COMPUTER NETWORKS

- Chapter 2. The Physical Layer 4

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Outline

- Communication Satellites
  - Overview
  - Types
  - Frequencies
  - Major problems
  - Comparing to fibres, and
  - The future

Communication Satellites

- Satellites are like big microwave repeaters in the sky:
  - contain transponders: listen to some portion of the spectrum, amplify the signal and then rebroadcast at another frequency (to avoid interference with incoming signals)
- The higher the satellite, the longer the orbital period (time it takes to rotate around the earth)
  - near the surface of the earth, period approx 90 min
  - at 35 800km, the period is 24 hours (therefore stationary with respect to the earth's surface)
  - at 384 000km (where the moon is) the period is 1 month

Types of satellites

- GEO (Geostationary Earth Orbit) satellites:
  - each satellite typically has multiple downward beams focused on small geographical areas (such as South Africa) called spot beams. Used for TV (e.g. DSTV)
- MEO (Medium Earth Orbit) satellites:
  - 24 satellites used for GPS (Global Positioning System). Not used for telecommunications.
- LEO (Low Earth Orbit) satellites:
  - Iridium & Globalstar: systems of satellites used for global satellite telephones (ships, rural areas, etc).
  - Teledesic: used for Internet users, completely bypasses telephone system (packet switching in space)

GEOs

- Originally proposed by Arthur C. Clarke
- Circular orbits above the equator
- Angular separation about 2 degrees - allows 180 satellites
- Orbital height above the earth about 23000 miles/35000km
- Round trip time to satellite about 0.24 seconds

GEOs (2)

- GEO satellites require more power for communications
- The signal to noise ratio for GEOs is worse because of the distances involved
- A few GEOs can cover most of the surface of the earth
- Note that polar regions cannot be “seen” by GEOs

GEOs (3)

- Since they appear stationary, GEOs do not require tracking
- GEOs are good for broadcasting to wide areas

Major problems for satellites

- Positioning in orbit
- Stability
- Power
- Communications
- Harsh environment

Positioning

- This can be achieved by several methods
- One method is to use small rocket motors
- These use fuel - over half of the weight of most satellites is made up of fuel
- Often it is the fuel availability which determines the lifetime of a satellite
- Commercial life of a satellite typically 10-15 years

Stability

- It is vital that satellites are stabilised
  - to ensure that solar panels are aligned properly
  - to ensure that communications antennae are aligned properly
- Early satellites used spin stabilisation
  - Either this required an inefficient omni-directional aerial
  - Or antennae were precisely counter-rotated in order to provide stable communications
- Modern satellites use reaction wheel stabilization - a form of gyroscopic stabilization

Reaction wheel stabilisation

- Heavy wheels which rotate at high speed - often in groups of 4.
- 3 are orthogonal, and the 4th (spare) is a backup at an angle to the others
- Driven by electric motors - as they speed up or slow down the satellite rotates
- If the speed of the wheels is inappropriate, rocket motors must be used to stabilise the satellite - which uses fuel

Power

- Modern satellites use a variety of power means
- Solar panels are now quite efficient, so solar power is used to generate electricity
- Batteries are needed as sometimes the satellites are behind the earth - this happens about half the time for a LEO satellite
- Nuclear power has been used

Harsh Environment

- Satellite components need to be specially “hardened”
- Circuits which work on the ground will fail very rapidly in space
- Temperature is also a problem - so satellites use electric heaters to keep circuits and other vital parts warmed up - they also need to control the temperature carefully

Alignment

- There are a number of components which need alignment
  - Solar panels
  - Antennae
- These have to point at different parts of the sky at different times, so the problem is not trivial

Antennae alignment

- A parabolic dish can be used which is pointing in the correct general direction
- Different feeder “horns” can be used to direct outgoing beams more precisely
- Similarly for incoming beams
- A modern satellite should be capable of at least 50 differently directed beams

Satellite - satellite communication

- It is also possible for satellites to communicate with other satellites
- Communication can be by microwave or by optical laser

LEOs

- Low earth orbit satellites - say between 100 - 1500 miles
- Signal to noise should be better with LEOs
- Shorter delays - between 1 - 10 ms typical
- Because LEOs move relative to the earth, they require tracking

Orbits

- Circular orbits are simplest
- Inclined orbits are useful for coverage of equatorial regions
- Elliptical orbits can be used to give quasi stationary behaviour viewed from earth

Communication frequencies

- Microwave band terminology
  - L band 800 MHz - 2 GHz
  - S band 2-3 GHz
  - C band 3-6 GHz
  - X band 7-9 GHz
  - Ku band 10-17 GHz
  - Ka band 18-22 GHz

Early satellite communications

- Used C band in the range 3.7-4.2 GHz
- Could interfere with terrestrial communications
- Beamwidth is narrower with higher frequencies

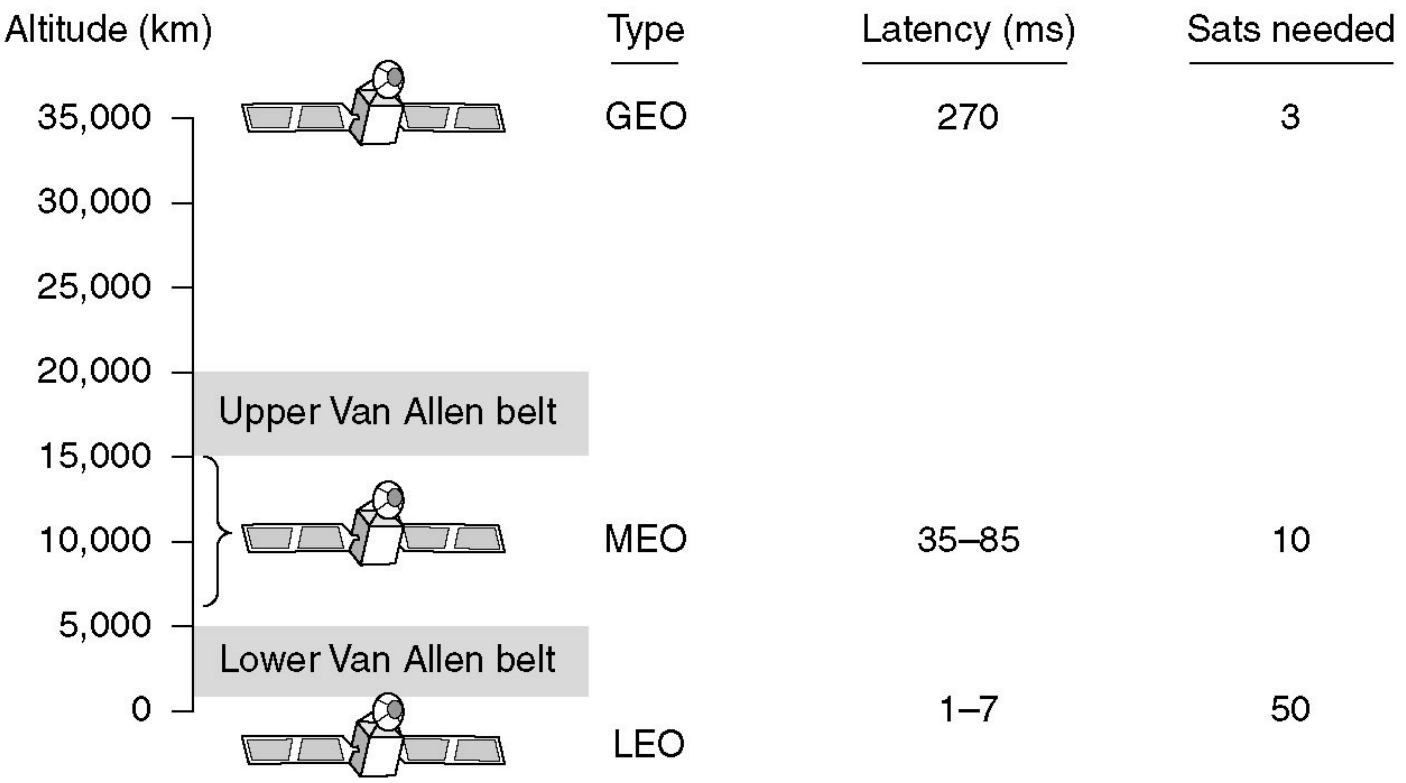
More recent communications

- Greater use made of Ku band
- Use is now being made of Ka band

Satellite management

- Satellites do not just “stay” in their orbits
- They are pushed around by various forces
- They require active management

Communication Satellites



Communication satellites and some of their properties, including altitude above the earth, round-trip delay time and number of satellites needed for global coverage.

Satellites vs. Fiber

- Satellites give users more bandwidth in practice:
  - A single fiber has (in principle) more bandwidth than all the satellites.
  - But in reality, this bandwidth is not available to all users (fiber used by telephone companies to share many calls)
  - A single user can put up a dish and have high bandwidth using Teledesic.
- Satellites have particular specialist uses:
  - mobile communication: where there is no cell phone reception, can use satellites
  - broadcasting: a message sent by satellite can be sent (cheaply) and received by thousands of ground stations at once.
  - other areas: hostile terrain, rapid deployment, etc.

The future

- Because Iridium has not been a commercial success the future of satellites is uncertain.
- Satellites still have major advantages for wide area distribution of data.

Summary

- Communication satellites have many advantages over other transmission media.
- Communication satellites have three types: GEO, MEO and LEO, each deployed with different goal .
- Different bands are divided and utilized in a variety occasions.