Week 2 – Physical Layer

COMP90007
Internet Technologies

Reading

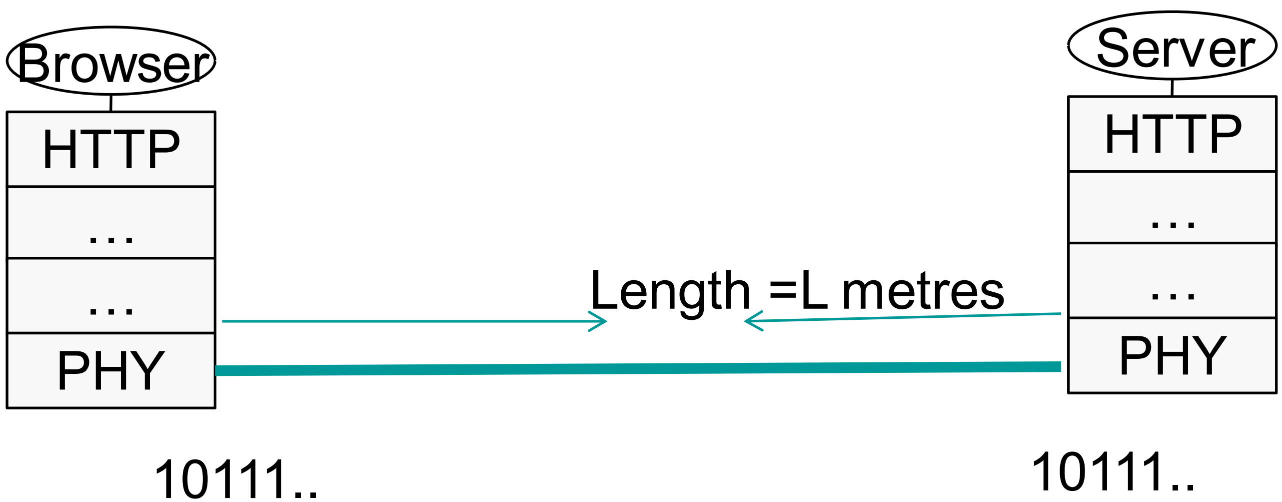
- Chapter 2:
  - This is a very long chapter
  - Reading the whole chapter is not recommended nor relevant to this subject
  - We discuss numerous key topics in this chapter
  - This almost touches all sections of the Chapter
  - But you need to only skim the chapter and read only the parts where we discuss in the lecture in detail

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
- This is 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 = 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 = 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
  - However, 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
    - 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 once of transfer better to use a car!
- Data transfer over a network is not always the most efficient method to use for extremely large such as archival scientific data

The Bandwidth Revolution

- Evolutionary steps in available bandwidth:
  - CPU speeds increase by a factor of ~20 per decade
    - 1981: PC 4.77Mhz vs 2001: PC 2 Ghz
- Bandwidth speeds increase by a factor of ~125 per decade (1981: Modem 56kbps vs 2001: Net 1Gbps)
- Current CPU speed now approaching physical limits - constrained by physical properties pertaining to granularity of engraving on silicon
- 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 some applications…

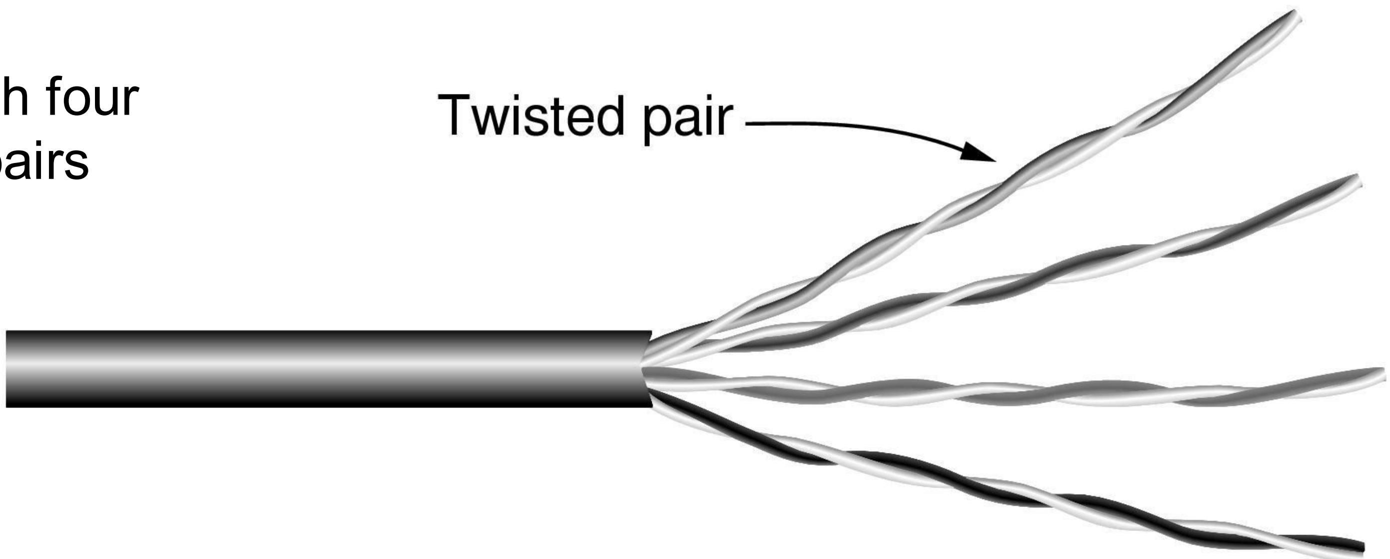
Lets start with simple media and concepts: Signal Attenuation

- 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



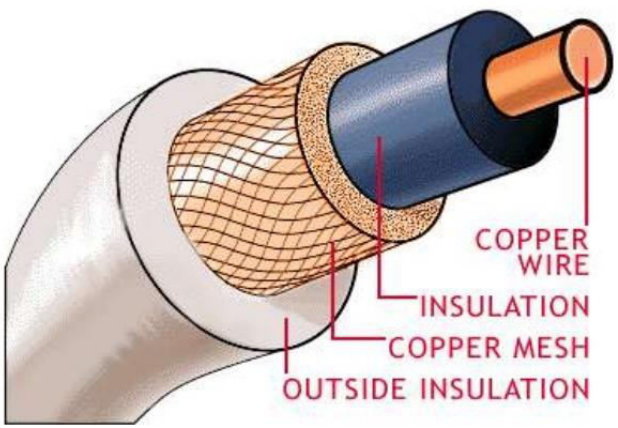
Properties and Types of Twisted Pair

- 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")

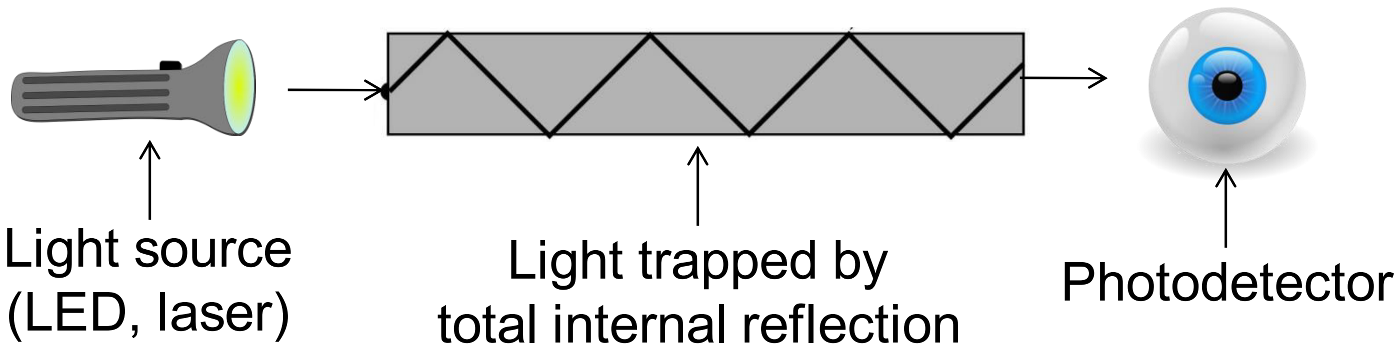
- Better shielding than twisted pair = higher speeds over greater distances
- Copper core with insulation, mesh, and sheath
- Bandwidth approaches **1Ghz**
- Still widely used for cable TV/Internet

A diagram of a coaxial cable



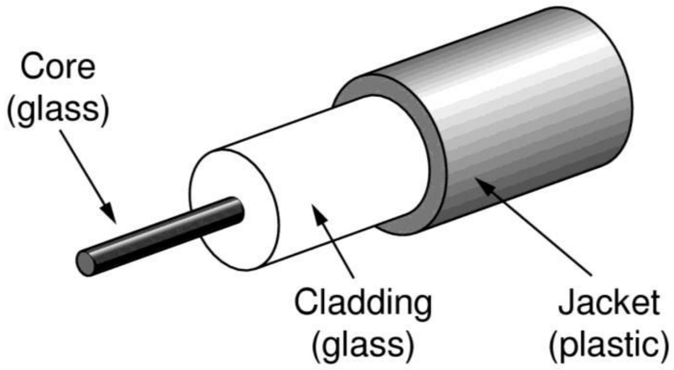
Fiber Optics

- Optical transmission has 3 components: light source, transmission medium, detector
- Base Semantics: light = 1, no light = 0 (basic binary system)
- 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

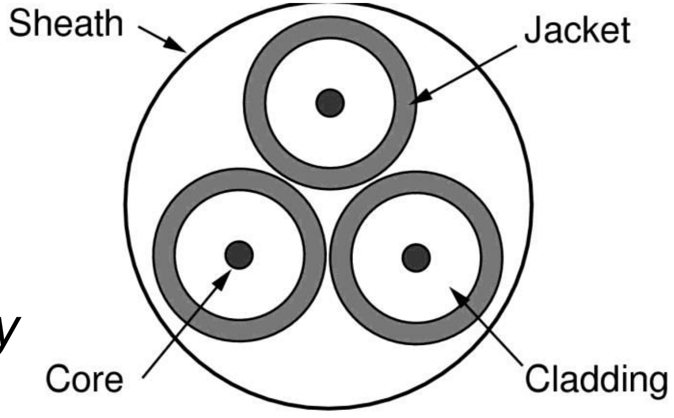
Fiber has enormous bandwidth (**THz**) and tiny signal loss – *hence* high rates over long distances and increasingly a popular choice…



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

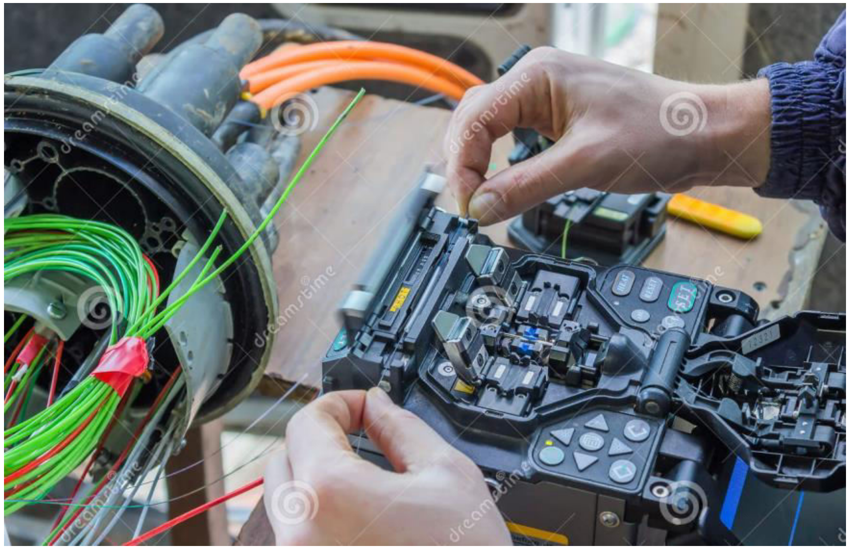
Multi-mode
- Other main type of fiber
- Light can bounce
- Used with LEDs for cheaper, shorter distance links

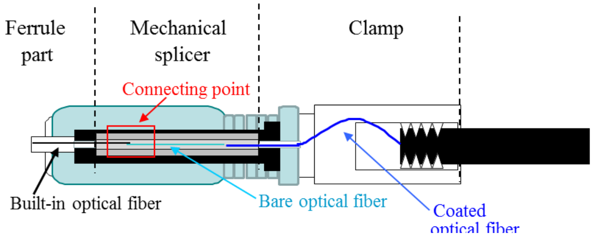


They come in bundles commonly

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)

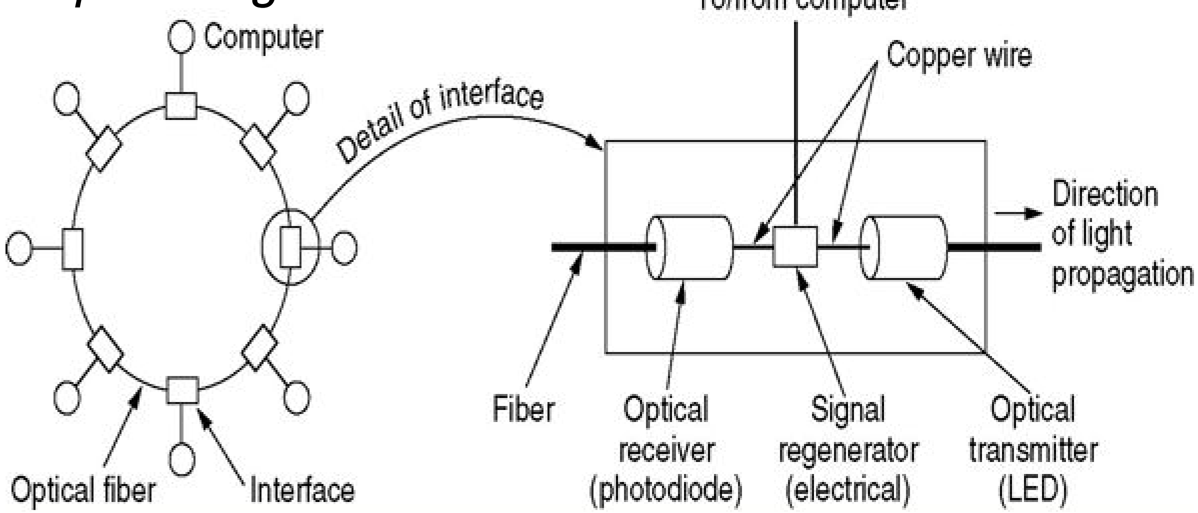




Fiber Optic Networks Contd

- 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:

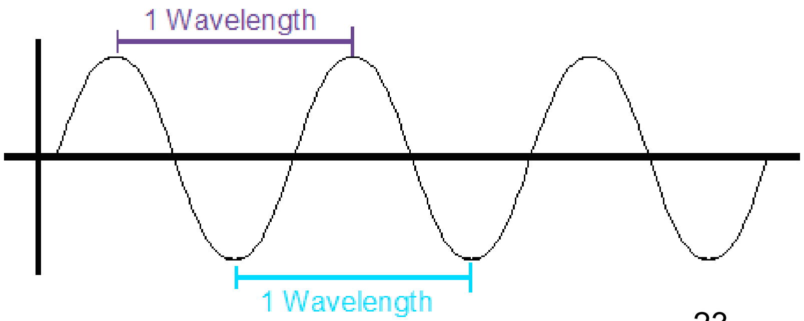
Property	**Wires**	**Fiber**
Distance	Short (100s of m)	Long (tens of km)
Bandwidth	Moderate	Very High
Cost	Inexpensive	More Expensive
Convenience	Easy to use	Harder to use
Security	Easy to tap	Hard to tap

Wireless Transmission

- Mobile users requires a **mobility enabled network** - contrast with the wired networks
- Wireless networks can provide advantages even in fixed location environments
- There are many types of wireless data transmission networks, but they all have a common basis - **radio wave propagation**
- Unlike previous mediums wireless signals are ***broadcasted over a region***
- **Potential signal collisions >> Need regulations**

ElectroMagnetic (EM) Spectrum

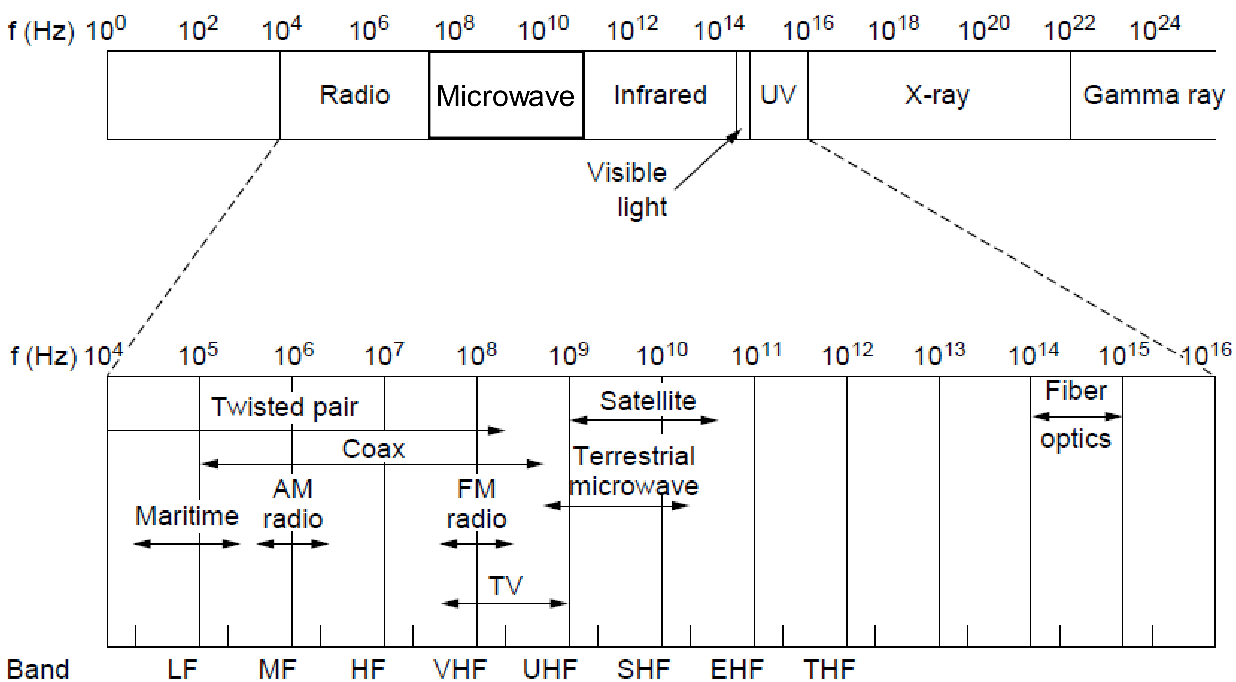
- Number of oscillations per second of a wave is called frequency, measured in Hertz (Hz).
- Distance between two consecutive minima or maxima is called wavelength.
- All EM waves travel at same speed (speed of light)
- Fundamental relationship:
  - Wavelength x Frequency = Speed of Light
  - Units: (m) x (1/s) = (m/s)



Electromagnetic Spectrum

Different bands have different uses:

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



Wireless vs. Wires/Fiber

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/Fiber:

- + 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

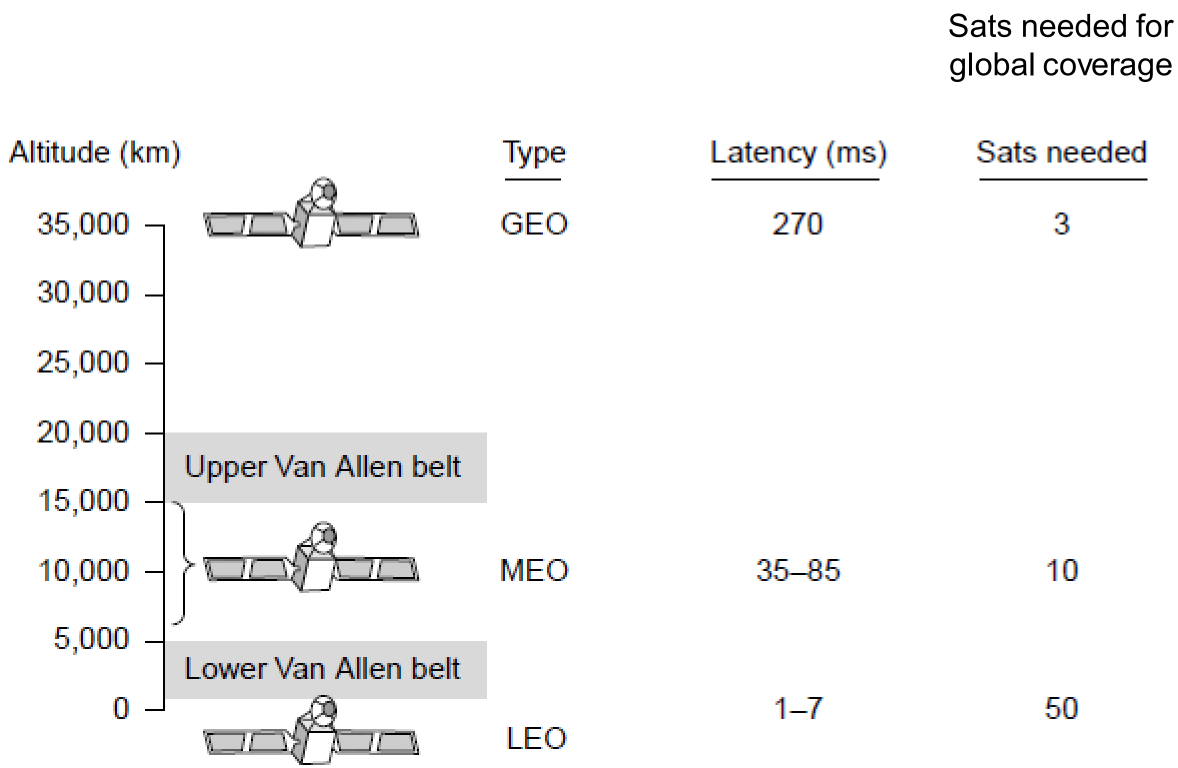
Satellites are effective for broadcast distribution and anywhere/anytime communications

- Kinds of Satellites
  - Geostationary (GEO) Satellites
  - Medium-Earth Orbit (MEO) Satellites
  - Low-Earth Orbit (LEO) Satellites

- Satellites vs. Fiber is a key comparison

Kinds of Satellites

Satellites and their properties vary by altitude: Geostationary (GEO), Medium-Earth Orbit, (MEO), and Low-Earth Orbit (LEO)

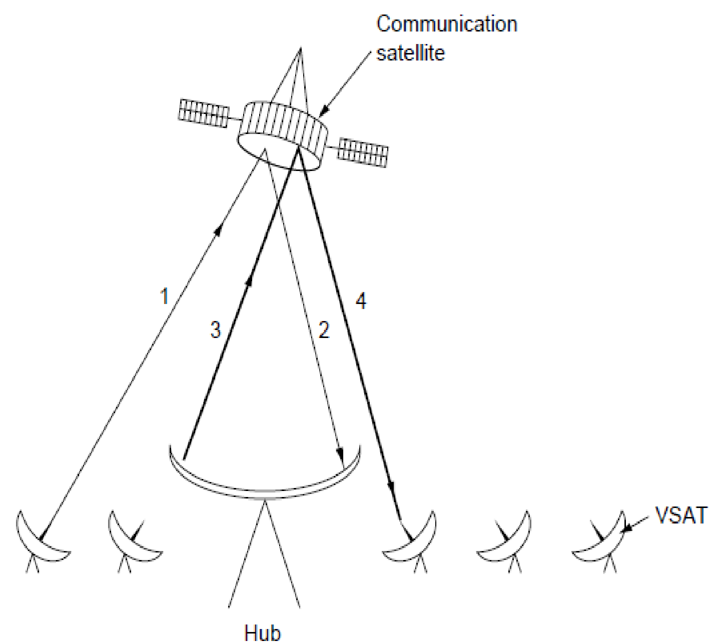


Geostationary Satellites

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.

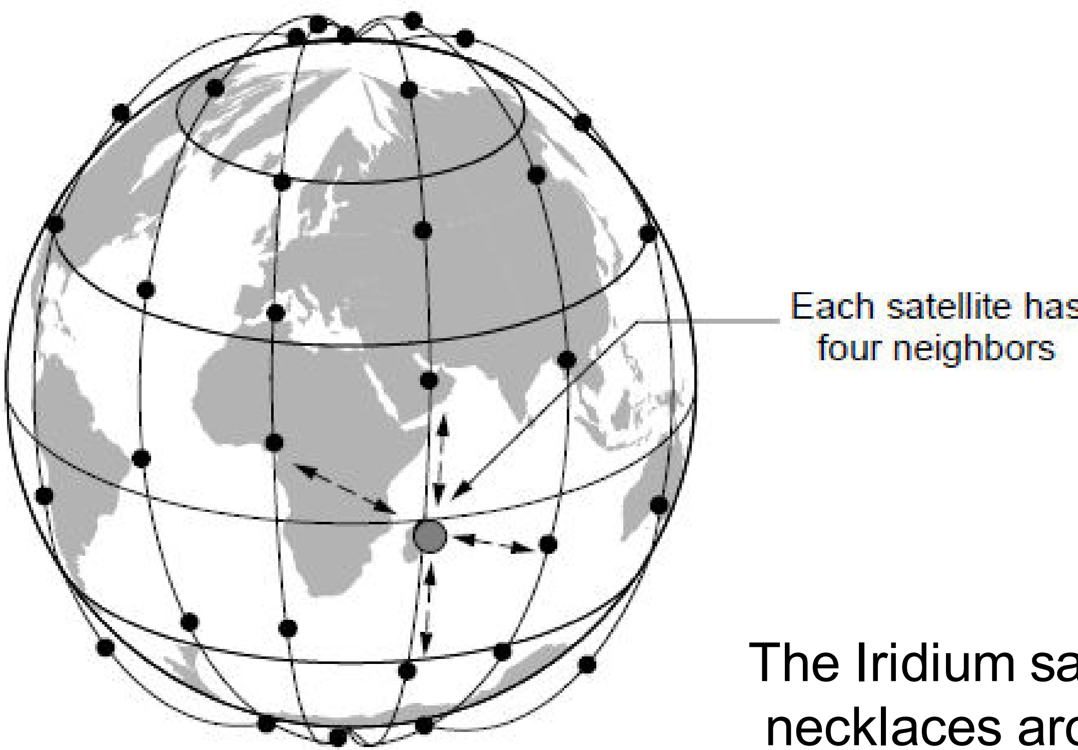
GEO satellite



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. Fiber

Satellite:

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

Fiber:

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