Satellite systems

Chapter 6

Satellite

- Any body orbiting around a planet or star.
- They introduces another system supporting mobile communications.
- Satellites offer global coverage without wiring costs for base stations.
- Real satellites v.s Artificial satellites
  - artificial satellites are preferred since we can easily install electronic equipment.
  - real satellites are also far from the earth creating a long delay in communication.
- can provide transmission capability to and from any location on earth;

History

- Scientists knew that it was possible to build rockets that would carry radio transmitters into space.
- **Arthur C. Clarke** publishes an essay about "Extra Terrestrial Relays" (1945)
- **Soviet Sputnik 1**, launched in 1957.
  - The first artificial satellite
  - SPUTNIK is not at all comparable to a satellite today; it was basically a small sender transmitting a periodic 'beep'.
- **SCORE in 1958**
  - The first American satellite to relay communications.
  - used a tape recorder to store and forward voice messages.
  - It was used to send a Christmas greeting to the world from U.S. President.
- **ECHO, in 1960**
  - the first reflecting communication satellite.
  - ECHO was basically a mirror in the sky enabling communication by reflecting signals.

History…

- **SYNCOM , in 1963**
  - the first geostationary (or geosynchronous) satellite followed.
  - rotation is synchronous to the rotation of the earth, so they appear to be pinned to a certain location.
- **Intel sat 1(1965):** 1.5 year lifetime
  - The first commercial geostationary communication satellite.
  - offers 240 duplex telephone channels/single tv channel.
- **Intel sat 2(1967)**
  - offers 240 duplex telephone channels/single tv channel
- **Intel sat 3(1965)**
  - offers1200 telephone channels

History…

- MARISAT
  - offers worldwide maritime communication.
  - large antennas on the ships.
- INMARSAT-A in 1982
  - The first mobile satellite telephone system
- INMARSAT-C in 1988
  - the first satellite system to offer mobile phone and data services.
- INMARSAT-M In 1993
  - satellite telephone systems finally became fully digital satellite telephone systems.
- Satellite data communication
  - global satellite systems for small mobile phones

advantages

- The advantages of satellite communication over terrestrial communication are:
  - The coverage area of a satellite greatly exceeds that of a terrestrial system.
  - Transmission cost of a satellite is independent of the distance from the center of the coverage area.
  - Satellite to Satellite communication is very precise.
  - Higher Bandwidths are available for use.

disadvantages

- The disadvantages of satellite communication:
  - Launching satellites into orbit is costly.
  - Satellite bandwidth is gradually becoming used up.
  - There is a larger propagation delay in satellite communication than in terrestrial communication.

Applications

- Satellites are used in the following areas:
  - **Weather forecasting**
    - using image analysis
  - **Radio and TV broadcast satellites:**
    - e.g Arab satellite dishs, Digital Satellite Television (DSTV))
  - **Military satellites**
    - Spying **…..**safer from attack by enemies
  - **Satellites for navigation** the global positioning system (GPS)

Applications…

- **Global telephone backbones**
  - Instead of using cables it was sometimes faster to launch a new satellite (aka 'big cable in the sky'). However, while some applications still use them, these, satellites are increasingly being replaced by fiber optical cables crossing the oceans.
  - Because of the tremendous capacity of fiber optical links & much lower delay compared to satellites.
- **Connections for remote or developing areas**
  - Due to their geographical location many places all over the world do not have direct wired connection to the telephone network.
  - e.g., researchers on Dallol-Afar
- **Global mobile communication**
  - The basic purpose of satellites for mobile communication is not to replace the existing mobile phone networks, but to extend the area of coverage.

Basics

- A satellite is essentially a microwave repeater in the sky which **receives signals** from transmitting stations on earth and relays these signals back to the receiving stations on the earth or another satellite.

Basics…

- **uplink :** transmission from the earth to the satellite.
- **downlink :** from the satellite to the earth.
- **orbit**: the path in which a satellite travels around the earth.
- **footprint**: the area that the signal from a satellite is aimed at (the signal power is maximum at the center of the footprint and decreases as we move away from it).
  - Within the footprint, communication with the satellite is possible for mobile users.
- **Earth Stations** – antenna systems on or near earth.

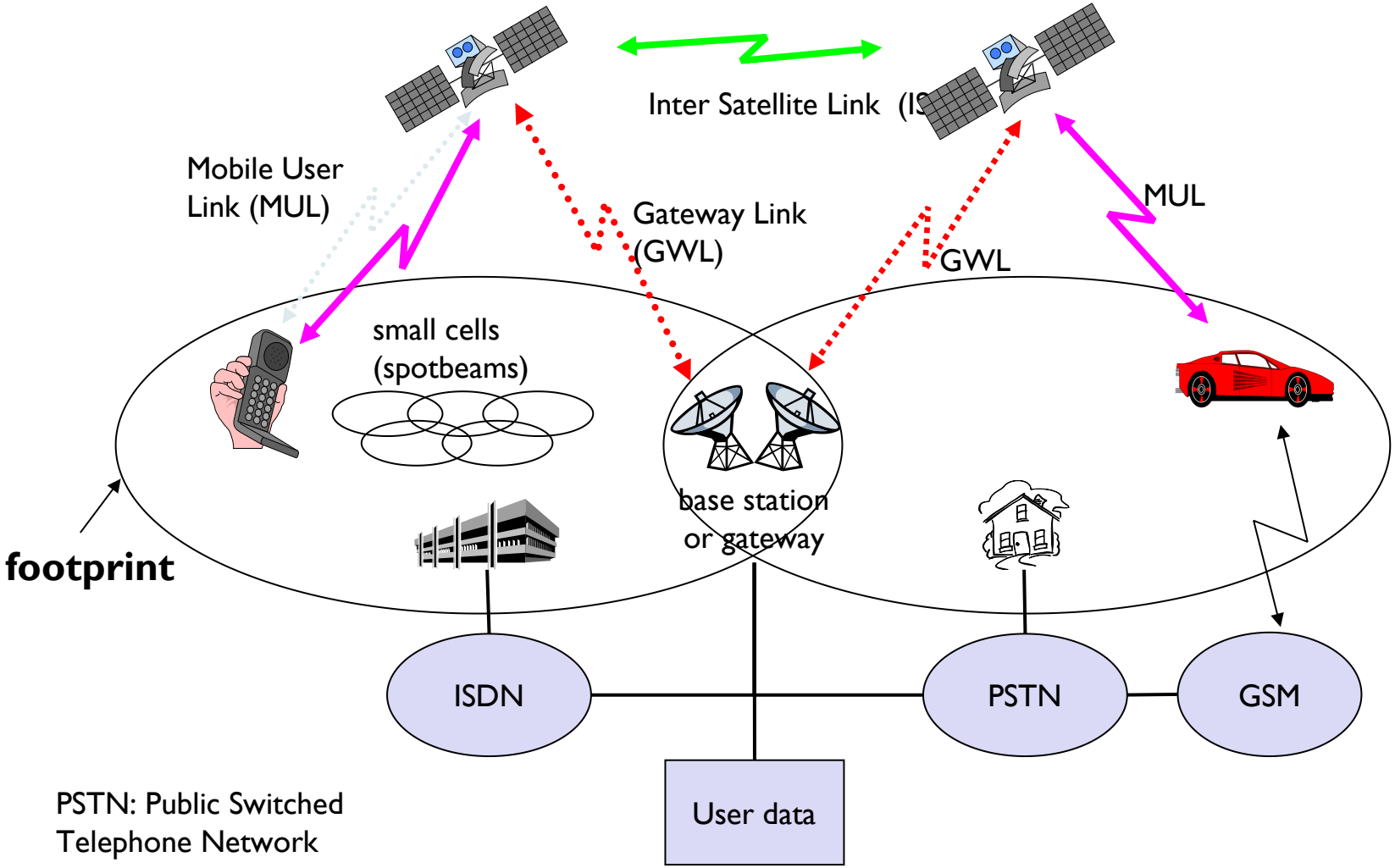
Basics…

- **Transponder** : electronics in the satellite that receive a signal on one frequency and amplify the signal and transmit it on another frequency.
- Todays satellites resemble flying routers. Today 's communication satellites provide many functions of higher communication layers, e.g., inter-satellite routing, error correction etc.

Basics…

- **Mobile user link (MUL) -** communication with the satellite and the mobile users.
- **Gateway link (GWL)** - communication with the satellite and the base station controlling the satellite, which acts as gateway to other networks.
- **Intersatellite links (ISL) -** Direct communication between Satellites .
  - facilitates direct communication between users within different footprints without using base stations.
  - Saving extra links from satellite to earth can reduce latency for data packets and voice data.
- Some satellites have special antennas to create smaller cells using **spot beams**.

Basics...



PSTN: Public Switched
Telephone Network

Basics…

- **Orbit**
- Satellite orbits can be circular or elliptical.
- Satellites in circular orbits always keep the same distance to the earth's surface.
- To keep the satellite in a stable circular orbit.

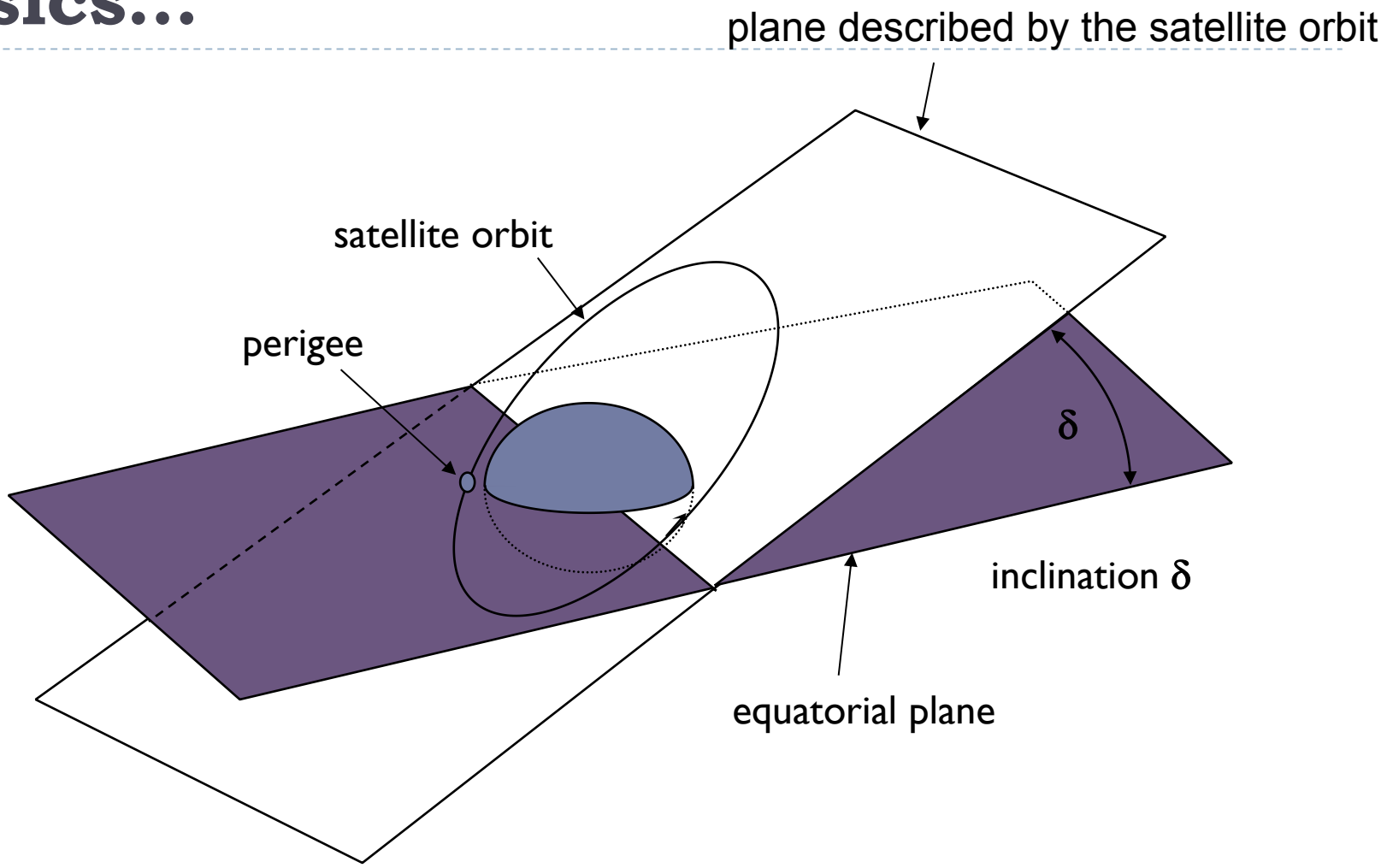
  Fg = Fc, i.e., both forces must be equal.

Where,

- Fg is the attractive force of the earth due to gravity.
- Fc is the centrifugal force trying to pull the satellite away

- If the satellite does not have a circular orbit, the closest point to the earth is called the **perigee**.
- orbit slot allocation done by ITU.

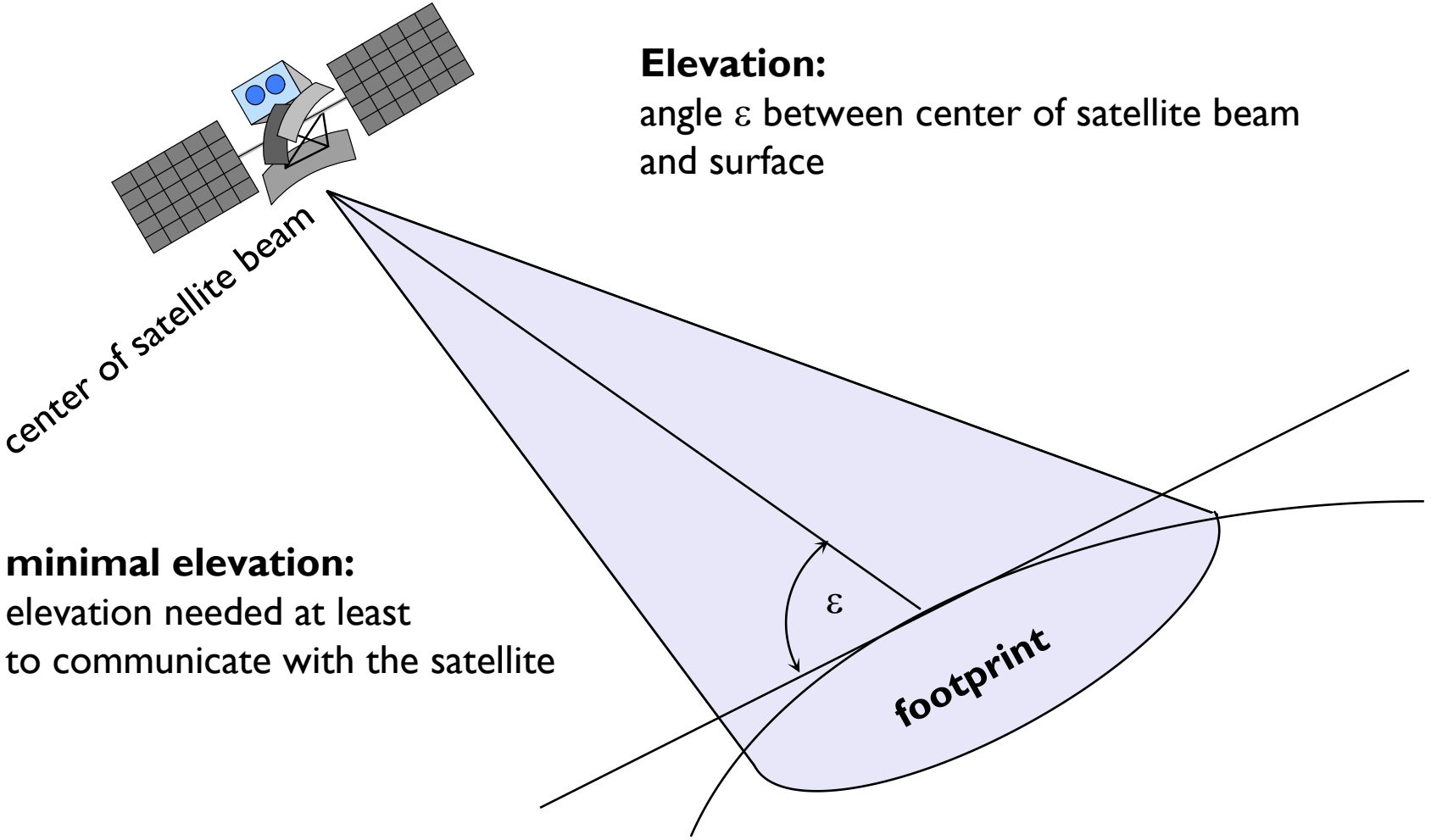
Basics…


plane described by the satellite orbit
satellite orbit
perigee
δ
inclination δ
equatorial plane

Basics : Factors in satellite communication

- The **inclination angle** δ: is the angle between the equatorial plane and the plane described by the satellite orbit.
  - An inclination angle of 0 degrees means that the satellite is exactly above the equator.
- The **elevation angle** ε: is the angle between the center of the satellite beam and the plane tangential to the earth's surface.
  - an elevation less than 10 degrees is considered useless for communication. (rain absorption)

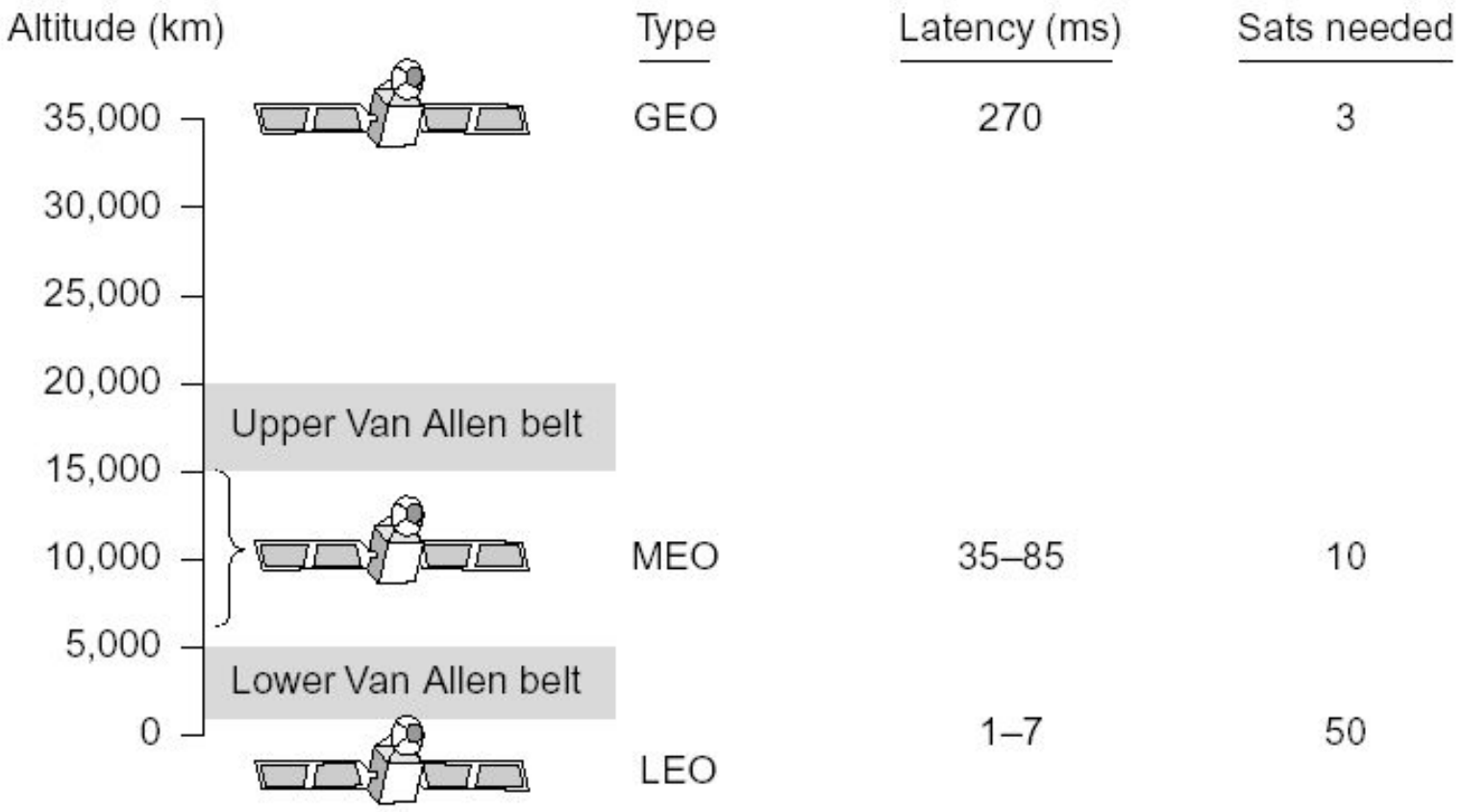
Basics…



Elevation:
angle ε between center of satellite beam and surface

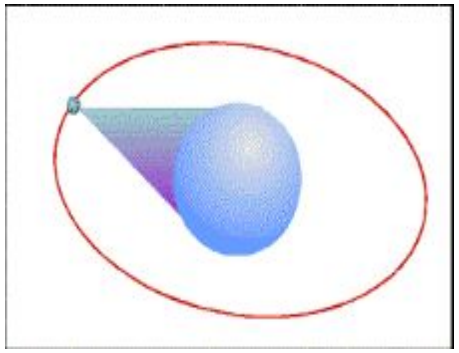
minimal elevation:
elevation needed at least to communicate with the satellite

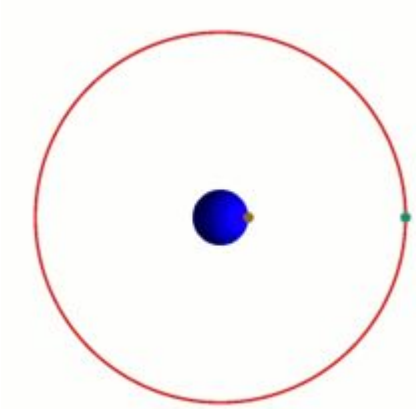
Classification of satellites



GEO(Geostationary orbit) satellites

- These satellites are in orbit 35,863 km above the earth's surface along the equator.
- Objects in Geostationary orbit revolve around the earth at the same speed as the earth rotates. This means GEO satellites remain in the same position relative to the surface of earth.
- Eg.VSATs, almost all TV and radio broadcast satellites.





GEO

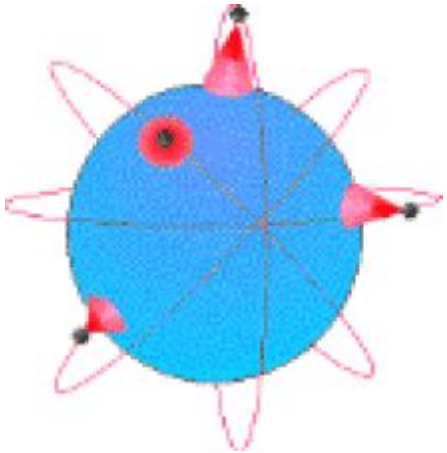
- **Advantages:**
  - Three GEO satellites are enough for a complete coverage of almost any spot on earth.
  - Senders and receivers can use fixed antenna positions, no adjusting is needed.
  - Lifetime expectations for GEOs are rather high, at about 15 years.
  - GEOs typically do not need a handover due to the large footprint.

GEO

- **Disadvantages:**
  - Northern or southern regions of the earth have more problems receiving these satellites i.e., larger antennas are needed in this case.
  - The transmit power needed is relatively high which causes problems for battery powered devices.
  - These satellites cannot be used for small mobile phones. The biggest problem for voice and also data communication is the high latency.

LEO(Low earth orbit) satellites

- LEO satellites are much closer to the earth than GEO satellites, ranging from 500 to 1,500 km above the surface.
- LEO satellites don't stay in fixed position relative to the surface, and are only visible for 15 to 20 minutes each pass.(period:95 to 120 minutes)
- A network of LEO satellites is necessary for LEO satellites to be useful.



LEO

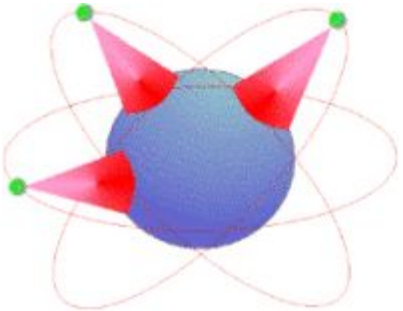
- **Advantage**
  - A LEO satellite's proximity to earth compared to a GEO satellite gives it a better signal strength and less of a time delay, which makes it better for point to point communication.
  - low transmit power
  - A LEO satellite's smaller area of coverage is less of a waste of bandwidth.

LEO

- **Disadvantage**
  - needs many satellites if global coverage is to be reached. 50–200 or even more satellites in orbit
  - The short time of visibility handover between different satellites.
  - The high number of satellites combined with the fast movements results in a high complexity of the whole satellite system.
  - short lifetime of about five to eight years due to atmospheric drag and radiation from the inner Van Allen belt1.

MEO(Medium earth orbit) satellites

- A MEO satellite is in orbit somewhere between 8,000 km and 18,000 km above the earth's surface.
- MEO satellites are similar to LEO satellites in functionality.
- MEO satellites are visible for much longer periods of time than LEO satellites, usually between 2 to 8 hours.
- MEO satellites have a larger coverage area than LEO satellites.
- Eg. GPS

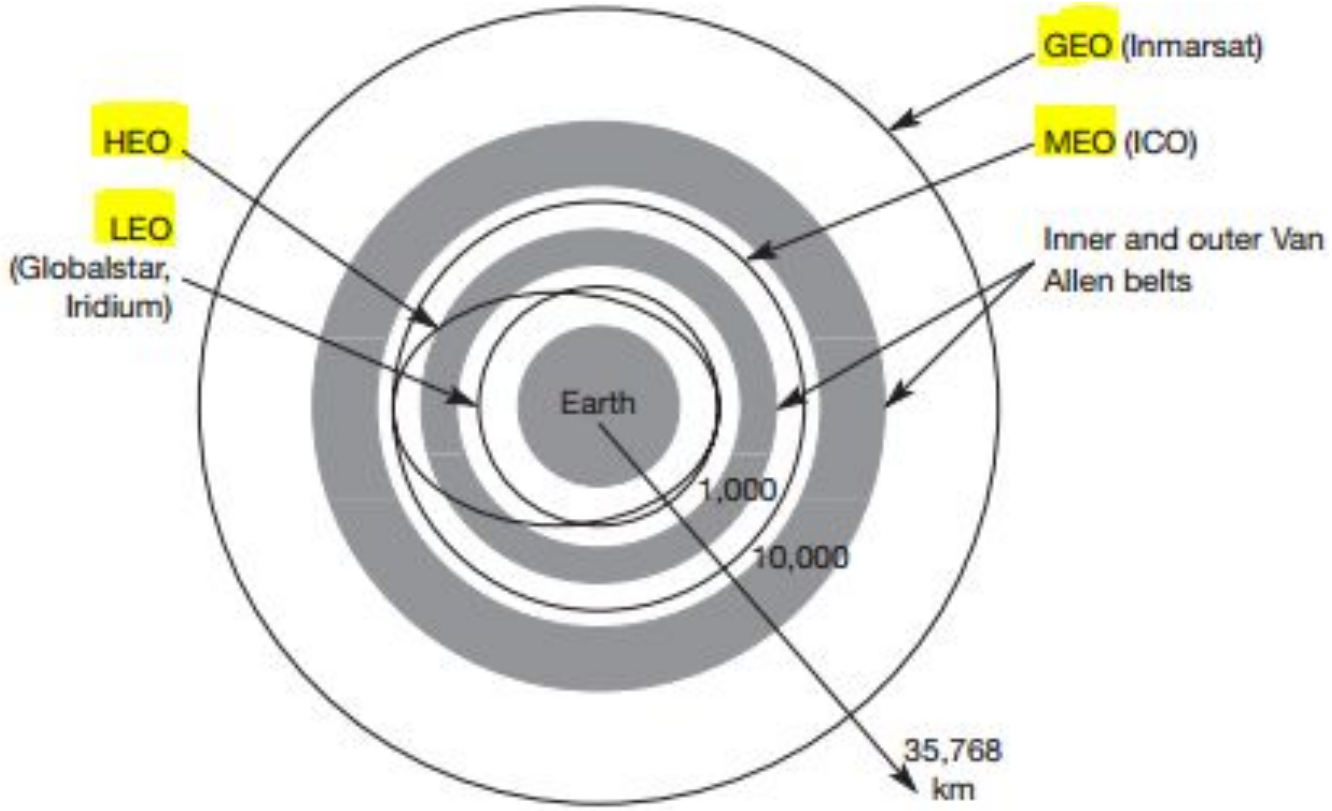


MEO

- Advantage
  - A MEO satellite's longer duration of visibility and wider footprint means fewer satellites are needed in a MEO network than a LEO network.
- Disadvantage
  - A MEO satellite's distance gives it a longer time delay and weaker signal than a LEO satellite, though not as bad as a GEO satellite.

- GEO > MEO > LEO interms of delay

Generally,

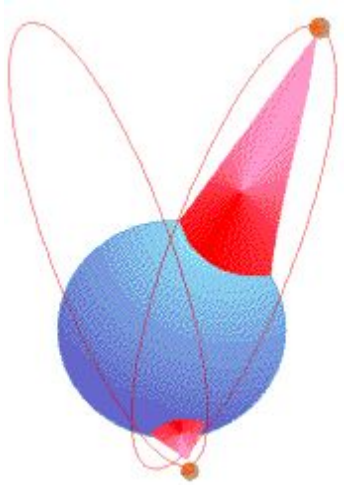

GEO (Inmarsat)
MEO (ICO)
HEO
LEO
(Globalstar,
Iridium)
Inner and outer Van
Allen belts
Earth
1,000
10,000
35,768
km

Recap Question?

- What is the difference b/n natural and artificial satellites?
- Explain the term uplink, downlink, orbit, foot print and transponder?
- What does it mean perigee?
- What are the three classification of satellites and explain their difference briefly?

HEO(Highly elliptical orbit) satellites

- **Highly elliptical orbit (HEO):** This class comprises all satellites with noncircular orbits.
- Currently, only a few commercial communication systems use satellites with elliptical orbits.
- These systems have their perigee over large cities to improve communication quality.



Routing

- A satellite system together with gateways and fixed terrestrial networks has to route data transmissions from one user to another as any other network does.
- two different methods
  - If satellites offer ISLs, traffic can be routed between the satellites.
  - If not, all traffic is relayed to earth, routed there, and relayed back to a satellite.
- routing with ISLs offer lower latency.
- The drawbacks of ISLs are higher system complexity due to additional antennas and routing hardware and software for the satellites

ISL - Inter Satellite Link

Localization

- Mechanisms similar to GSM(cellular networks) but here the ‘base stations’, i.e., the satellites, move as well.
- Gateways maintain several registers with user data:
  - HLR (Home Location Register): static user data
  - VLR (Visitor Location Register): (last known) location of the mobile station
  - SUMR (Satellite User Mapping Register):
    - stores the current position of satellites and
    - map each user(mobile station) to the current satellite.
- Functions of the VLR and HLR are similar to those of the registers in, e.g., GSM.

Localization…

- Registration of mobile stations
  - Mobile station sends a signal to one or more satellites.
  - Satellites receiving such signals report to gateway.
  - Gateway determines the location of the user.
  - request user data from HLR.
  - update VLR and SUMR.
- Calling a mobile station
  - Call is forwarded to a gateway. HLR/VLR are referred.
  - Using SUMR, the appropriate satellite can be found to setup the connection.

Handover

- important topic in satellite systems using MEOs and in particular LEOs.
- The handover is divided into four types:
  a) **Intra-satellite handover:** user moves between spot beams of the *same satellite*.
  b) **Inter-satellite handover:** If a user leaves the footprint of a satellite or if the satellite moves away, a handover to the *next satellite* takes place.
    - This might be a hard handover switching at one moment or a soft handover using both satellites (and even more) at the same time.
    - Inter-satellite handover can also take place between satellites if they support ISLs.

Handover…

c) **Gateway handover:** While the mobile user and satellite might still have good contact, the satellite might move away from the current gateway. The satellite has to connect to another gateway.

d) **Inter-system handover:** This type of handover concerns *different systems* (handover between terrestrial and satellite links). (vertical handover).

- seamless handover between satellite systems and terrestrial systems or vice versa is still a hot research issue .

Launching of satellite

The main steps in launching of a satellite are:

- The launch vehicle carries a satellite into space.
- Once in space, the satellite is separated from its carrier.
- Once on its own, the satellite is directed by its propulsion systems to reach the correct orbit.
- Once in the correct orbit, the satellite is considered successfully launched but not operational.
- To be operational, the satellite goes through a series of tests and system activations.
- Once operational, the satellite starts serving its users.

- Redundant hardware is usually installed in satellites for fault tolerance.
- satellites are built with technology that takes into consideration harsh space conditions.

Reading assignment

- Read about Frequency Allocations in Satellites.
- Ethiopia‘s Satellite Communication Earth Station.

Yuri Gagarin

- The first human to travel into space, and
- The first to orbit the earth.
- **April 12, 1961**. More than 50 years before today !