SATELLITE BASED MOBILE COMMUNICATIONS
Advanced Technology in Radio Communications

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Summary

- Introduction
- Global constellations: design
- Big LEO systems for voice services
- Wideband systems
  - Not GEO (ICO) and GEOs
- Future trends

Introduction

- Mobile communications satellites:
  - GEO (Inmarsat, bag terminals) vs LEO and MEO
- Hugh amount of LEOs because of commercial activity
  - Although there were economic troubles with ICO and Iridium (1º)
- Objectives:
  - Global media, quick, ubiquitous, cheap
  - Cellular terrestrial network complement (duality)
  - Integration in future terrestrial standards: UMTS
  - ‘handy’ terminals (like terrestrial mobiles)
  - Potential customers: executives, areas without infrastructures, crude oil companies, mines, environmental disasters.

Classification

- By service (and given band by ITU)
  - Narrow band (Little LEOs): operatives and commercials
    - It is not necessary real time during the communication process: store & forward (the opposite of bent-pipe)
    - Terminals like paging or beeper ones
    - e-mail communication, small amount of data
  - Voice (Big LEOs): huge expectation and commercial failure
    - It requires short delays and high power to reduce terminals that will be similar to terrestrial mobiles
  - not GEO wideband: in progress, a great investment
  - GE0 wideband: high capacity and ISL
    - Wideband systems will give services to semi-fixed terminals, usually not ‘handy’

Mobile orbits: GEO

- High congestion of orbital activity
  - More interesting areas are in Europe and America
- Launch systems more expensive
- High delays
  - Both ways ~600 ms (voice and error correction)
- Big and powerful satellites, easy tracking
- Propagation losses much more higher
  - Higher power transmissions
  - Big antennas in Earth
- Low latitude coverage above 81º
  - Most of capitals are above 45ºN, so elevation grades<40º, what is impossible in urban areas

Mobile orbits: LEO

\+ They improve GEO disadvantages

\+ There can be completely globals (poles)

\+ Lightweight satellites, cheap launch

\- More complexity in constellation
  - Great amount of satellites (from 60 to 90 in LEO)

\- More complicated maintenance
  - High dinamic tracking from Earth
  - Atmosphere effect, stabilization

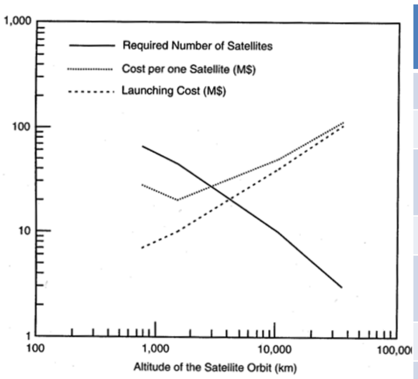
\- Doppler displacement in frequency
  - for h≈800km, v≈7000 m/s in LEO

\- handover/handoff processes: cell change

Mobile orbits: MEO

+ Compromise between LEO and GEO
+ Smaller complexity in constellation than LEO
  - Small satellite number (from 10 to 15)
- Satellites are easier than LEO and GEO
- The same disadvantages that LEO and GEO but there are attenuated
  - Maintenance
  - Doppler frequency displacement (but smaller than LEO)
  - handover/handoff processes: cell change
  - More important delay than LEO

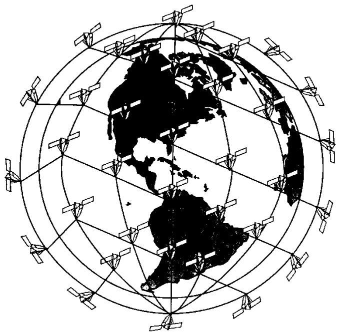
Constellations

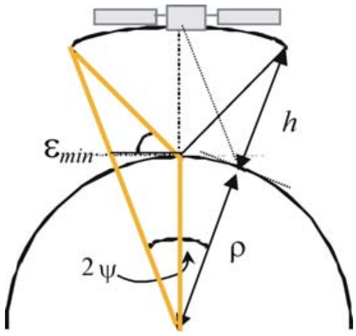


item\type of orbit	LEO	MEO	GEO
Satellite cost	Maximum	Minimum	Maximum
Lifetime	3-7	10-15	10-15
Handy terminal	Possible	Possible	Very difficult
Delay	Low	Medium	High
Propagation losses	Low	Medium	High
Network	Complex	Medium	Simple
Hand-off	Frequent	Medium	Not used
Development period	long	Medium	Long
visibility	short	Medium	Permanent

Global constellations: design

- Objective: #satelites by every constellation
- We start from some conditions: *h* and ε_{min}





Constellations design

- Starting from *h* and ε_{min} (minimum elevation angle), we calculate the coverage area (spherical hexagon)
- First step is calculate ψ angle
- Law of sines in triangle

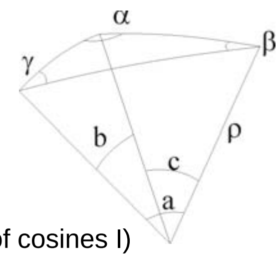
$$\frac{\sin(\alpha)}{a} = \frac{\sin(\beta)}{b} = \frac{\sin(\gamma)}{c}$$

(law of sines in plane trigonometry)

$$\frac{\sin(\varepsilon_{\min} + \pi/2)}{\rho + h} = \frac{\sin(\pi - \psi - \pi/2 - \varepsilon_{\min})}{\rho} \Rightarrow \psi = \pi/2 - \varepsilon_{\min} - \arcsin\left(\frac{\rho}{\rho + h}\cos(\varepsilon_{\min})\right)$$

Constellations design

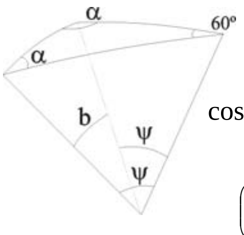
- Spherical trigonometry



$$\frac{\sin(\alpha)}{\sin(a)} = \frac{\sin(\beta)}{\sin(b)} = \frac{\sin(\gamma)}{\sin(c)}$$ (law of sines)

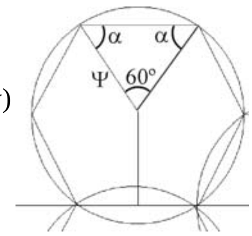
$$\cos(\alpha) = -\cos(\beta)\cos(\gamma) + \sin(\beta)\sin(\gamma)\cos(a)$$ (law of cosines I)

$$\cos(a) = \cos(b)\cos(c) + \mathrm{sen}(b)\mathrm{sen}(c)\cos(\alpha)$$ (law of cosines II)



$$\cos(\alpha) = -\cos(\alpha)\cos(60) + \sin(\alpha)\sin(60)\cos(\psi)$$

$$\left(\frac{1+\cos(60)}{\sin(60)\cos(\psi)}\right) = \frac{\sin(\alpha)}{\cos(\alpha)} \Rightarrow \alpha = \arctan\left(\frac{\sqrt{3}}{\cos(\psi)}\right)$$



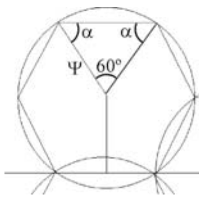
Constellation design

- Spherical hexagon area
  - 6 spherical triangles
  - Spherical triangle area=ρ^2*exceeded angle

$$A\,triangle = \rho^2(\alpha + \beta + \gamma - \pi)$$ (spherical triangle area)

$$A = 6\rho^2(excess) = 6\rho^2(2\alpha - 2\pi/3)$$ (spherical hexagon area)

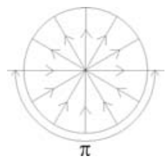
$$N = \frac{4\pi\rho^2}{6\rho^2(2\alpha - 2\pi/3)} = \frac{\pi}{3\alpha - \pi}$$



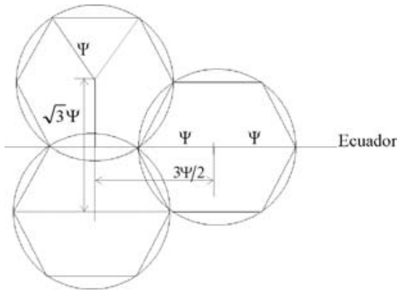
- Satellite number lower limit
  - We will take a bigger number of satellites (orbital planes)

Constellations

- Approximation by orbital planes
  - It is better for launch
  - It is better for satellite redundancy



- If we choose polar orbits, the number of Ω planes in Equator (worst case)



$$\Omega = \frac{\pi}{3\Psi/2} = \frac{2\pi}{3\Psi}$$

$$n' = \frac{2\pi}{\sqrt{3}\Psi}$$

$$N = \frac{2\pi}{3\psi}\frac{2\pi}{\sqrt{3}\psi}$$

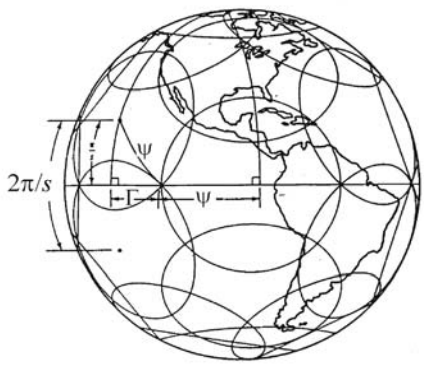
Constellations

- Improvement of plane models having considered the s contrarotating planes is # by plane

$$\cos(a) = \cos(b)\cos(c) + \sin(b)\sin(c)\cos(\alpha)$$

$$a \equiv \psi, \quad b \equiv \Gamma, \quad c \equiv \pi/s, \quad \alpha = \pi/2$$

$$\cos(\Gamma) = \frac{\cos(\psi)}{\cos(\pi/s)} \qquad (\Omega - 1)(\Gamma + \psi) + 2\Gamma = \pi$$



- Minimizing

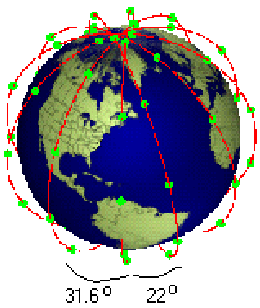
$$\Omega \approx \frac{2\pi}{3\psi} \qquad s \approx \frac{2\pi}{\sqrt{3}\psi}$$

Big LEO systems for voice services

- Power and BW enough for telephony
- Frequencies (1600 uplink; 2500 downlink)
- Dual terminals
  - With GSM, DECT, PCS, UMTS
  - To give an adequate coverage in urban area
- Potential users
  - Businessmen
  - Remote areas from terrestrial mobile coverage
  - Disaster areas
- Added value fax and messenger services

Iridium

- 66+6 LEO poles *i*=86.4º, *h*=780km,T=100m, v=28000 km/h



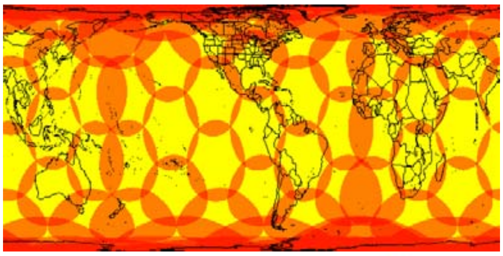
At least 1 clear satellite

6 orbital planes

48 Sub-beams/satellite

3168 cells

2150 operatives (poles, Cuba)



Iridium

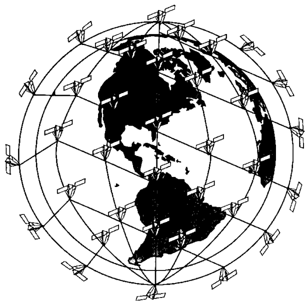
- System developed by Motorola
- Technology: the state of the art
- It implements ISL links
- Smater satellites:
  - OBP (On-Board Processing)
  - It covers oceanic area because it does not need any station
  - Small # of terrestrial stations (15-20)
- FDMA-TDMA-TDD
  - It uses different frequencies with TDMA and time division duplex
- Handoff types:
  - Intrabeam, interbeam, inter-satellite

Iridium

- Elongated (4.5m) and special shapes in order to multiple launches
- 689 Kg (with fuel)
- 5-7 years of life
- Stabillization with 3 axles
- 4 xlink Ka panels
  - 2 fixed, 2 adjustables
- 3 L user band panels
- 4 Ka terrestrial station reflectors

Iridium: ISLs (23.18 - 23.38 GHz)

- It permits traffic routing (25 Mbps)
- Intraplane: simple (fixed planes)
- Interplane: complex (adjustable planes)
  - Adjustable distances and positioning
  - It switch off in contra-rotating planes, y>60º



Dimensions:
158x62x59 mm

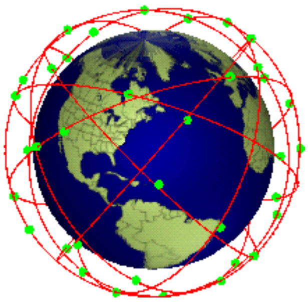
Iridium: Iridium NEXT

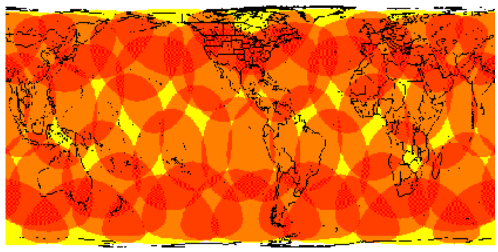
- Higher speed data
- New services and devices
- Advantages of IP technology
- Backwards compatibility with mobiles of today, devices and applications.
- EMSS (Enhanced Mobile Satellite Service) with the US Department of Defense.
- They are planned to start the launches in 2015.

Wide spectrum sensors:
Deforestation, desertified land,
Ocean colour

Globalstar

- 48+8 LEO not polar *i*=52º, *h*=1414 km, *T*=114 m
- Bad coverage in extreme latitude areas
- Simple satellites: it requires terrestrial networks
- More overlapping: 2 or more clear satellites





Globalstar

- Main partners:
  - Alcatel, Vodafone, Loral, Qualcomm y otros
- Terrain segments with > 100 stations
- Communication depends upon gateways to the Public Switched Telephone Network (PSTN)
- Very simple satellites (≠ Iridium)
- Weight: 450 kg each one
- CDMA/FDMA/FDD in user links, FDM/FDMA in base station
- Optimized handover : soft handover

Dimensions: 224x65,5x50 mm

Globalstar 2

- Launched in 6th February 2013
- 6 satellites
- Weight: 693 kg each one
- Lifetime: 15 years
- LEO not polar *i*=52º, *h*=1414 km
- Total constellation: 24 satellites
- 16 transponders in C-S bands, and 16 receivers in L-C bands
- 400000 users in 120 countries

Wideband systems

- Not GEO (ICO, Inmarsat) and GEOs (Thuraya, Solaris, ICO mim)
- Global use (ICO, Inmarsat) and regional use (Thuraya, ICO mim)
- Mobile telephony
- GPS
- High speed data (DSL) Digital Subscriber Line
- Fax
- Digital Video Broadcasting - Satellite services to Handhelds (DVB-SH in Europe, ATSC-M/H in USA)
- Emergency communications

ICO

- Promoted by Inmarsat, now commercial
- 10+2 in ICO i=45º, h=10390 km, T=6h

163 Sub-beams/satellites

2 orbital planes +45º/-45º

It was planned to launch more satellites on 2008 (ICO mim)

Lesson 5. Mobile Communications via Satellite

ICO

- It uses MEO orbits, as a compromise solution
- TDMA: Higher power, irregularity
- Compatible (GSM, JDC, DAMPS)
- Bent-pipe satellites and big antennas
- 12 terrestrial stations : ICONET network
  - Owner terrestrial network
- Late development, but experienced one
- TRW (Odyssey), ex-competitor partner
- New platform: ICO mim

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ICO mim (mobile interactive media)

- Regional satellite communications supplier focused on continental area of the USA, Alaska, Hawaii, Puerto Rico and Virgin Islands.
- Digital Video Broadcasting - Satellite services to Handhelds, interactive browsing and emergency communication systems.
- It uses GEO orbits, as a compromise solution.
- ICO G1, launched in April of 2008.
- Nowadays it is on Geosynchronous Transfer Orbit (GTO).

Inmarsat

- Originally, Intergovernment agency, nowadays, private company in the UK.
- 11 geostationary satellites (85% of Earth).
- New generation satellites of Inmarsat, F1 and F2 (as known as I4) are the biggest commercial satellites of telecommunications since today.

Dimensions: 130 x 50 x 32 mm

Thuraya

- Regional satellite communications supplier focused on Europe, Middle East and Africa (Thuraya-2) and in the southeast of Asia and Oceania (Thuraya-3).
- It actually works because of two satellites in geostationary orbit (the last was launched in 2008).
- Company matrix came from United Emirates.
- Number of subscribers in March of 2006 was 250.000 with more than 320.000 sold terminals since the launch in 2001.

Thuraya

- Voice mobile communications.
- SO-2510 and SO -2520 satellite mobile phone or fixed terminals.
- SMS service.
- 9.6 Kbps for data or fax.
- 144 Kbps of high speed data through a mobile sized terminal commercially known as ThurayaDSL.
- GPS in terminals where supported is available.

Dimensions: 118x53x19 mm

Vizada

- Independent supplier of global mobile services based on satellites.
- It is part of Astrim Services (EADS) since August of 2011, worldwide leader company in secure communications via satellite and commercial communications for military and governmental customers.
- It offers communication via satellite for maritime services(commercial, fishing, leisure time and military).
- It works with: Inmarsat, Iridium, Thuraya, Eutelsat, Intelsat, Loral, New Skies and SES Americom.
- 200.000 users: merchant ships, emergency organizations, military units, global media companies, Internet and telecommunication access suppliers; commercial,military and civil flights.

Solaris Mobile

- Eutelsat and Ses Astra combine initiative.
- Regional supplier of satellite communications focused on Europe.
- Digital Video Broadcasting - Satellite services to Handhelds (DVB-SH).
- DVB-SH uses S band, adjacent to UMTS band.
- Mixed architecture: information broadcasting, aplications and services via satellite and redirecting to handhelds directly or through terrestrial repeaters.

Solaris Mobile

- W2A satellite.
- Communication equipment with almost six tons of weight made by Thales Alenia Space in Cannes (France).
- Launched in April of 2009.
- Ku, C and S bands (the last band for transmission from TV to mobile phone).

Lesson 5. Mobile Communications via Satellite

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