Transmission Media

The media is the matter or substance that carries the voice or data transmission.
There are **two type of media:**

Guided media: those in which the message flows through a physical media (twisted pair, coaxial, fiber optic)

Unguided (Radiated media): those in which the message is broadcast through the air, (infrared, microwave, satellite).

Transmission Media

- **Copper**
  - Coaxial Cable - Thick or Thin
  - Unshielded Twisted Pair - CAT 3,4,5,5e,6 & 7
- **Optical Fiber**
  - Multimode
  - Singlemode
- **Wireless**
  - Short Range
  - Medium Range (Line of Sight)
  - Satellite

Radio link types:

Terrestrial microwave
  e.g. up to 45 Mbps channels
LAN (e.g., Wifi)
  11Mbps, 54 Mbps
wide-area (e.g., cellular)
  3G cellular: ~ 1 Mbps
satellite
  Kbps to 45Mbps channel (or multiple smaller channels)
  270 msec end-end delay
  geosynchronous versus low altitude

Design Factors for Transmission Media

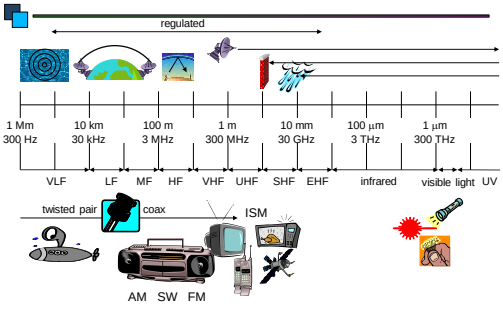
Bandwidth: All other factors remaining constant, the greater the band-width of a signal, the higher the data rate that can be achieved.

Transmission impairments. Limit the distance a signal can travel.

Interference: Competing signals in overlapping frequency bands can distort or wipe out a signal.

Number of receivers: Each attachment introduces some attenuation and distortion, limiting distance and/or data rate.

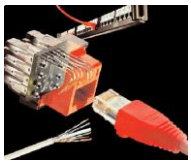
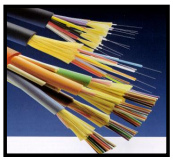
Wireless Frequencies



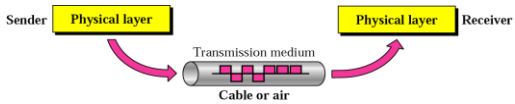
Frequency Bands

Band	Range	Propagation	Application
VLF	3–30 KHz	Ground	Long-range radio navigation
LF	30–300 KHz	Ground	Radio beacons and navigational locators
MF	300 KHz–3 MHz	Sky	AM radio
HF	3–30 MHz	Sky	Citizens band (CB), ship/aircraft communication
VHF	30–300 MHz	Sky and line-of-sight	VHF TV, FM radio
UHF	300 MHz–3 GHz	Line-of-sight	UHF TV, cellular phones, paging, satellite
SHF	3–30 GHz	Line-of-sight	Satellite communication
EHF	30–300 GHz	Line-of-sight	Long-range radio navigation

GUIDED MEDIA

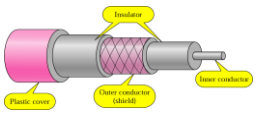



Guided Media



Copper Media: Coaxial Cable

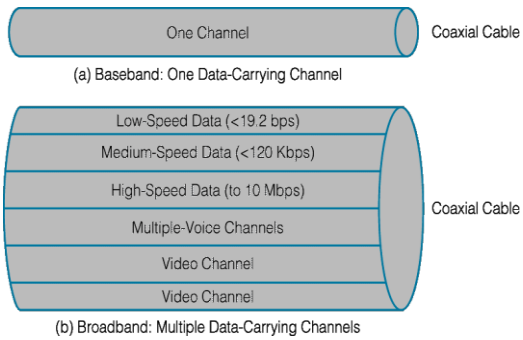
- Coaxial cable is a copper-cored cable surrounded by a heavy shielding and is used to connect computers in a network.
- Outer conductor shields the inner conductor from picking up stray signal from the air.
- High bandwidth but lossy channel.
- Repeater is used to regenerate the weakened signals.



Category	Impedance	Use
RG-59	75 Ω	Cable TV
RG-58	50 Ω	Thin Ethernet
RG-11	50 Ω	Thick Ethernet

Two types of Coaxial Cable
- **Thin Ethernet, Thinnet, Thick Ethernet, Thicknet, Thickwire.**

Institute of Electrical and Electronic Engineers (IEEE) designations
- **10Base2**
- **10Base5**



Guide Media
Coaxial Cable:

Coaxial cable consist of a copper core (inner conductor) with an Outer cylindrical shell for insulation.

More transmission capacity than twisted pair.

a two inch cable can support about 2000 voice or data calls.

Types of Radio Government (RG) Cable:

Designation	Type	Impedance	Description
RG-58/U	ThinWire	50 Ohms	Solid Copper Core
RG-58 A/U	ThinWire	50 Ohms	Stranded Copper Core
RG-58 C/U	ThinWire	50 Ohms	Military version of RB-58 A/U
RG-59	CATV	75 Ohms	Broadband cable, used in Cable TV
RG-6	Broadband	93 Ohms	Larger Dia, higher bandwidth than RG59
RG-62	Broadband	93 Ohms	Used for ARCnet & IBM 3270 Terminals.
RG-8	Thickwire	93 Ohms	Solid core, approx. 0.4" diameter
RG-11	Thickwire	93 Ohms	Stranded core, approx. 0.4" diameter

Thinwire Ethernet Characteristics:

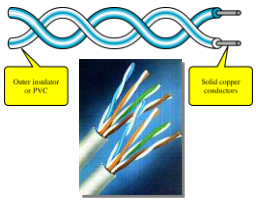
Characteristic	Value
Maximum Cable Length	185 meters (607) feet
Bandwidth	10 Mbps.
Bend Radius	360 degrees / foot.
Install/ Maintain.	Easy to install and reroute. Flexible
Cost	Cheaper from of coax cable. Prefabricated cables average $1 per foot.
Connector type	British Navel Connector (BNC)
Interference rating	Good: lower than Thcknet, Higher than Twisted Pair (TP)

Thickwire Ethernet Characteristics:

Characteristic	Value
Maximum Cable Length	500 meters (16407) feet
Bandwidth	10 Mbps.
Bend Radius	30 degrees / foot.
Install/ Maintain.	Hard to install and reroute. Rigid
Cost	More expensive than from of Thinwire. Cheaper than fiber Optic.
Connector type	British Navel Connector (BNC)
Interference rating	Good: lowest of all electrical cable types

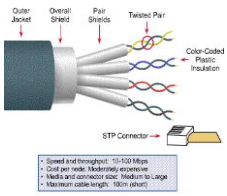
Copper Media: Twisted Pair

- **Twisted-pair is a type of cabling that is used for telephone communications and most modern Ethernet networks.**
- **A pair of wires forms a circuit that can transmit data. The pairs are twisted to provide protection against crosstalk, the noise generated by adjacent pairs.**
- **There are two basic types, shielded twisted-pair (STP) and unshielded twisted-pair (UTP).**



Twisted pair (TP) wire minimize the electromagnetic interference between one pair and any other pair in the bundle.

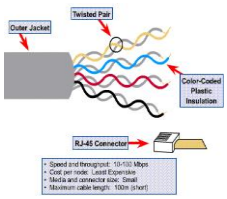
Shielded Twisted Pair (STP)



Unshielded Twisted Pair (UTP)

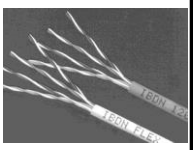
IEEE Ethernet designation 10Base T
T standing for UTP

Most popular form of LAN cabling
Max length 100 meters or 328 feet.
Specifications include number of twists per foot



Unshielded Twisted Pair (UTP)

- Consists of 4 pairs (8 wires) of insulated copper wires typically about 1 mm thick.
- The wires are twisted together in a helical form.
- Twisting reduces the interference between pairs of wires.
- High bandwidth and High attenuation channel.
- Flexible and cheap cable.
- Category rating based on number of twists per inch and the material used
- CAT 3, CAT 4, CAT 5, Enhanced CAT 5 and now CAT 6.



Categories of UTP

- UTP comes in several categories that are based on the number of twists in the wires, the diameter of the wires and the material used in the wires.
- Category 3 is the wiring used primarily for telephone connections.
- Category 5e and Category 6 are currently the most common Ethernet cables used.

Categories of UTP: CAT 3

- Bandwidth 16 Mhz
- 11.5 dB Attenuation
- 100 ohms Impedance
- Used in voice applications and 10baseT (10Mbps) Ethernet

Categories of UTP: CAT 4

- 20 MHz Bandwidth
- 7.5 dB Attenuation
- 100 ohms Impedance
- Used in 10baseT (10Mbps) Ethernet

Categories of UTP: CAT 5

- 100 MHz Bandwidth
- 24.0 dB Attenuation
- 100 ohms Impedance
- Used for high-speed data transmission
- Used in 10BaseT (10 Mbps) Ethernet & Fast Ethernet (100 Mbps)

Categories of UTP: CAT 5e

- 150 MHz Bandwidth
- 24.0 dB Attenuation
- 100 ohms Impedance
- Transmits high-speed data
- Used in Fast Ethernet (100 Mbps), Gigabit Ethernet (1000 Mbps) & 155 Mbps ATM

Categories of UTP: CAT 6

- 250 MHz Bandwidth
- 19.8 dB Attenuation
- 100 ohms Impedance
- Transmits high-speed data
- Used in Gigabit Ethernet (1000 Mbps) & 10 Gig Ethernet (10000 Mbps)

Unshielded Twisted Pair Standards:

Category	Description
Category 1	Traditional UTP Telephone Voice grade cable
Category 2	Bandwidth up to 4 Mbps consisting of four pairs of wire. Slower than most networking technologies. Voice Grade Cable
Category 3	Bandwidth up to 10 Mbps. This includes most networking technologies. Minimum of 3 twists per foot Voice Grade Cable
Category 4	Bandwidth of 16 Mbps. Included 10BaseT Ethernet and16 Mbps Token Ring. Datagrade Cable
Category 5	Bandwidth 100 Mbps. 100BaseX, Asynchronous Transfer Mode (ATM), 25, 155 Mbps & up to 1Gbps technologies Datagrade Cable

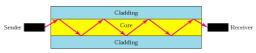
Cat.	Max. Data Rate	Typical Use	Cost (Relative to Category 1)
1	1 Mbps	telephones, low speed LANs	1
2	4 Mbps	token ring LANs	1.5
3	10 Mbps	Ethernet LANs	2
4	16 Mbps	token ring LANs	3
5	100 Mbps and 1 Gbps	Ethernet and fast Ethernet LANs, LANs and Asynchronous Transfer Mode (ATM)	4

10BaseT Ethernet Characteristics:

Characteristic	Value
Maximum Cable Length	100 meters (328) feet
Bandwidth	10 Mbps.
Bend Radius	TP not subject to bend radius limitations.
Install/ Maintain.	Easy to install no need to reroute. The most flexible cable
Cost	Least expensive of all cabling options
Connector type	RJ-45 for device and wall plate connections
Interference rating	Low : most susceptible of all electrical cable types.

Fiber Media

- Optical fibers use light to send information through the optical medium.
- It uses the principal of total internal reflection.
- Modulated light transmissions are used to transmit the signal.



Communicates a signal utilizing high speed streams of light pulses from a laser or LED (light emitting diode).

Cable made of either plastic or glass. latest cabling made of very pure halide glass which increases the distance the cable can support.

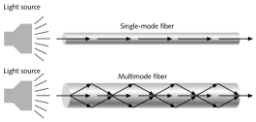
Average cables range from 24 to 144 fibers, with an average size of 72 cables.

Fiber Media

- Light travels through the optical media by the way of total internal reflection.
- Modulation scheme used is intensity modulation.
- Two types of Fiber media :
  - Multimode
  - Singlemode
- Multimode Fiber can support less bandwidth than Singlemode Fiber.
- Singlemode Fiber has a very small core and carry only one beam of light. It can support Gbps data rates over > 100 Km without using repeaters.

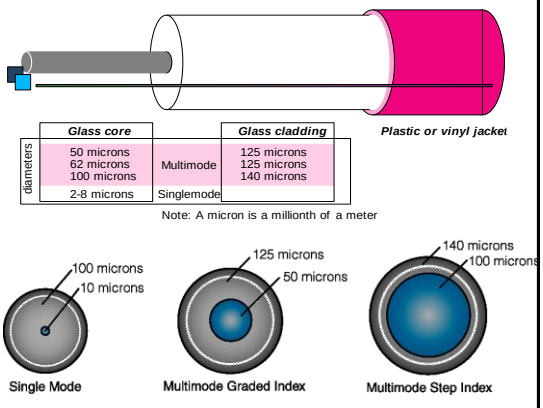
Single and Multimode Fiber

- Single-mode fiber
  - Carries light pulses along single path
  - Uses Laser Light Source
- Multimode fiber
  - Many pulses of light generated by LED travel at different angles



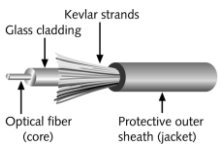
Fiber Media

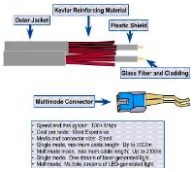
- The bandwidth of the fiber is limited due to the dispersion effect.
- Distance Bandwidth product of a fiber is almost a constant.
- Fiber optic cables consist of multiple fibers packed inside protective covering.
- 62.5/125 µm (850/1310 nm) multimode fiber
- 50/125 µm (850/1310 nm) multimode fiber
- 10 µm (1310 nm) single-mode fiber



Fiber-Optic Cable

- Contains one or several glass fibers at its core
- Surrounding the fibers is a layer called cladding

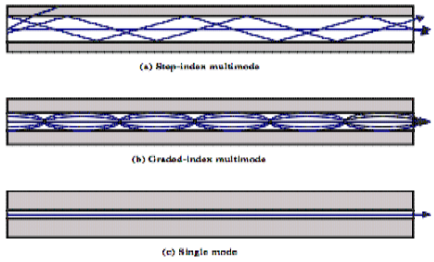




Fiber Optic Cable

- FO Cable may have 1 to over 1000 fibers

Fiber Optic Transmission Modes



Fiber Optic Advantages

- Greater Capacity (Bandwidth of up to 2 Gbps).
- Smaller Size and Lighter Weight.
- Lower Attenuation Immunity to Environmental Interference.
- Highly Secure
- Due to Tap Difficulty and Lack of Signal Radiation

Fiber Optic Cable Characteristics:

Characteristic	Value
Maximum Cable Length	2KMm (6562 feet) - 100 Km (62.14 miles)
Bandwidth	100 Mbps - 1 Gbps.
Bend Radius	30 degrees / foot.
Install/ Maintain.	Difficult to install and reroute. Sensitive to strain and bends
Cost	Most expensive of all cabling options.
Connector type	Several types:ST, SC, MIC, SMA
Interference rating	None: least susceptible of all cable types.

Fiber Optic Connector Characteristics:

Connector Type:	Characteristics
Straight Tip (ST)	2Km (6562 feet) - 100 Km (62.14 miles)
Straight Connection (SC)	100 Mbps - 1 Gbps.
Medium Interface Connector (MIC)	30 degrees / foot.
Subminiature Type A (SMA)	Difficult to install and reroute. Sensitive to strain and bends

Comparison of Cable Characteristics:

Type	Maximum Length	Bandwidth	Installation	Interference	Cost
UTP	100 meters	10 -100 Mbps	Easy	High	Cheapest
STP	100 meters	16 - 1000 Mbps	Moderate	Moderate	Moderate
10Base2	185 meters	10 Mbps	Easy	Moderate	Cheap
10Base5	500 meters	10 Mbps	Hard	Low	Expensive
Fiber	2 - 100 Kilo	100 Mbps-10 Gbps	Very Hard	None	Very Expensive

Wireless (Unguided Media) Transmission

Transmission and Reception Are Achieved by Means of an Antenna

Directional

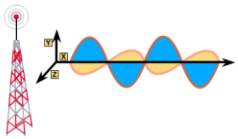
Transmitting Antenna Puts Out Focused Beam
Transmitter and Receiver Must Be Aligned.

Omnidirectional

Signal Spreads Out in All Directions
Can Be Received by Many Antennas

Wireless Media

- Very useful in difficult terrain where cable laying is not possible.
- Provides mobility to communication nodes.
- Right of way and cable laying costs can be reduced.
- Susceptible to rain, atmospheric variations and Objects in transmission path.



Wireless Examples

Terrestrial Microwave
Satellite Microwave
RF Propagation
WiFi
WiMax
Bluetooth
Infrared

Unguided Media Microwave Transmission:

Consists of extremely high frequency radio communication beam.

Direct line of site path of transmissions. range of 25 to 30 miles between repeater stations.

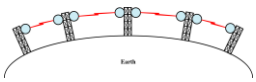
Exhibit the same characteristics are light transmissions. (reflection, focusing, and refraction).

Two Basic Types

Terrestrial
Satellite

Terrestrial Microwave

- Microwaves do not follow the curvature of earth
- Line-of-Sight transmission
- Height allows the signal to travel farther
- Two frequencies for two way communication
- Repeater is used to increase the distance Hop-by-Hop



Used for Long-distance Telephone Service
Uses Radio Frequency Spectrum, From 2 to 40 Ghz
Parabolic Dish Transmitter.

Mounted High Used by Common Carriers As Well As Private Networks.

Requires Unobstructed Line of Sight Between Source and Receiver.

Curvature of the Earth Requires Stations (Repeaters) ~30 Miles Apart.

Terrestrial Microwave Characteristics:

Characteristic	Value
Frequency Range	2 - 4 GHz or 21 - 23 GHz
Maximum Distance	Typically 1 to 50 miles
Bandwidth	1 - 10 Mbps
Install/ Maintain.	Difficult
Interference	Varies, longer distances susceptible to weather difficulties
Cost	Expensive
Security	Highly susceptible, but signal usually encoded.

Unguided Media
Satellite Transmission:

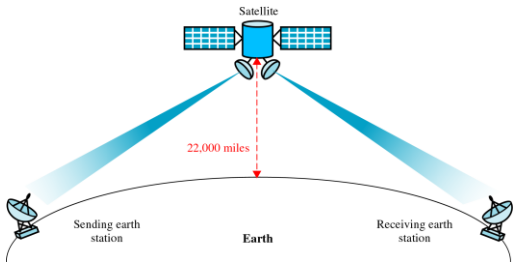
Satellites

RF communication can be used for longer distances when combined with satellites.

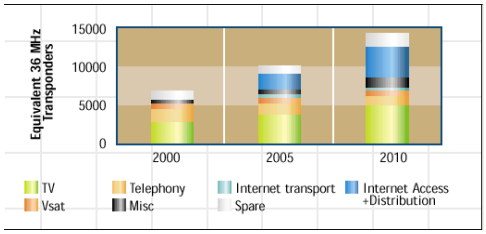
Satellite ***transponders*** receive, amplify, and transmit the RF signal back to the ground.

A single satellite contains six to twelve transponders each operating at a different frequency.

Satellite Communication



Evolution of Satellite Usage

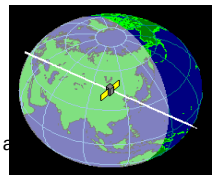


Satellite
Microwave Transmission

A Microwave Relay Station in Space

Can Relay Signals Over Long Distances

Geostationary Satellites



Remain Above the Equator at a Height of 22,300 Miles (Geosynchronous Orbit)

Travel Around the Earth in Exactly the Time the Earth Takes to Rotate

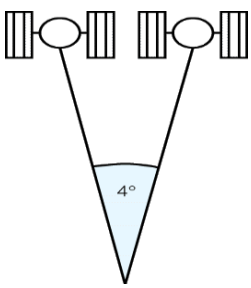
Geosynchronous Satellites:

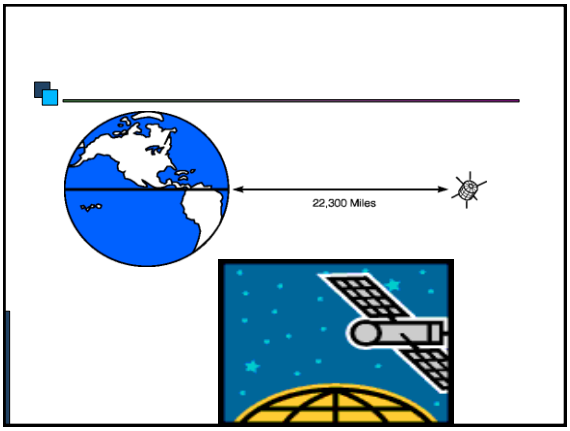
Geosynchronous satellites placed in an orbit (at 35,785km distance from earth) that is exactly syncronized with the rotation of the earth.

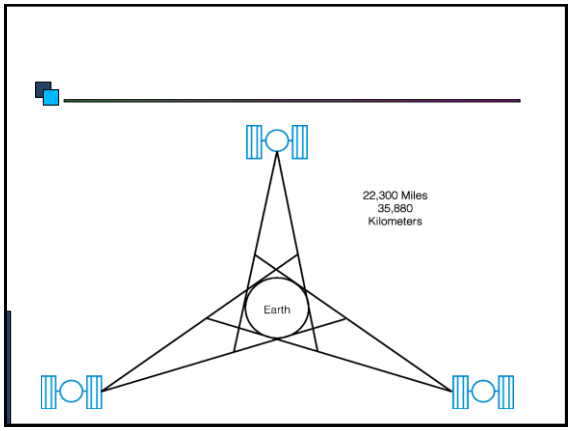
From the ground, it appears to stay at the same position at all times.

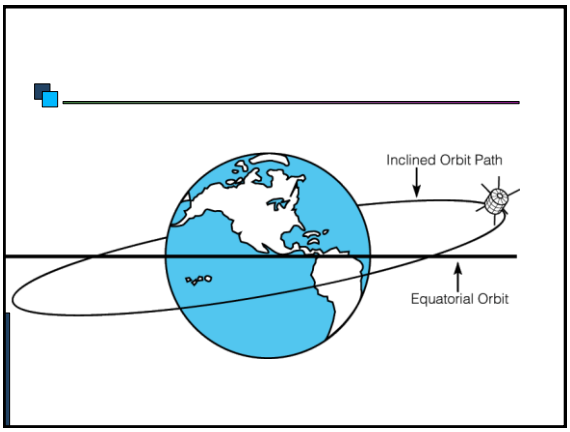
Satellites must be seperated (4 to 8 degrees) from each other to avoid interference.

The entire orbit can hold 45 to 90 satellites.







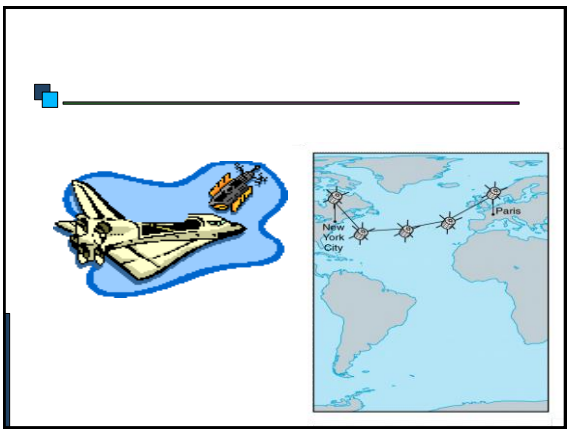


Satellite Transmission Links

Earth Stations Communicate by Sending Signals to the Satellite on an Uplink

The Satellite Then Repeats Those Signals on a Downlink

The Broadcast Nature of the Downlink Makes It Attractive for Services Such As the Distribution of Television Programs.



Disadvantages

Security posed a serious problem in terms of satellite transmissions, as they can be readily intercepted.

One solution would be the use of **Intersatellite links (ISL)** which would allow for direct satellite to satellite transmission and reduce the need from earth based ground stations.

Disadvantages

One disadvantage is that the transmission is delayed due to the distance the signal must travel. (propagation delay)

Typically, the propagation delay is about 0.5 seconds.

Another problem area with satellite transmissions is raindrop attenuation, where because the extremely high frequency signals can be absorbed by raindrops, resulting in reduction in signal strength.

Principal Satellite Transmission Bands

C band: 4(downlink) - 6(uplink) GHz
the first to be designated
Ku band: 12(downlink) -14(uplink) GHz
rain interference is the major problem
Ka band: 19(downlink) - 29(uplink) GHz
equipment needed to use the band is still very expensive

Satellite Orbits

Satellites can be classified by how far out into orbit each one is (LEO, MEO, GEO, and HEO).

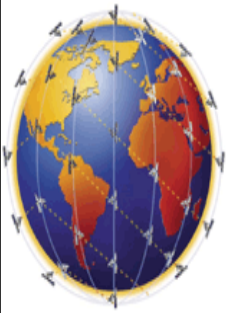
LEO - Low Earth Orbit - 100 miles to 1000 miles. Used for pagers, wireless e-mail, special mobile telephones, spying, videoconferencing.

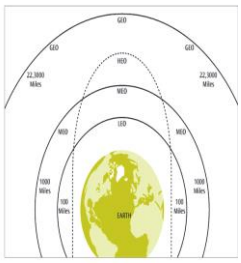
MEO - Middle Earth Orbit - 1000 to 22,300 miles. Used for GPS and government.

GEO - Geosynchronous Orbit - 22,300 miles. Used for weather, television, and government operations.

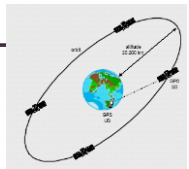
HEO – Highly Elliptical Orbit
A fourth type of orbit used by the military for spying and by scientific organizations for photographing celestial bodies.

When satellite is far out into space, it takes photos.
When satellite is close to earth, it transmits data.





Satellite microwave can also be classified by its configuration:



- Bulk carrier configuration
- Multiplexed configuration
- Single-user earth station configuration (e.g. VSAT)

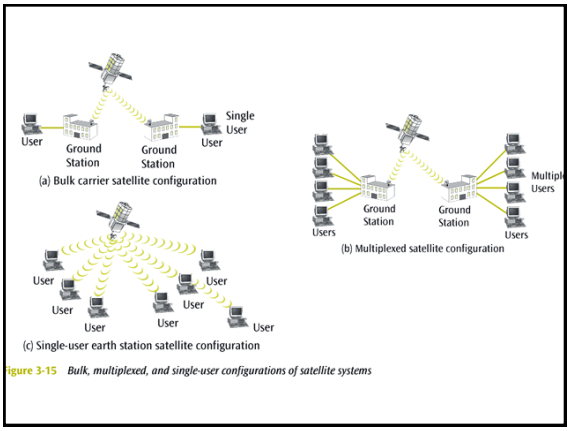
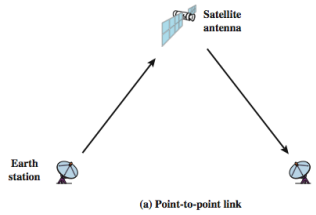
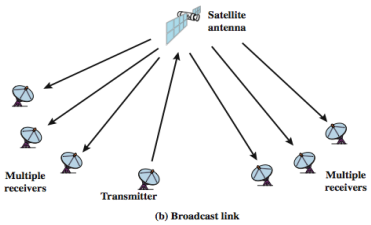


Figure 3-15 *Bulk, multiplexed, and single-user configurations of satellite systems*

Satellite Point to Point Link



Satellite Broadcast Link



Low Earth Orbit Satellites

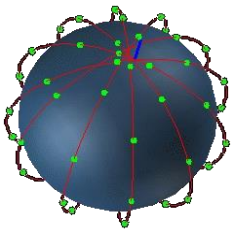
Rotates faster than the rotation of the earth at 200 to 400 miles above the earth.

They do not appear to remain stationary.

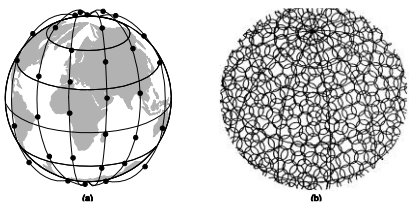
Sixty-six satellites are required to cover the entire surface of the earth.

Iridium

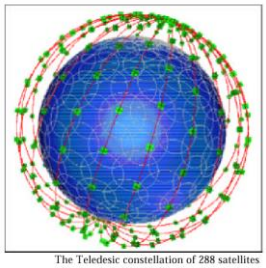
A flock of inexpensive LEOS
Global network of 66 LEOS to provide voice and paging Services
Put in service in 1998



Low-Earth Orbit Satellites Iridium

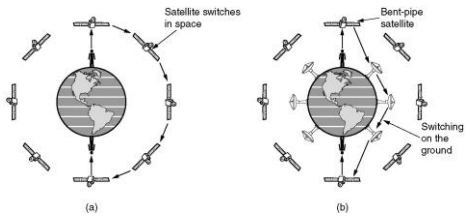


(a) The Iridium satellites from six necklaces around the earth.
(b) 1628 moving cells cover the earth.



The Teledesic constellation of 288 satellites

Globalstar



(a) Relaying in space.
(b) Relaying on the ground.

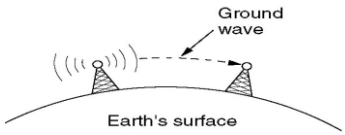
RF (Radio Frequency) Propagation

There are three types of RF (radio frequency) propagation:

- **Ground Wave**
- **Ionospheric**
- **Line of Sight (LOS)**

Ground wave propagation

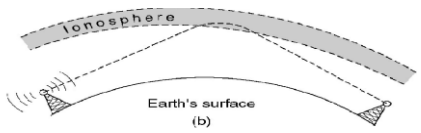
follows the curvature of the Earth. Ground waves have carrier frequencies up to 2 MHz. AM radio is an example of ground wave propagation.



(a) In the VLF, LF, and MF bands, radio waves follow the curvature of the earth.

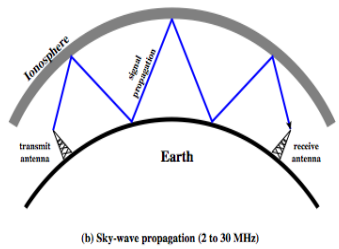
Ionospheric propagation:

Bounces off of the Earth's ionospheric layer in the upper atmosphere.
It is sometimes called double hop propagation.
It operates in the frequency range of 30 - 85 MHz.
Because it depends on the Earth's ionosphere, it changes with the weather and time of day.
The signal bounces off of the ionosphere and back to earth. Ham radios operate in this range.



(b) In the HF band, they bounce off the ionosphere.

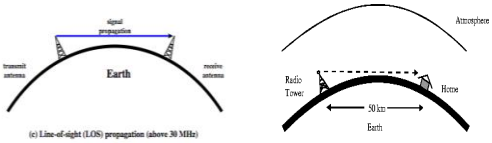
Sky Wave Propagation



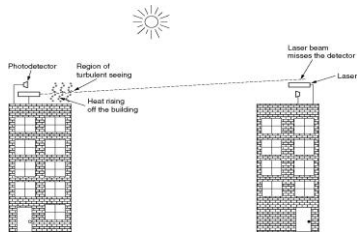
(b) Sky-wave propagation (2 to 30 MHz)

Line of sight propagation:

Transmits exactly in the line of sight.
The receive station must be in the view of the transmit station.
It is sometimes called space waves or tropospheric propagation.
It is limited by the curvature of the Earth for ground-based stations (100 km, from horizon to horizon).
Reflected waves can cause problems. Examples of line of sight propagation are: FM radio, microwave and satellite.



Lightwave Transmission



Convection currents can interfere with laser communication systems.
A bidirectional system with two lasers is pictured here.

Unguided Media

- **Indoor : 10 – 50m : BlueTooth, WLAN**
- **Short range Outdoor : 50 – 200m: WLAN**
- **Mid Range Outdoor : 200m – 5 Km : GSM, CDMA, WLAN Point-to-Point, Wi-Max**
- **Long Range Outdoor : 5 Km – 100 Km : Microwave Point-to-Point**
- **Long Distance Communication : Across Continents : Satellite Communication**

Bluetooth

Bluetooth is a radio standard and communications protocol primarily designed for low power consumption, with a short range (power class dependent:

1 meter, 10 meters, 100 meters) based around low-cost transceiver microchips in each device.

Intended to replace the cable(s) connecting portable and/or fixed electronic devices.

Designed to operate in noisy frequency environments, the Bluetooth radio uses a fast acknowledgement and frequency hopping scheme to make the link robust.

Bluetooth radio modules operate in the unlicensed ISM band at 2.4GHz, use frequency hopping and change freq. every 42 times a millisecond, hop is synchronized by cell master.

Bluetooth applications:

Wireless control and communication between a cell phone and a hands free headset or car kit.

Wireless networking between PCs in a confined space and where little bandwidth is required Wireless communications with PC input devices such as mice and keyboards.

Wireless communications to PC output devices such as printers.

Bluetooth v. Wi-Fi

Bluetooth is oriented to connecting close devices, serving as a substitute for cables.

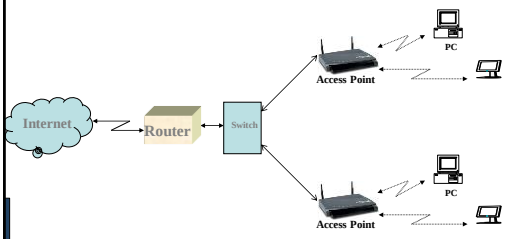
Wi-Fi is oriented towards computer-to-computer connections, as an extension of or substitution for cable LANs.

802.11b and Blutooth both utilize the free 2.4GHz band bandwidth is up to 11Mbps

special protocol implementations needed to cope with noise, fading, ...

802.11a/h WLAN standards use the free 5Ghz band is reserved for WLAN only range is more restricted than with 802.11b bandwidth is increased up to 54Mbps.

Wireless LAN



WiMAX

WiMAX system consists of two parts

- WiMAX Base station (tower): can cover up to 10 km radius
- WiMAX Subscriber station (receiver): sits in your laptop or computer.

Several base stations are connected with one another by high-speed backhaul microwave links, allowing for roaming by a WiMAX subscriber from one base station to another base station area.

WiMAX has two main topologies:

- Point to Point
- Point to Multi-Point Base station

Line-of-sight

A fixed dish antenna points straight at the WiMAX tower from a rooftop or pole.
11 GHz to 66 GHz frequency range
At higher frequencies - there is less interference and lots more bandwidth.
The connection is stronger and more stable, so it is able to send a lot of data with fewer errors.

Non-line-of-sight

A small antenna on your computer connects to the WiMAX tower
2 GHz to 11 GHz frequency range
At lower frequencies – longer wavelength transmissions are not as easily disrupted by physical obstructions – they are better able to diffract, or bend, around obstacles

Infrared

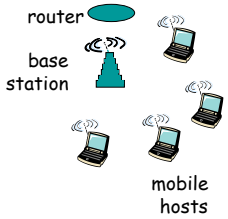
- Uses Transmitters/receivers (Transceivers)
- Transceivers Must Be Within Line of Sight of
- Each Other (Directly or Via Reflection).
- Unlike Microwaves, Infrared Does Not Penetrate Walls.

Light From a Laser:

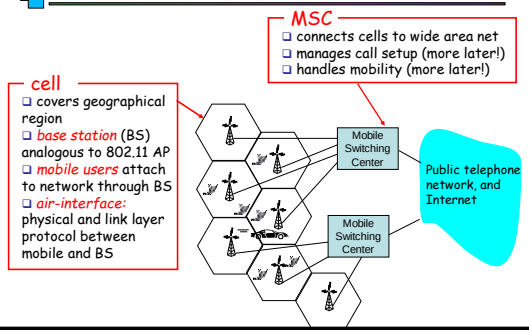
- A beam of light can also be used to carry data through the air.
- Both the transmitter and the receiver must see each other.
- Laser beam stays focused over a long distance.
- Cannot pass through snow or fog.

Wireless access networks

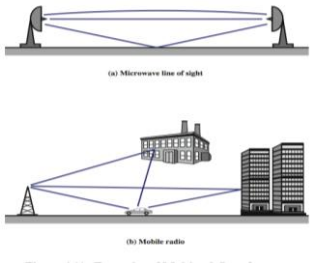
shared *wireless* access network connects end system to router
via base station "access point"
wireless LANs:
802.11b/g (WiFi): 11 or 54 Mbps
wider-area wireless access
provided by telco operator ~1Mbps over cellular system
next up (?): WiMAX (10's Mbps) over wide area



Components of cellular network architecture



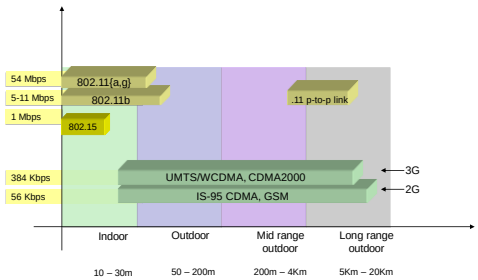
Multipath Interference



Cellular standards: brief survey

2.5 G systems: voice and data channels
for those who can't wait for 3G service: 2G extensions
general packet radio service (GPRS) evolved from GSM data sent on multiple channels (if available)
enhanced data rates for global evolution (EDGE)
also evolved from GSM, using enhanced modulation
data rates up to 384K
CDMA-2000 (phase 1)
data rates up to 144K
evolved from IS-95

Characteristics of selected wireless link standards



WHY SPREAD SPECTRUM?

- Code Division Multiple Access in a common bandwidth (CDMA)
- Secure communication Can hide/encrypt signals
- Only receiver who knows spreading code can retrieve signal.
- Several users can share same higher bandwidth with little interference etc.
- Protection to intentional interference makes jamming and interception harder
- Availability to license-free band
- Signal to noise improvement.

Implementation:

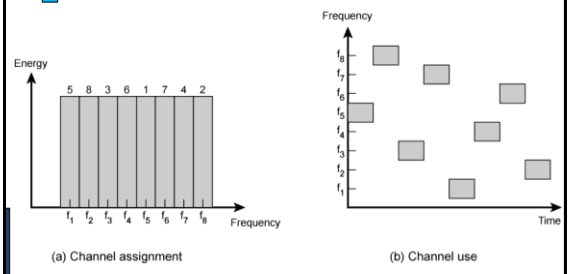
Frequency hoping
Signal broadcast over seemingly random series of frequencies.

Direct Sequence
Each bit is represented by multiple bits in transmitted signal Chipping code.

Frequency Hopping Spread Spectrum (FHSS)

- Signal transmits using a random series of frequencies
- Transmitter hops from one frequency to another
- The hopping is predetermined & assumed to be known by both transmitter & receiver
- Receiver hops/jumps between frequencies in sync with transmitter
- The transmitter remains on the same frequency for the predetermined time, so does receiver
- Transmitter jumps to a channel, sends wide band signal & hops to the other channel
- Transmitter & receiver remain in one channel for the predetermined time

Frequency Hopping Example



Frequency Hopping Spread Spectrum (FHSS)

- signal is transmitted over a random sequence of frequencies, hopping from one to an other in fixed interval.

•Data is carried on all the frequency hops;

•If the noise do not affect all the hops, the nformation can be recovered;

•Multiple system can co-exist in the same band if they use different spreading sequences.

Direct Sequence Spread Spectrum (DSSS)

Each bit represented by multiple bits using spreading code
Spreading code spreads signal across wider frequency band
- In proportion to number of bits used
- 10 bit spreading code spreads signal across 10 times bandwidth of 1 bit code

One method:
- Input bit 1 inverts spreading code bit
- Input zero bit doesn't alter spreading code bit
- Data rate equal to original spreading code

Performance similar to FHSS

Direct Sequence Spread Spectrum Example