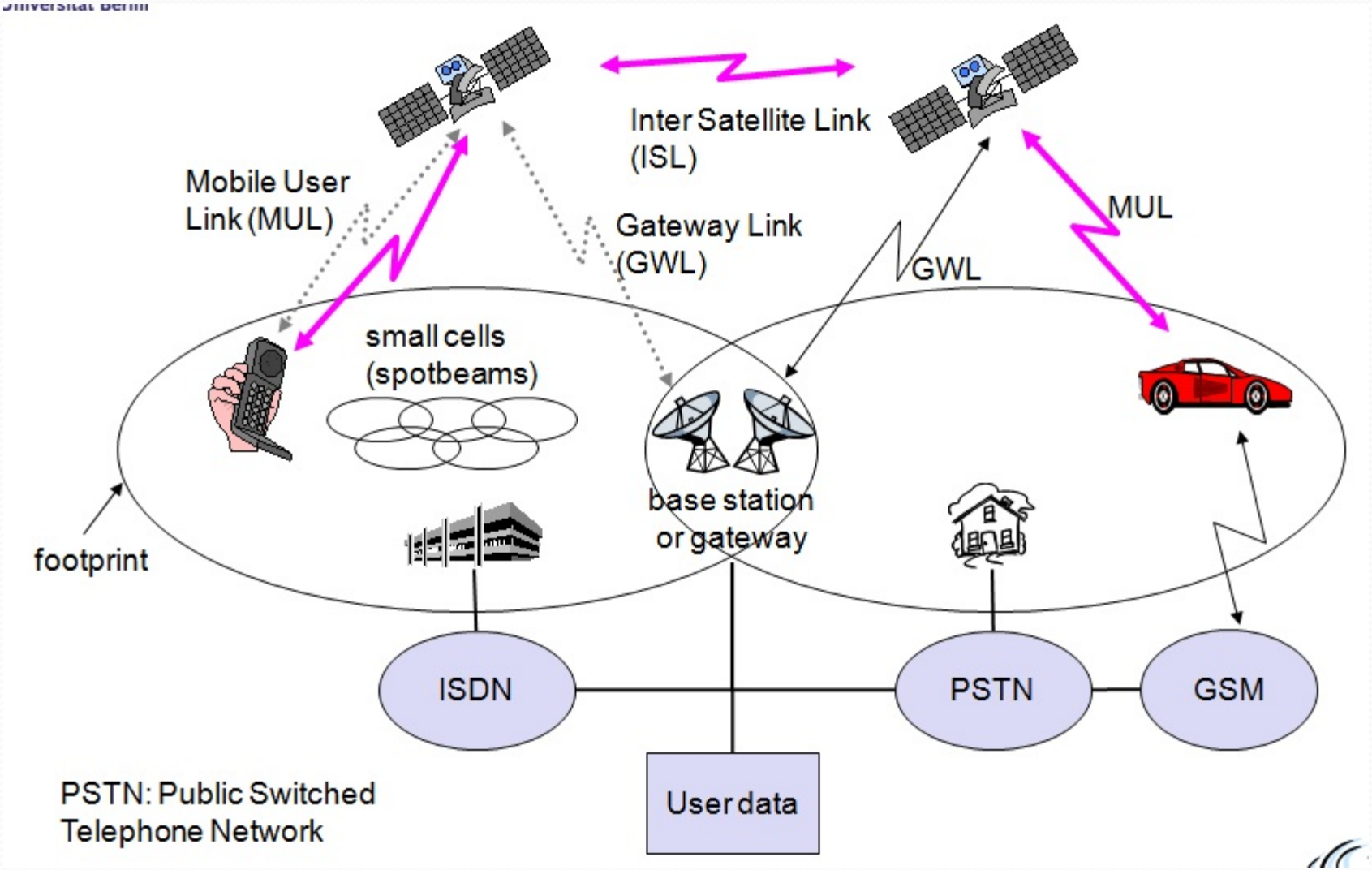
Mobile Computing – Satellite Systems

- 1945 Arthur C. Clarke publishes an essay about "Extra Terrestrial Relays"
- 1957 First satellite SPUTNIK
- 1960 First reflecting communication satellite ECHO
- 1963 First geostationary satellite SYNCOM
- 1965 First commercial geostationary satellite Satellit "Early Bird" (INTELSAT I): 240 duplex telephone channels or 1 TV channel, 1.5 years lifetime
- 1976 Three MARISAT satellites for maritime communication
- 1982 First **mobile satellite telephone system** INMARSAT-A
- 1988 First satellite system for **mobile phones and data communication** INMARSAT-C
- 1993 First **digital satellite telephone system**
- 1998 Global satellite systems for **small mobile phones**

Applications

- Traditionally
  - **Weather** satellites
  - **Radio and TV broadcast** satellites
  - **Military** satellites
  - Satellites for **navigation and localization** (e.g G.P.S)
- Telecommunication – Mobile
  - **Global telephone** backbone
  - Connections for communication in **remote places/under developed areas**
  - Global **mobile communication**

Classical satellite systems

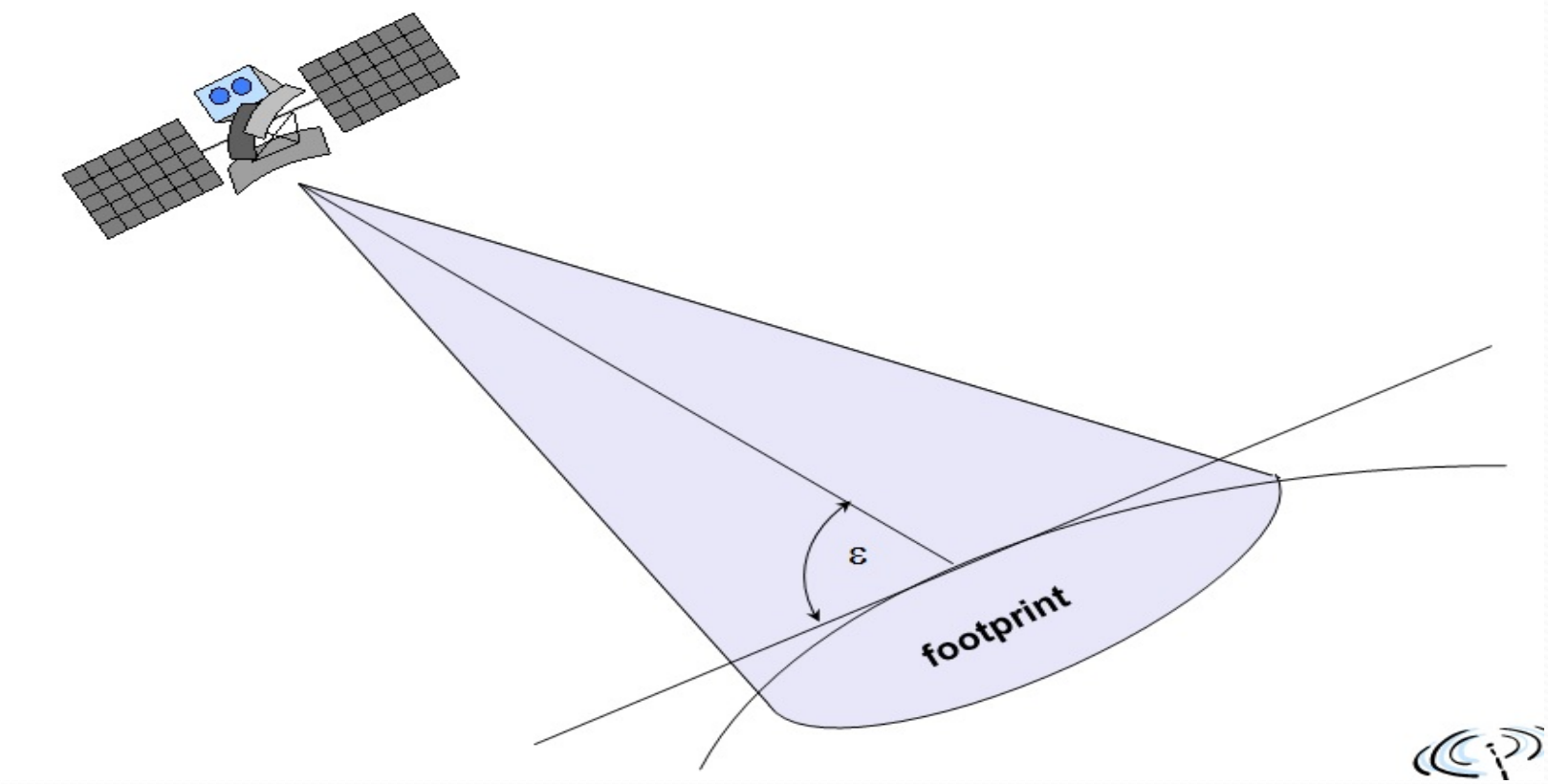


Basics of satellite Systems

- **Elliptical** or **circular** orbits
- Complete **rotation time** depends on **distance satellite-earth**
- **Inclination**: angle between orbit and equator
- **Elevation**: angle between satellite and horizon
- **LOS** (Line of Sight) to the satellite necessary for connection
  - High elevation needed, less absorption due to e.g. buildings
- **Uplink**: connection base station - **satellite**
- **Downlink**: connection satellite - **base station**
- Typically separated frequencies for uplink and downlink
  - **Transponder** used for sending/receiving and shifting of **frequencies**

Elevation

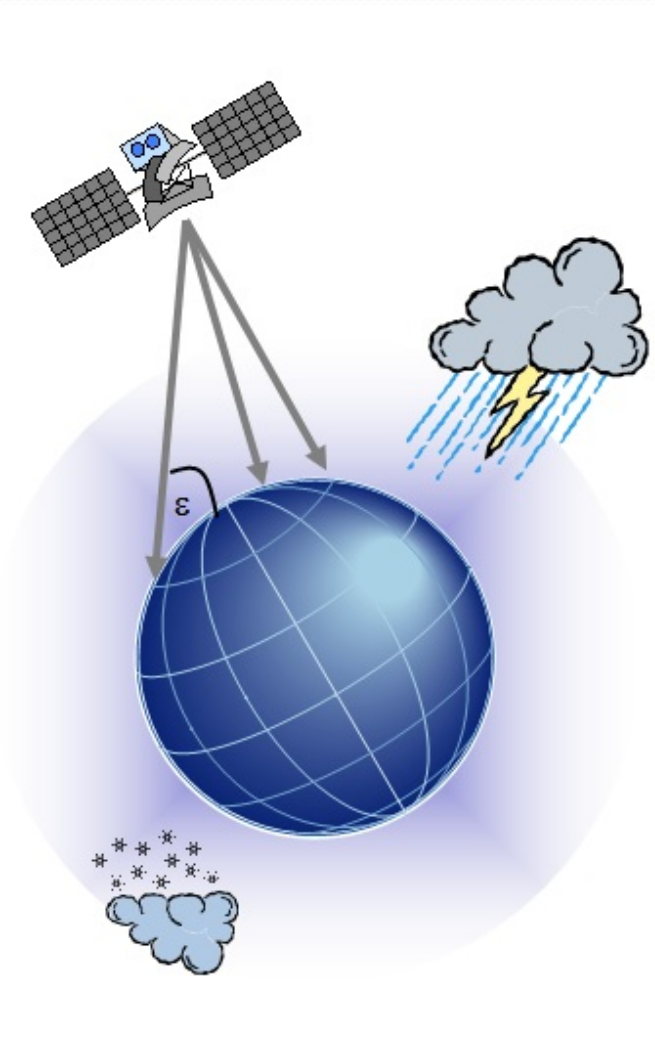
- **Elevation:** Angle between center of satellite beam and surface
- **Minimal elevation:** Elevation needed atleast to communicate with the satellite

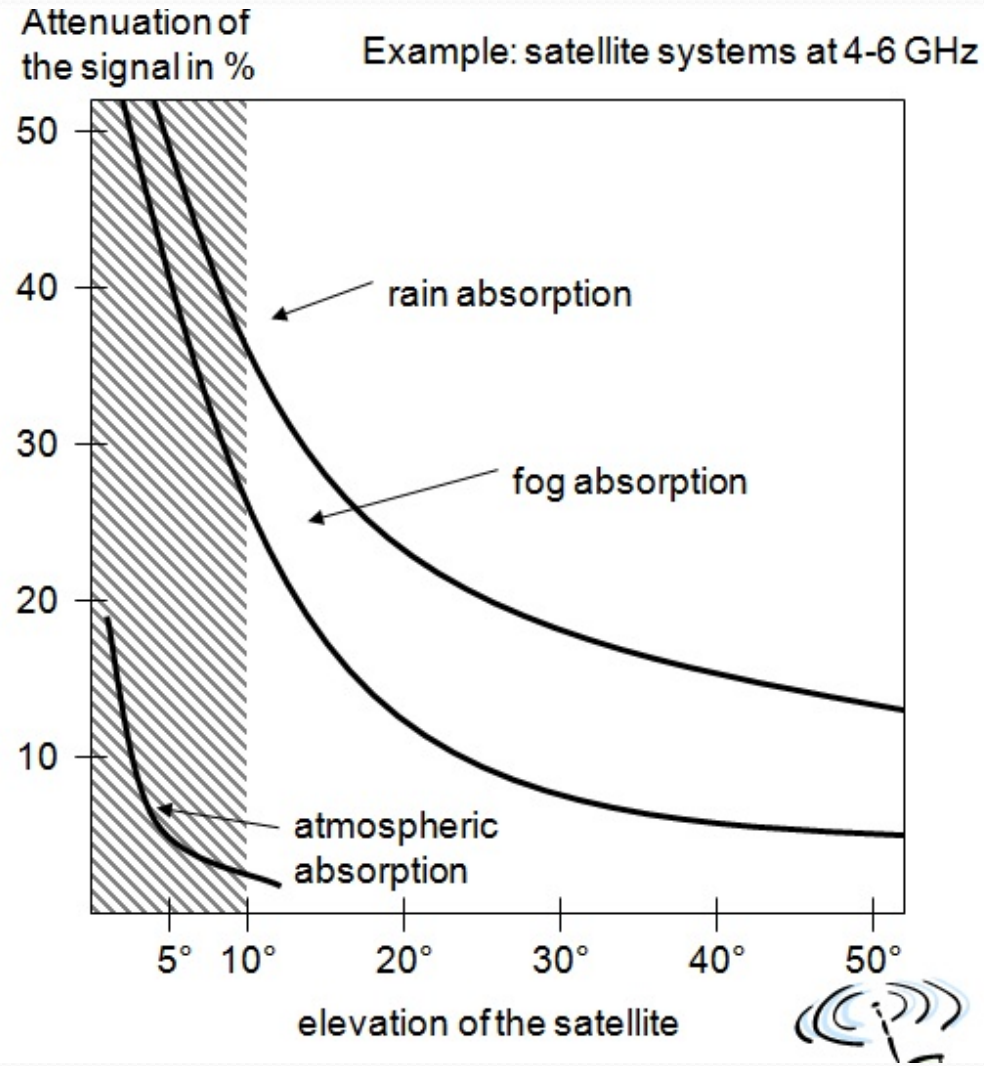


Factors Determining Satellite Systems

- **Parameters** like **attenuation** or received **power** determined by four parameters
  - **Sending power**
    - **Spreading**
  - **Gain of sending antenna**
  - **Distance** between sender and receiver
    - Based on gateway
  - **Gain of receiving antenna**
- **Problems**
  - Varying strength of received signal due to **multipath propagation**
  - Interruptions due to shadowing of signal (**no LOS**)

Atmospheric attenuation

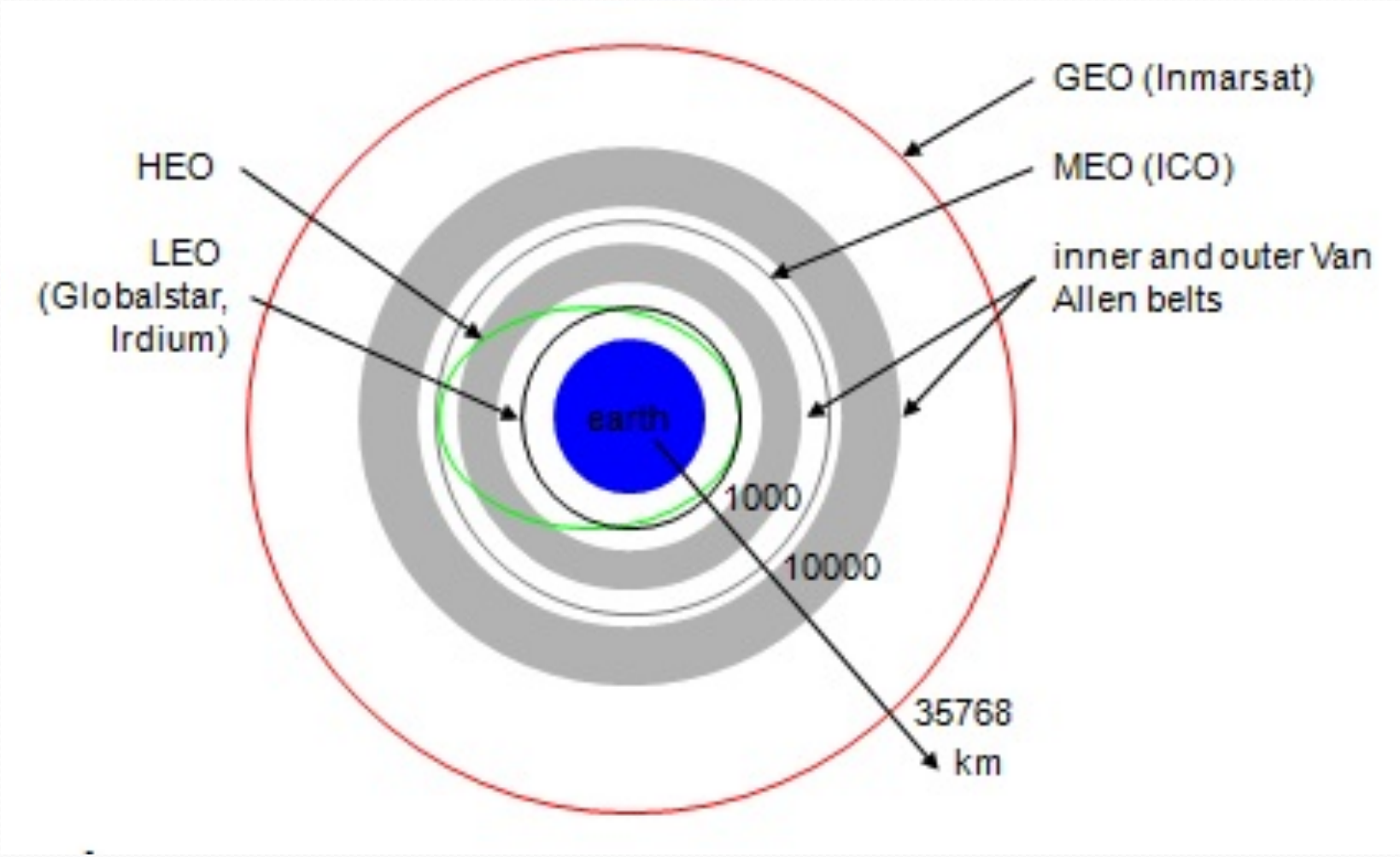




Satellite Orbits

- Four different types of satellite orbits can be identified depending on the shape and diameter of the orbit:
  - **Geostationary Earth Orbit (GEO):** 36000 km above earth surface
    - Most of TV & radio broadcast satellites
  - **Medium Earth Orbit (MEO):** 5000-12,000 km
    - Intermediate Circular Orbit (ICO)
  - **Low Earth Orbit (LEO):** 500-1500 km
  - **Highly Eliptical Orbit (HEO):** satellites with non-circular orbits.

Satellite Orbits



Geostationary satellites (GEO)

- Orbit 35.786 km distance to earth surface, orbit in equatorial plane (inclination 0°)
  - Complete rotation exactly one day, **satellite is synchronous to earth rotation**
    - **Fix antenna positions**, no adjusting necessary
    - Satellites typically have a **large footprint** (cover bigger area)
    - **High transmit power** needed
    - **High latency** due to long distance
  - Not useful for global coverage for small mobile phones and data transmission, typically **used for radio and TV transmission**

Low Earth Orbit (LEO)

- **Global radio coverage** possible
- **Smaller footprints**, better frequency reuse
- **Handover necessary** from one satellite to another
- **Many satellites** necessary **for global coverage**
- **More complex** systems due to moving satellites

Medium Earth Orbit (MEO)

- **Slower** moving satellites
- **Less satellites** needed
- **Simpler** system design
- For many connections **no hand-over needed**
- **Higher latency**
- **Higher sending power** needed
- **Special antennas** for small footprints needed

Routing

- **Satellite Routing**: Routing of data transmission from one user to another.
  - Two strategies:
    - **Between Inter satellite link (ISL)**
      - Traffic is routed **between the satellites**
      - **Advantage:** only one uplink and one downlink , offers lower latency
      - **Disadvantage: system complexity** due to additional antennas
    - **Relayed through earth station**
      - Traffic is routed between earth station and satellite
      - **Disadvantage:** two uplinks and two downlinks needed

Localization

- **Satellite gateways**: maintains several **registers**
- **HLR**: stores all **static information about a user** as well as his/her **current location**
- **VLR:** maintains the **last known location of a mobile user**
- **Satellite User Mapping Register(SUMR):** Stores the **current position of satellites** and a mapping of each **user to the current satellite**
- **Registration:** mobile station sends a signal which may be received by one or several satellites
  - Satellites receiving such signal report this event to gateway
  - Gateway determines the location of the user via the location of the satellites
  - User data is requested from the user's HLR, VLR & SUMR are updated

Handover

- Handover in satellite systems caused by the movement of satellites
- Four types
  - **Intra-satellite handover**
    - Handover from **one spot beam to another**
    - Mobile station still in the footprint of the satellite, but in another cell
  - **Inter-satellite handover**
    - Handover from one **satellite to another satellite**
    - Mobile station leaves the footprint of one satellite
  - **Gateway handover**
    - Handover from **one gateway to another**
    - Mobile station still in the footprint of a satellite, but gateway leaves the footprint
  - **Inter-system handover**
    - Handover from the **satellite network to a terrestrial cellular network**
    - Mobile station can reach a terrestrial network again which might be cheaper, has a lower latency etc