Low-Earth Orbit Satellites

Systems such as Iridium use many low-latency satellites for coverage and route communications via them



The Iridium satellites form six necklaces around the earth.

Satellite vs. Fibre

Satellite:

- + Can rapidly set up anywhere/anytime communications (after satellites have been launched)
- + Can broadcast to large regions
- Limited bandwidth and interference to manage

Fibre:

- + Enormous bandwidth over long distances
- Installation can be more expensive/difficult