



Block I: Fundamentals

## Topic 2: *wireless technologies*

Mobile Internet

Master in Computer Engineering



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Dpt. Signal Theory, Telematics and Communications



one. Basic concepts

two. IEEE 802.11

3. Bluetooth

Four. Zigbee

5. NFC

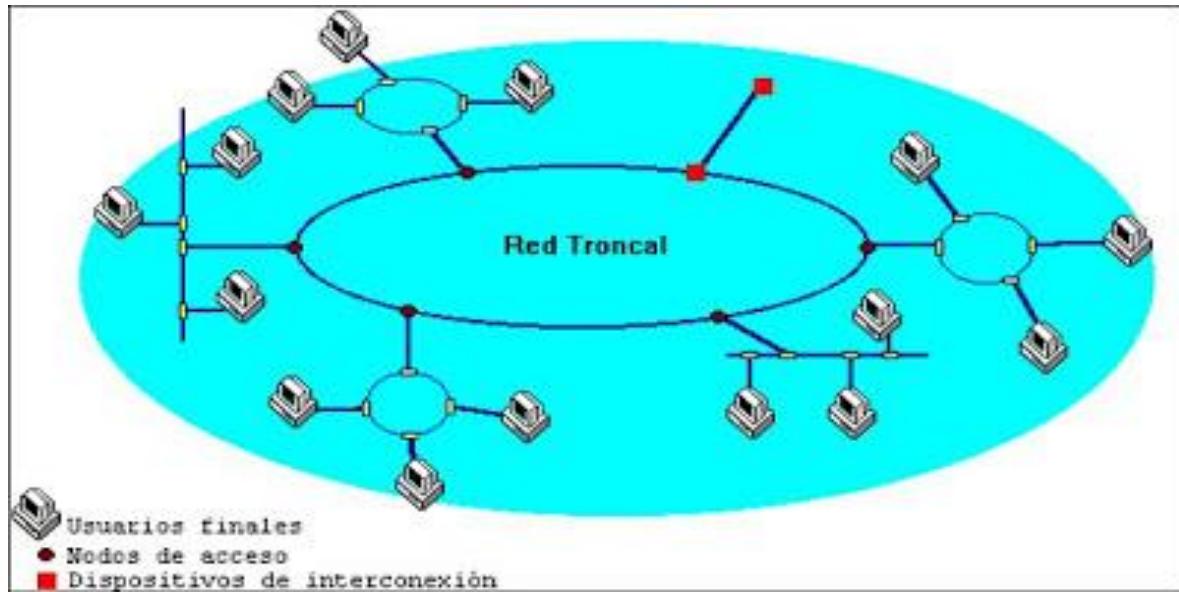
6. cellular systems

7. WiMAX

8. satellite systems

# 1. Conceptos básicos

- Types of networks:
  - *Size*: BAN / PAN / HAN / LAN / MAN / WAN
  - *End*: data / voice / storage / ...
  - *Medium*: wired / fiber / wireless / microwave ...
  - *topology*: bus / point-to-point / ring / ...
  - *Hierarchy*: user / access / transport



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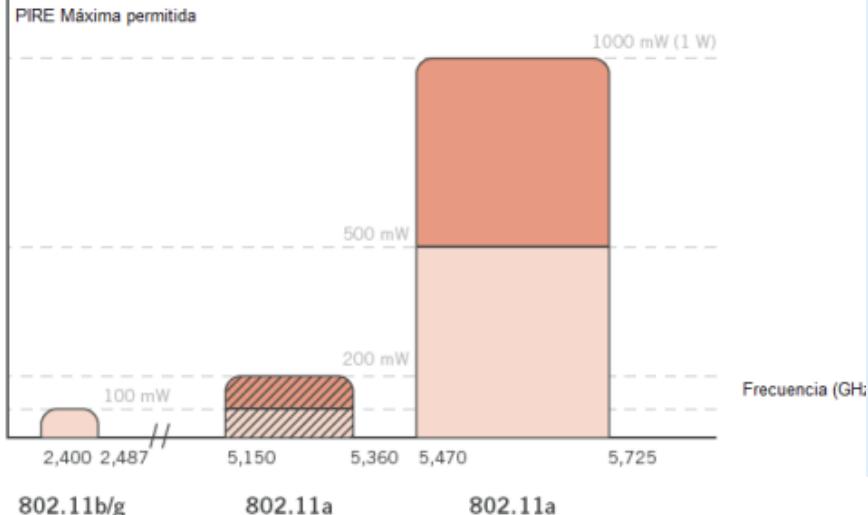
7. WiMAX

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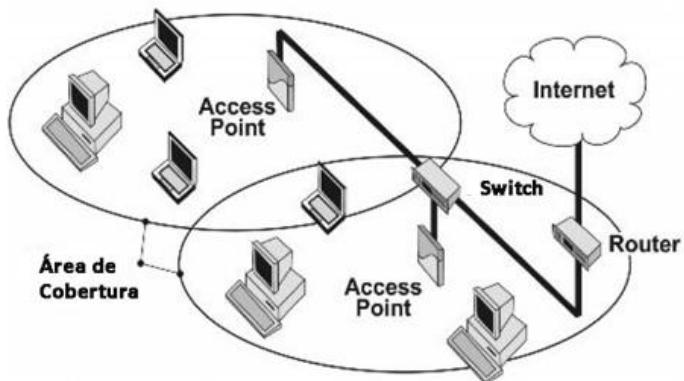


## 2. IEEE 802.11 (i)

- systems:

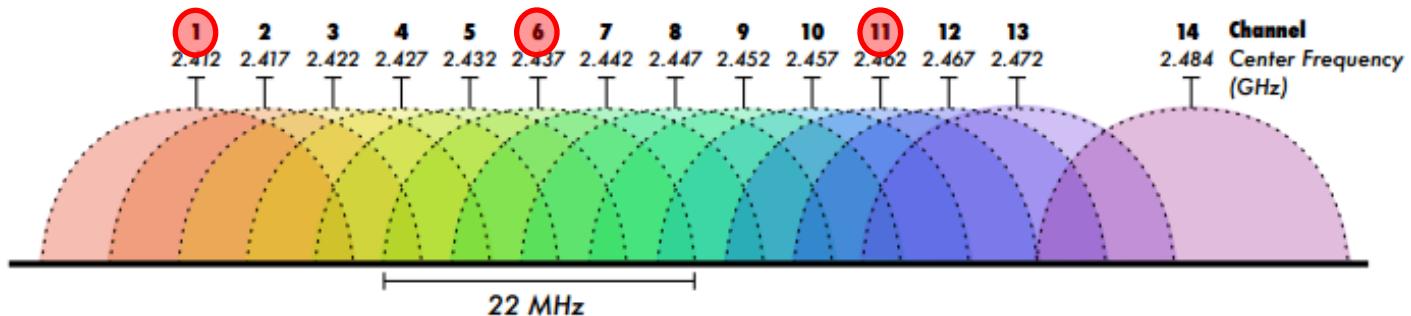


- Infrastructure  
vs. ad hoc:

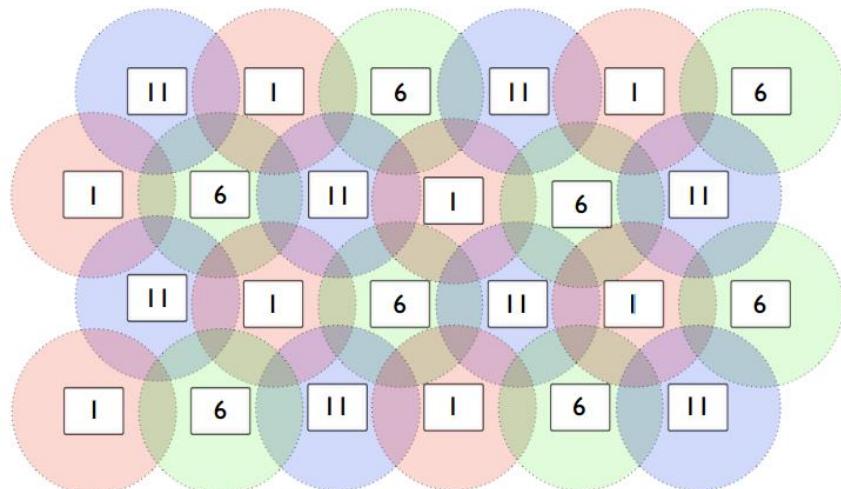


## 2. IEEE 802.11 (ii)

- ISM 2.4 GHz band (22 MHz / channel; 5MHz separation)
  - Spanish Regulation (NTFA): A-85 (2400-2483.5 MHz)  
A-128 (5 GHz)

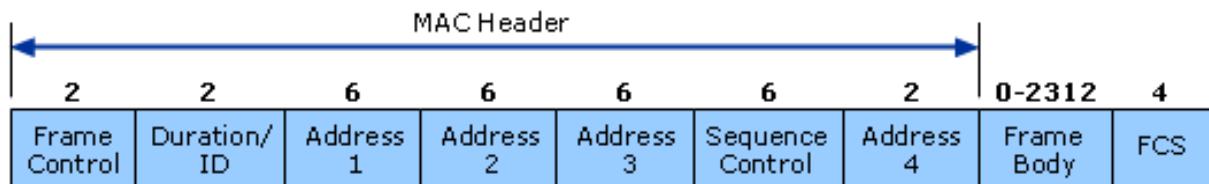


- Frequency reuse AP:

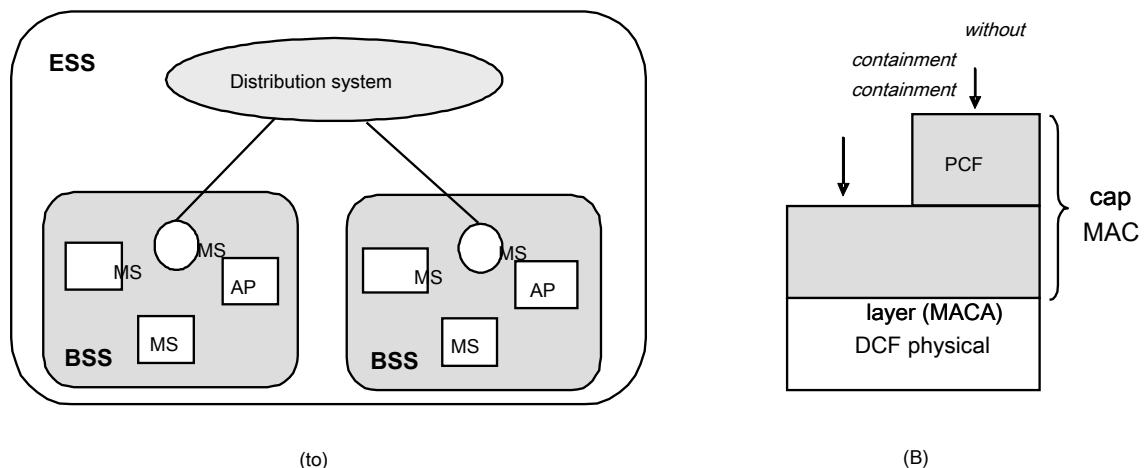


## 2. IEEE 802.11 (iii)

- MAC frames:

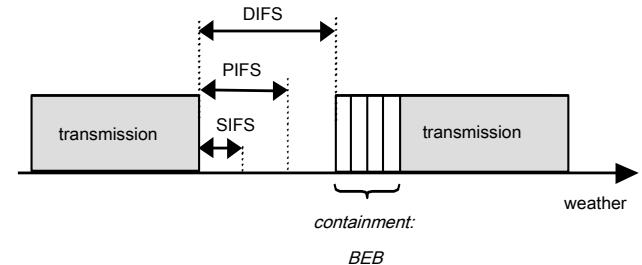
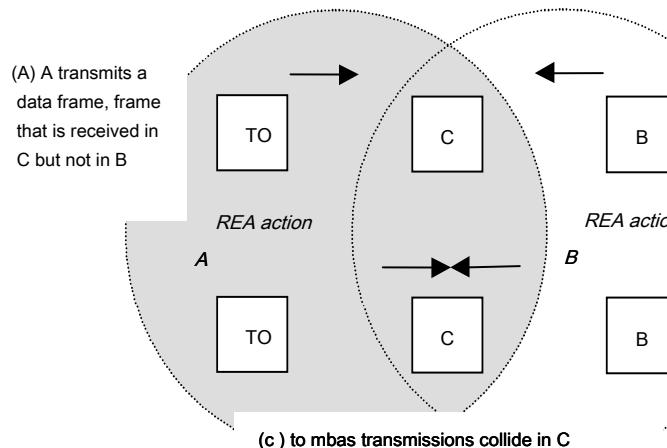


- Architecture (a): ESS BSS + + distribution system
- Protocols (b): DCF (MS) + PCF (AP) • DFWMAC



## 2. IEEE 802.11 (iv)

- Access PCF (AP): MS survey
- Access DCF (MS):
  - CSMA and the hidden station problem
  - CSMA / CA • Polling virtual carrier (RTS + CTS)



- 802.11 Access: CP + PIC • superframe
- IEEE 802.11 Security • 802.11i



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### 3. Bluetooth (i)



- wireless PAN
- He moved to IrDA ( *Infrared Data Association*)
- Originally defined in IEEE 802.15.1
- Initial rúnicas of *Harald Blatand*
- 24 Mbps USB 3.0 + HS ( *high speed*)
- Applications several leisure and professional

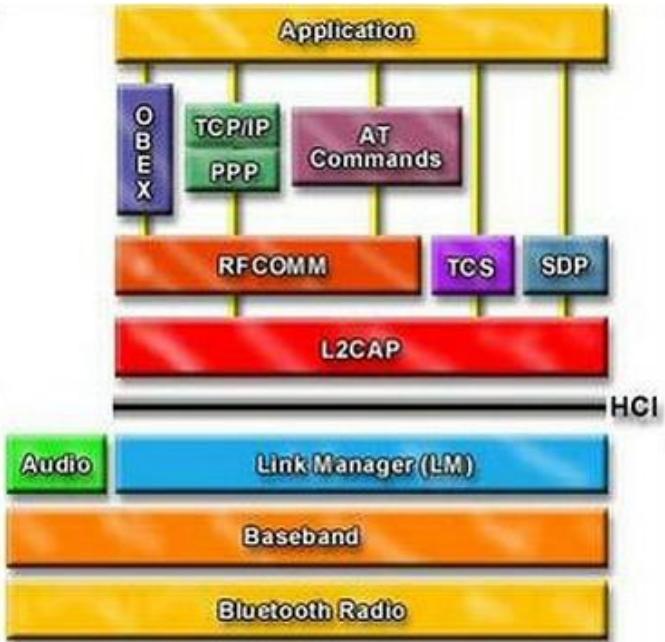
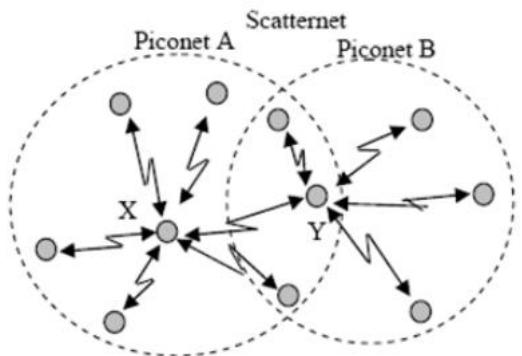


- 3 classes:

Clase	Pot. Máx.	Pot. Mín.	Alcance
1	100 mW	1 mW	100 m
2	2,5 mW	0,25 mW	10 m
3	1 mW	NA	1 m

## 3. Bluetooth (ii)

- Protocol stack



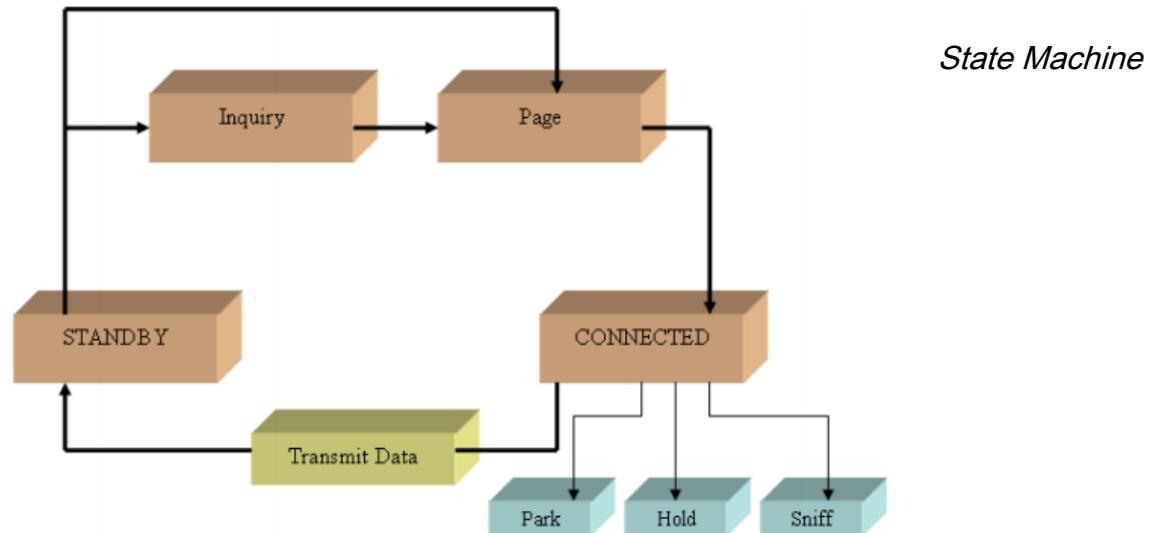
- Physical aspects

- ISM band, from 2400 to 2483.5 MHz
- Access AFHSS (1,600 Changes / s)
- 79 channels 1 MHz and  $625 \cdot s$
- Piconet: 7 devices + master (sync)
- synchronized shipments (SCO) and asynchronous (ACL)

## 3. Bluetooth (iii)

- *LMP*: Radio Link Control

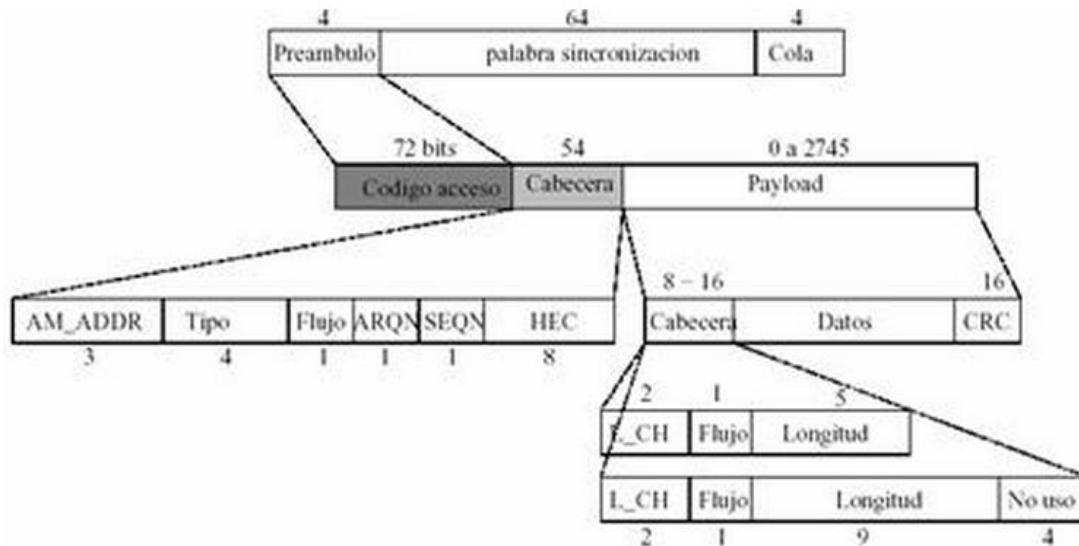
- Services: discovery, connection, authentication
- modes: *sniff*, Waiting, "parked"



- *A2DP*: Advanced Audio Distribution
- *AVRCP*: control *streaming* Audio and Video

### 3. Bluetooth (iv)

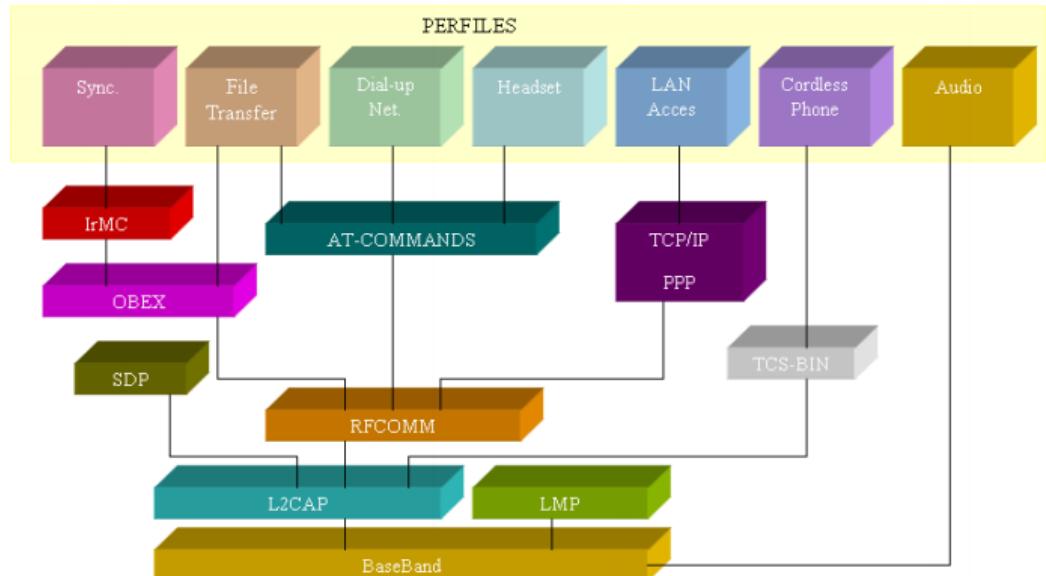
- *HCI*: device discovery ( *inquiry*) + Connection
- *L2CAP*: multiplexing logical connections / channels
  - Channel • Protocol
  - Packages up to 64 kB:



- *RFCOMM*: serial port emulation on L2CAP

## 3. Bluetooth (v)

- *SDP*: service discovery client-server
- *TCS*: call control voice and data telephony
- Bluetooth profiles



- Security:
  - Modes 1 (no), 2 (L2CAP) and 3 (LMP)
  - Pairing with PIN encryption key to generate:  
 $\text{PIN} + \text{length} + \text{número\_aleatorio} \cdot \text{E22 algorithm}$
  - challenge-response authentication from the key



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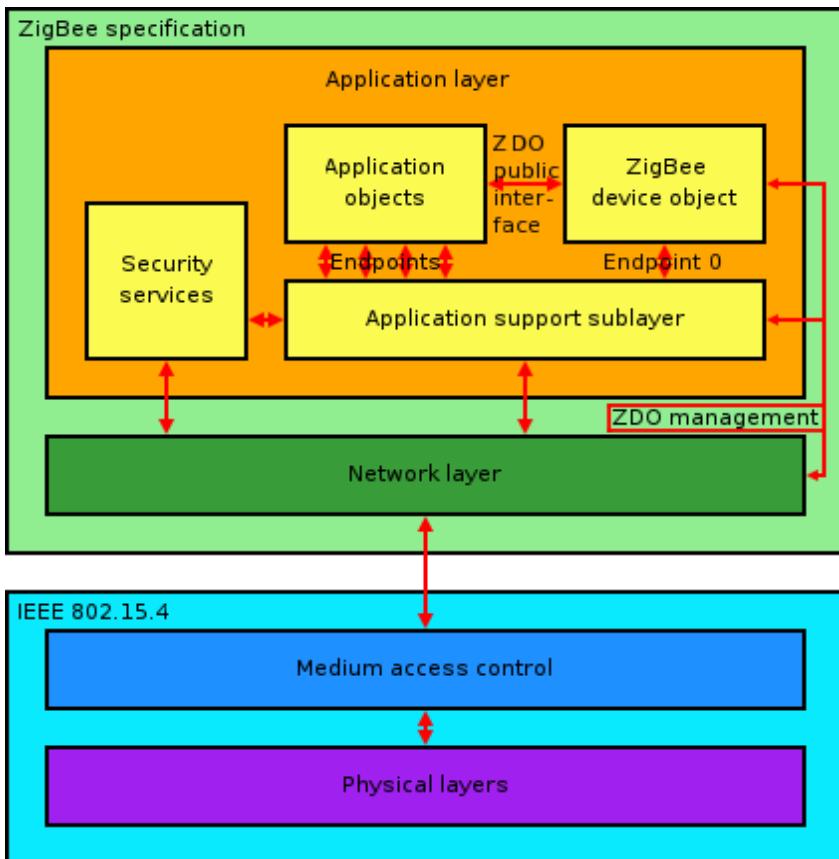
## 4. Zigbee (i)



- Based on IEEE 802.15
- Low-power Radio Communications
  - (Wider by configurations *mesh*)
- Simple and low-power Bluetooth and WiFi
- Mainly oriented monitoring and control
- ISM band: 868 MHz (20 kbps) - 2.4 GHz (250 kbps)
- Star topologies, tree and *mesh*
- *ZigBee device objects (ZDO):*
  - Coordinator (ZC)
  - *router (ZR)*
  - end device (ZED)

## 4. Zigbee (ii)

- Layers structure:
  - Radio:
    - 5 MHz / channel
    - CDMA, OQPSK
    - 10-20 m (1,500 m)
  - MAC (IEEE 802.15.4):
    - transmissions *beacon and non-beacon* (CSMA / CA)
    - So active sleep <30ms
  - Net:
    - *routing*: AODV
  - Application:
    - ZDO: Managing devices
    - APS: Services interface devices
    - Up to 240 objects / application device
    - Device Discovery
    - Security: 128-bit keys for encryption and integrity CBC-MAC





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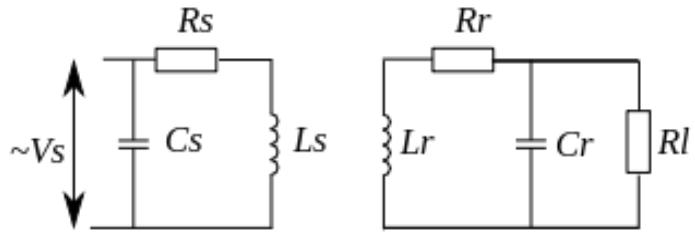
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## 5. NFC

- NFC Forum (Nokia, NXP Semiconductor, Sony)
- ISO / IEC 18092 on ISO / IEC 18000-3:
  - Resonant power transfer ( • 10-50cm):



- 13.56 MHz • 7 kHz, 106-424 kbps
- active communications vs. passive (RFID tags; 96-4096 B)

Speed	Active device	Passive device
424 kbit/s	Manchester, 10% ASK	Manchester, 10% ASK
212 kbit/s	Manchester, 10% ASK	Manchester, 10% ASK
106 kbit/s	Modified Miller, 100% ASK	Manchester, 10% ASK

- NFC Data Exchange Format (MIME, URLs, ...)
- Used for identification and subsequent communications
  - Bluetooth, WiFi, ... (eg, S-Beam)



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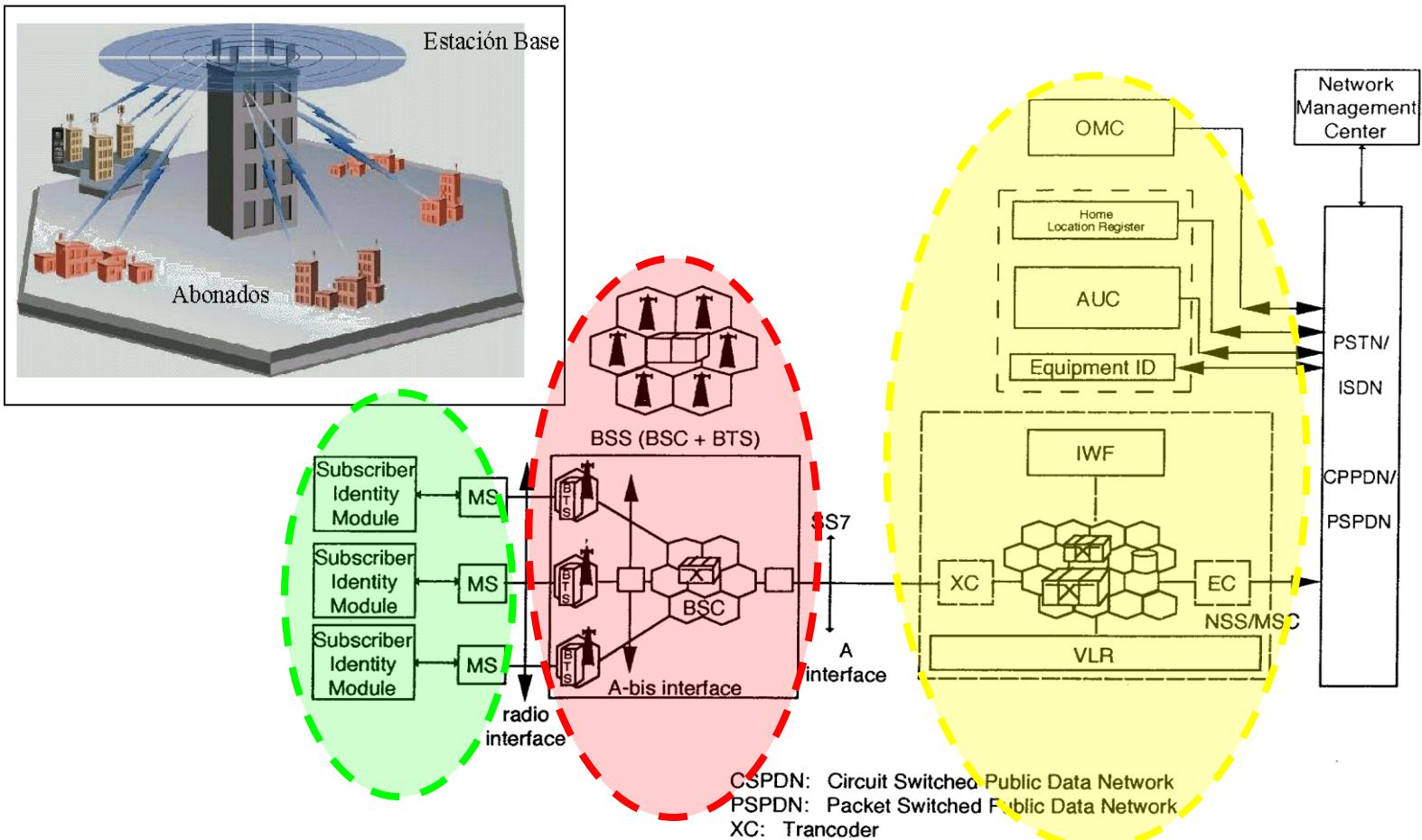
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## 6. Cell Systems (i)

- cellular / mobile systems: GSM and UMTS



# 6. Sistemas celulares (ii)

- GSM

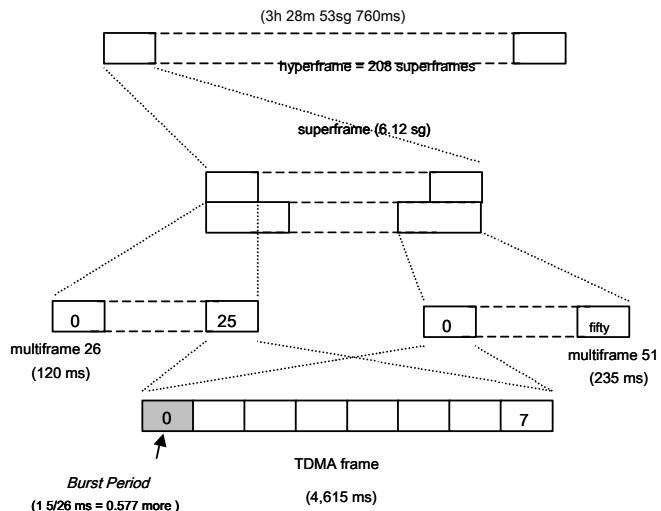
- FDM:

- Signals 200 KHz bandwidth
    - 124 carriers in GSM
    - 374 carriers in DCS



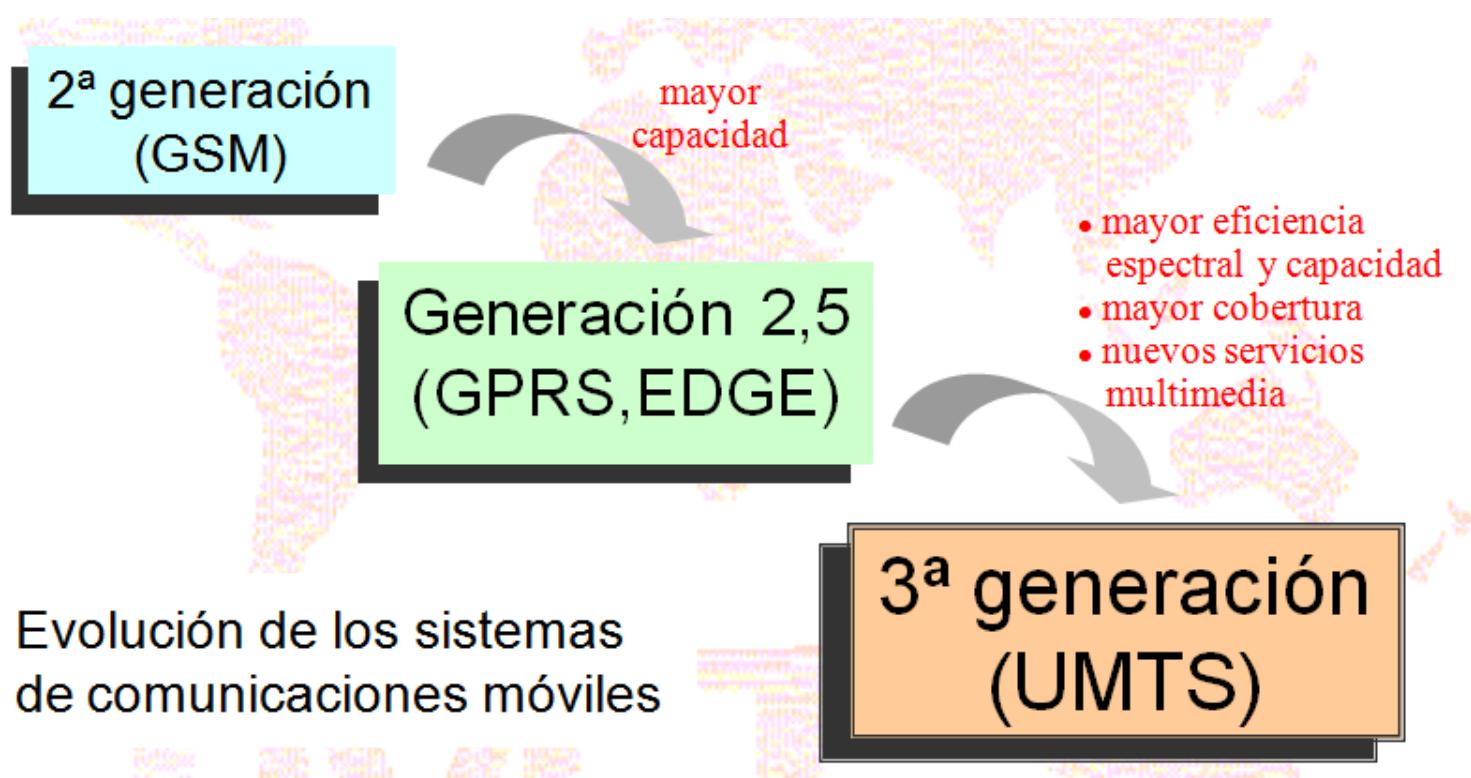
- TDM:

- BP: 156 bits / 0.577 ms
    - 270 Kbps

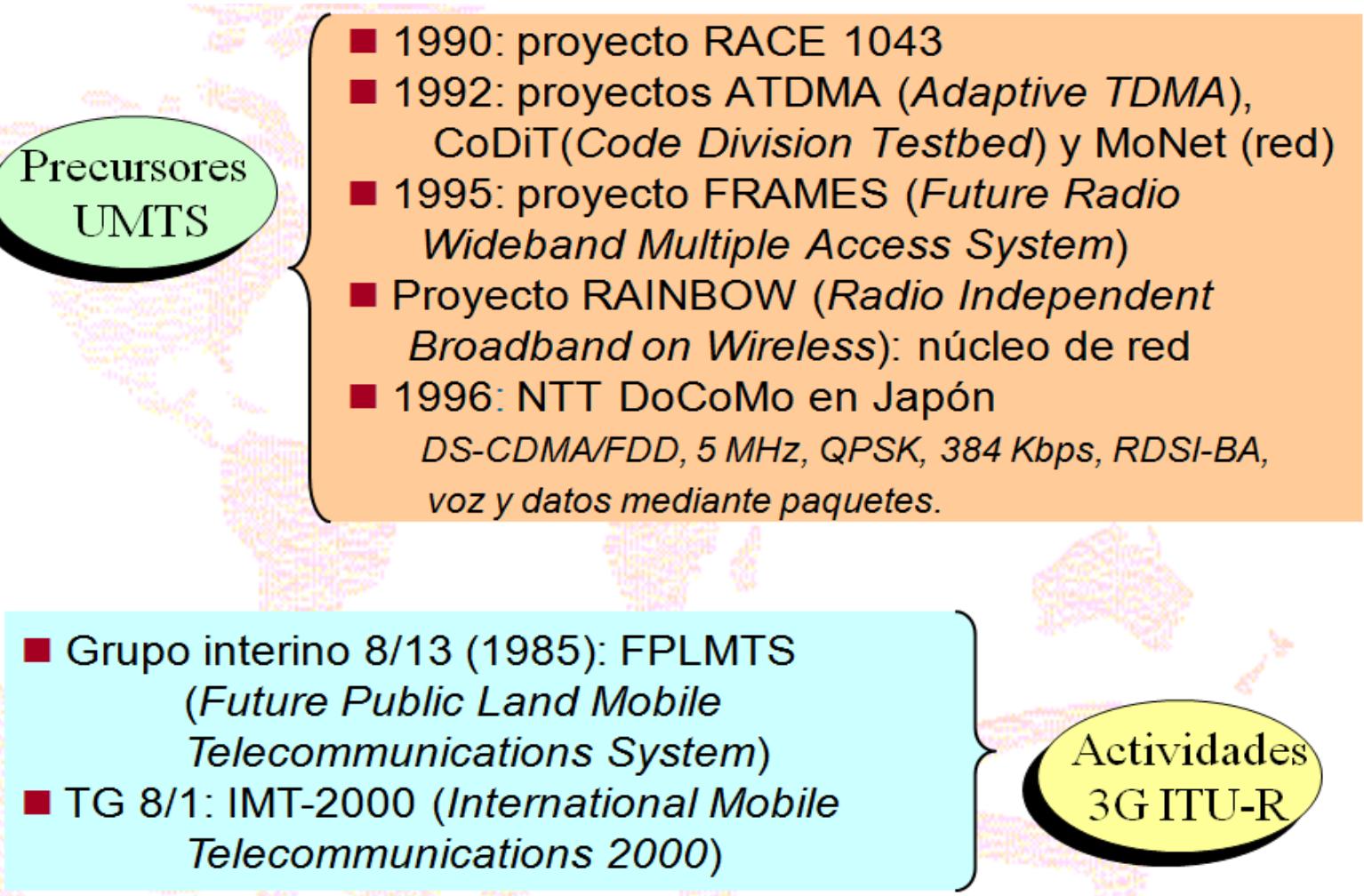


## 6. Cell Systems (iii)

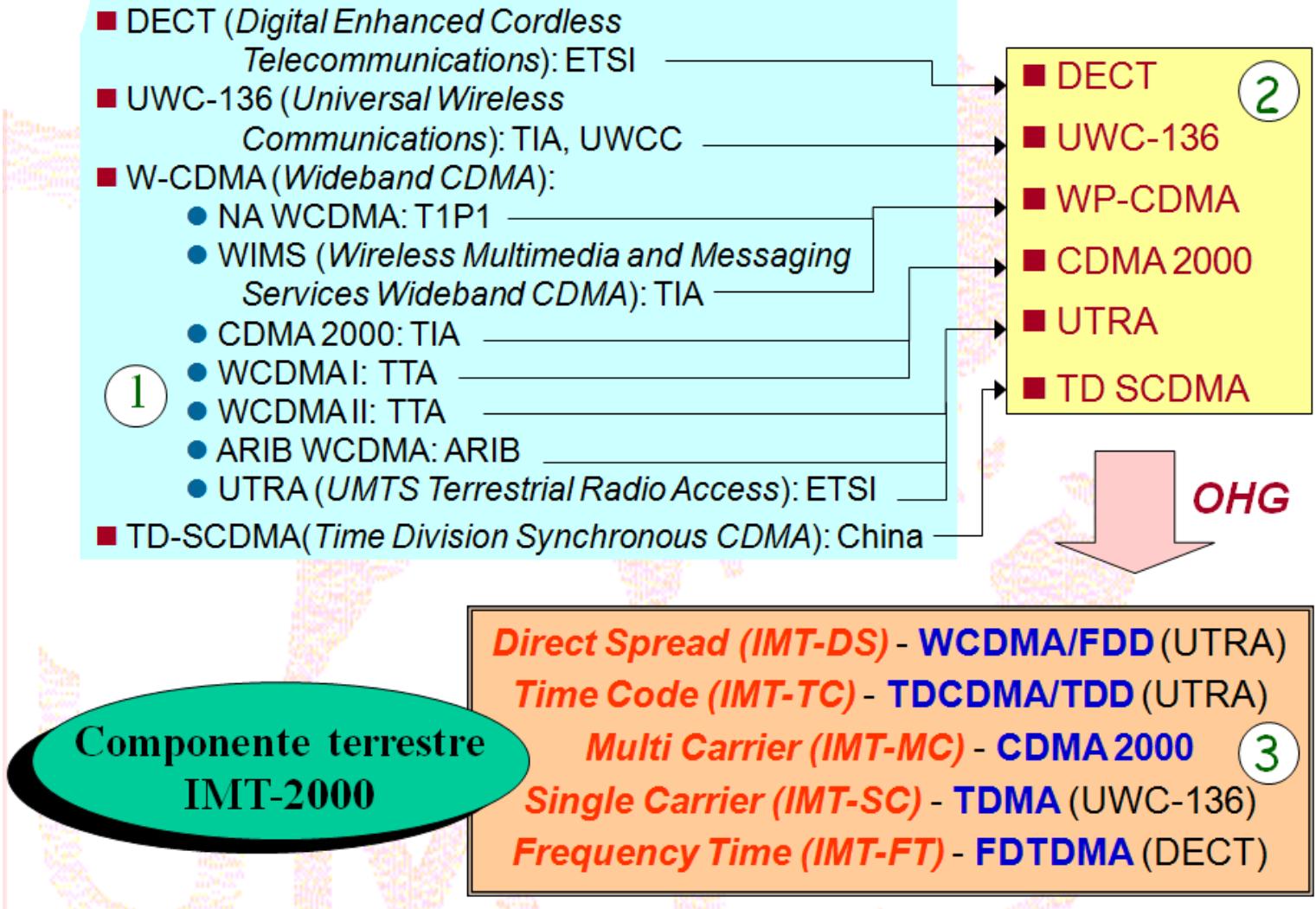
- UMTS: genesis and policy development



## 6. Sistemas celulares (iv)

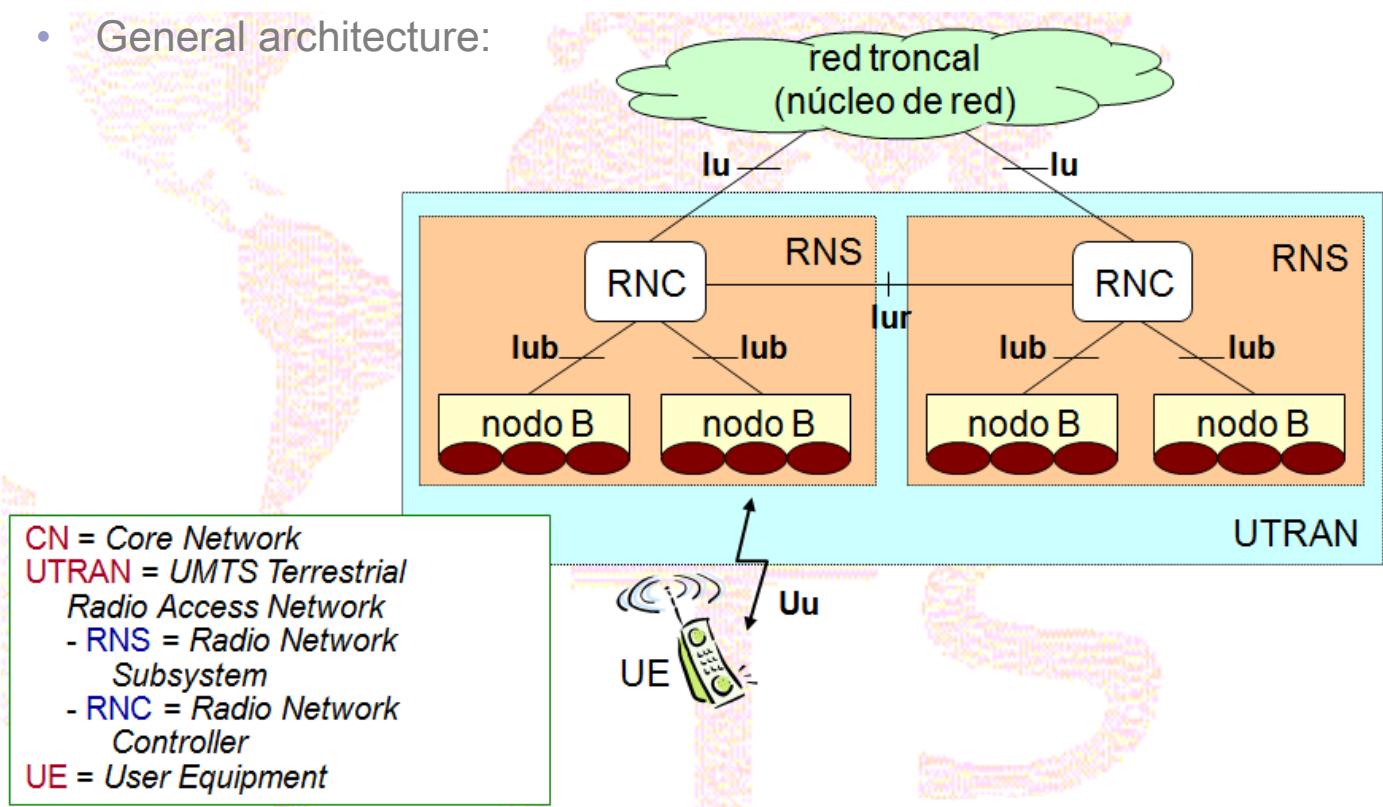


# 6. Cell Systems (v)



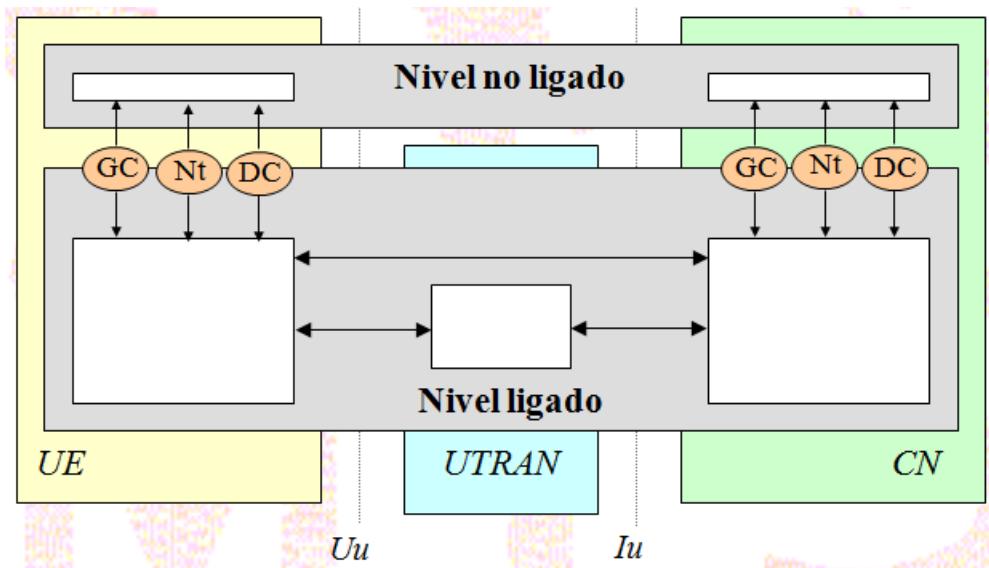
# 6. Sistemas celulares (vi)

- Description of the UMTS system:
  - *Universal Mobile Telecommunications System (UTRA)*
  - 3GPP ( *Third Generation Partnership Project*)
  - • 2Mbps
  - General architecture:



# 6. Sistemas celulares (vii)

- General architecture:
  - Two levels:
    - Bound*: intervention of the access network
    - Unbound*: CN-UE, without the intervention of UTRAN
  - Communication between the two through SAP ( *ServiceAccess Point*):
    - GC ( *General Control*): broadcasting services
    - Nt ( *Notification*): targeted broadcasting services
    - DC ( *Dedicated Control*): establishment, release, transmission



# 6. Systems celulares (viii)

- Core Network:

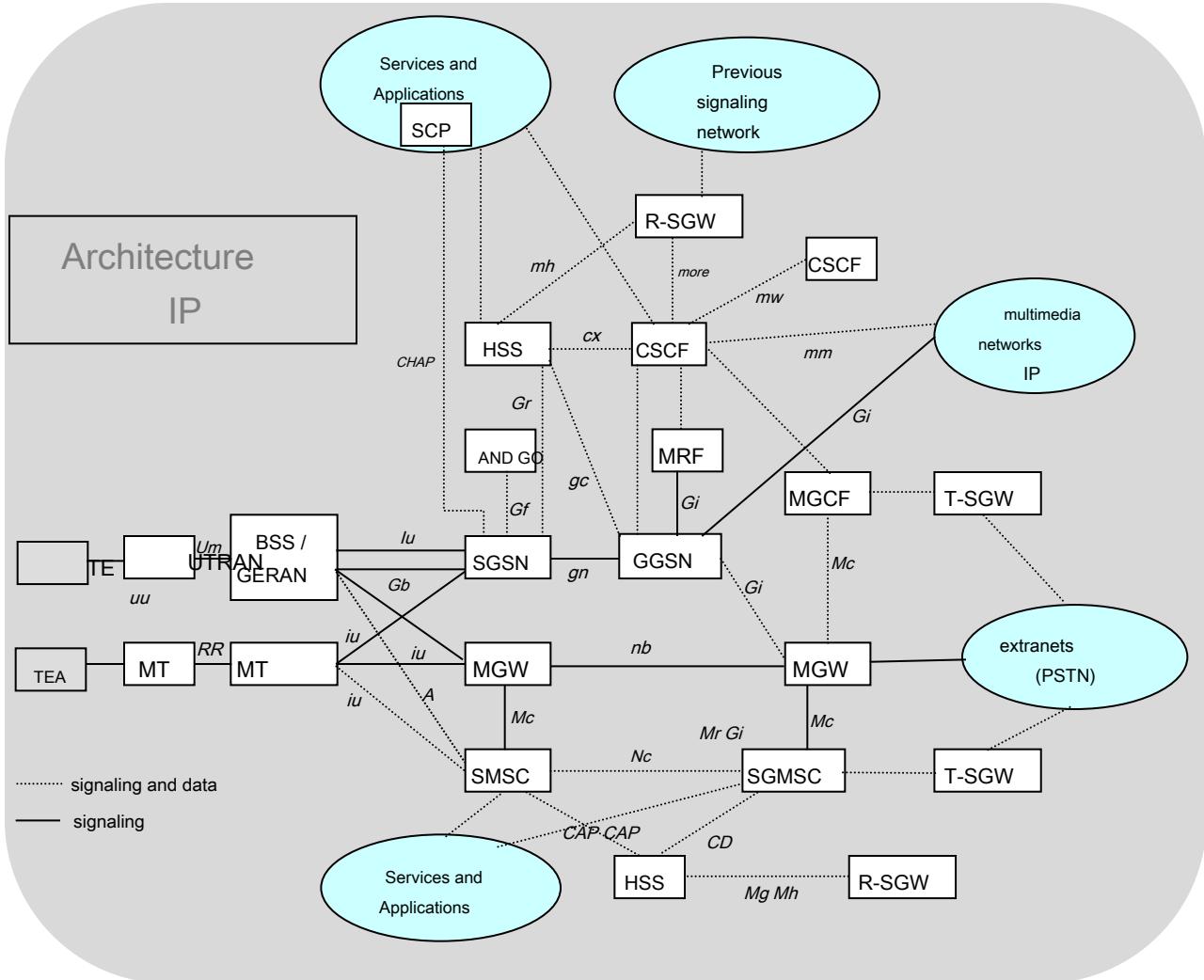
- Transport functions: signaling traffic and intelligence functions: control services (routing,
    - mobility, interconnection with other networks, etc.) Two
  - domains:
    - Circuit switched (CS, *Circuit Switching*)
    - Packet switched (PS, *Packet Switching*)
  - common functional elements:
    - HLR ( *Home Location Register*)
    - VLR ( *Visitor Location Register*)
    - AuC ( *Authentication Center*)
    - AND GO ( *Equipment Identity Register*)
    - SMS-GMSC ( *Short Messages Services Gateway MSC*)
    - SMS-IMSC ( *Short Messages Services Interworking MSC*)
  - CS functional elements:
    - U-MSC ( *Mobile-services Switching Center*)
    - U-GMSC ( *Gateway MSC*)
    - IWF ( *Interworking Function*)
  - PS functional elements:
    - U-SGSN ( *UMTS Serving GPRS Support Node*)
    - U-GGSN ( *UMTS Gateway GPRS Support Node*)
    - BG ( *Border Gateway*)

## 6. Sistemas celulares (ix)

- Core Network (cont.):
  - functional entities in architecture "all IP" (R5):
    - CSCF ( *Call State Control Function*): ICGW ( *Incoming Call Gateway*) TLC ( *Call Control Function*) SPD ( *Serving Profile Database*) AH ( *Address Handling*)
    - HSS ( *Home Subscriber Server*)
    - T-SGW ( *Transport Signaling Gateway Function*)
    - R-SGW ( *Roaming Signaling Gateway Function*)
    - MGCF ( *Media Gateway Control Function*)
    - MGW ( *Media Gateway Function*)
    - MRF ( *Multimedia Resource Function*)
    - SMSC ( *MSC Server*)
    - SGMSC ( *Server Gateway MSC*)

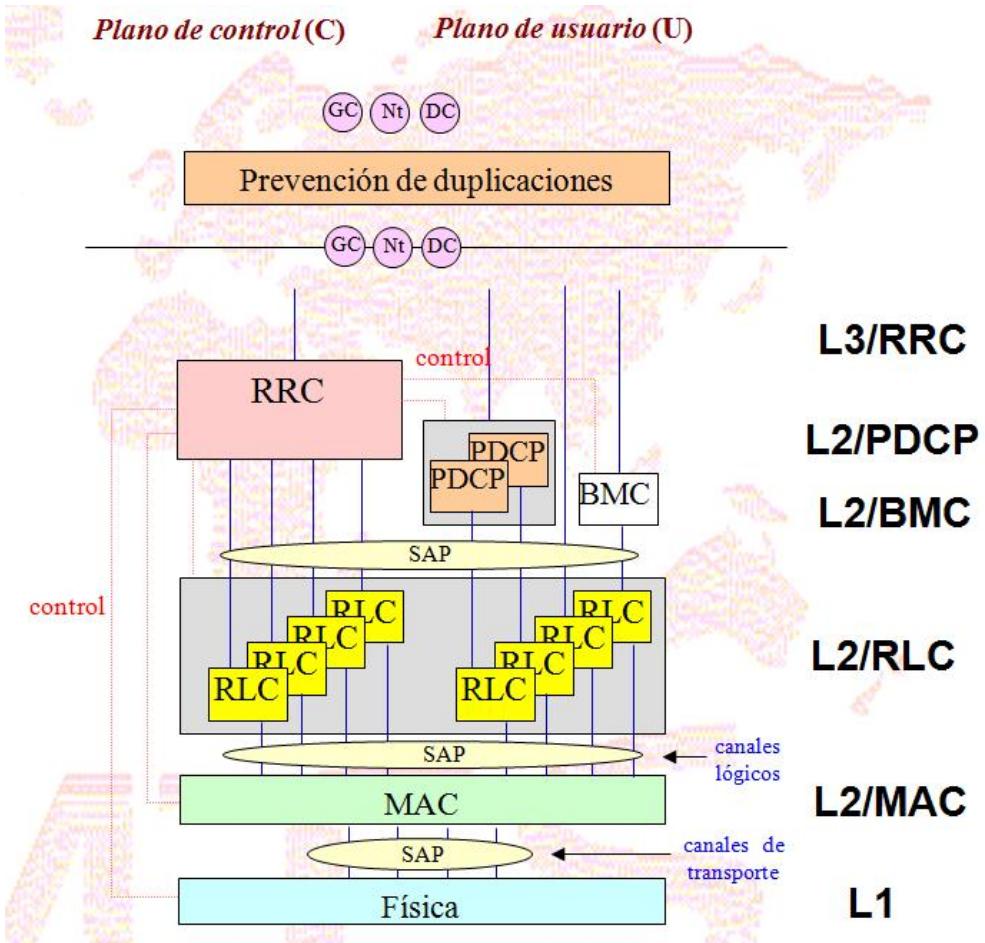
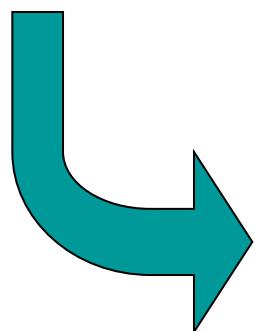


# 6. Cell Systems (x)



# 6. Sistemas celulares (xi)

- Radio interface ( $U_{or}$ ):
  - CDMA FDD and TDD
  - Structure protocols:



# 6. Sistemas celulares (xii)

- Functions of the layers of the radio interface:
  - Physical (L1): error detection, coding / decoding, multiplexing, speed adaptation or adjustment power, modulation, timing, etc.
  - MAC ( *Medium Access Control*): lógicos de correspondence channels transport, multiplexing / demultiplexing, switching, priority management, encryption, etc.
  - RLC ( *Radio Link Control*): RRC-MAC (transparent, with confirmation without confirmation), assembly / disassembly packets, error detection and correction, flow control, etc. Transfer

- Plano usuario**
- BMC ( *Broadcast / Multicast Control Protocol*): Control services broadcast / multicast.
  - PDCP ( *Packet Data Convergence Protocol*): compression packages and isolate the rest of the packet mode protocols
  - The network layer (L3) is divided into three sublayers: *RRM (Radio Resource Management)*, *CC (Call Control)* Y *MM (Mobility Management)*. The functions performed in this layer are: establishment / reconfiguration and release of resources / connections RRC, mobility management, QoS control, encryption control and open loop power, admission control, congestion control, etc.
  - Preventing duplication: Above the RRM sublayer, limited below the access network and over the core network

# 6. Cell Systems (xiii)

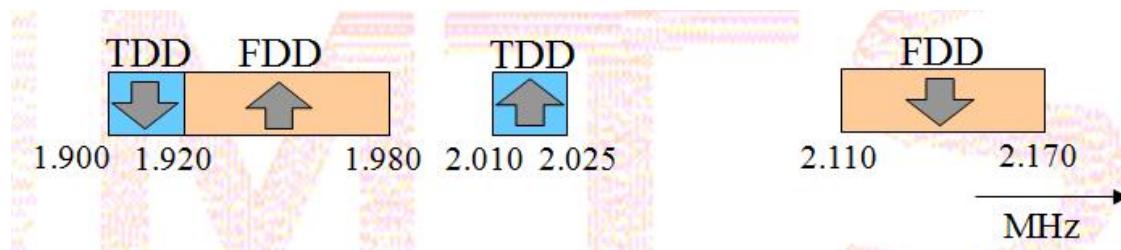
- Channel types in the interface U or:
  - logicians: Type of data transmitted by them  
traffic control

- Of transport: Transmission characteristics

common  
dedicated

- physicists: Transmission format

FDD: 60 + 60 MHz • 12 carriers   TDD: 15 + 20  
MHz • 7 carriers

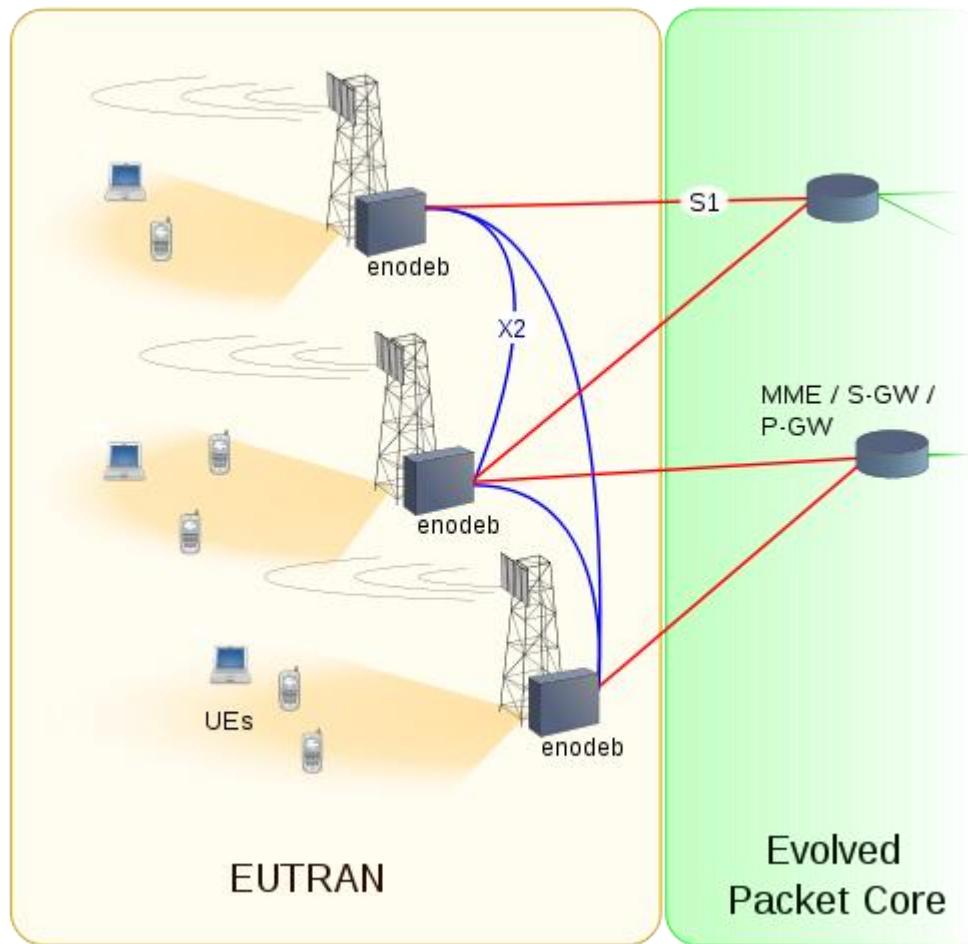


## 6. Sistemas celulares (xiv)

- LTE ( "Long Term Evolution"):
  - Evolution of GSM / UMTS to 4G
  - Defined by *NTT DoCoMo*, Japan 2004
  - 300 Mbps *downlink*, 75 Mbps *Uplink*
  - Latency <5 ms in the radio link
  - It supports mobility for terminals 300-500 km / h
  - Femto / Pico-cells (10m) to macro-cells (100 km)
  - It supports up to 200 clients in every cell of 5 MHz

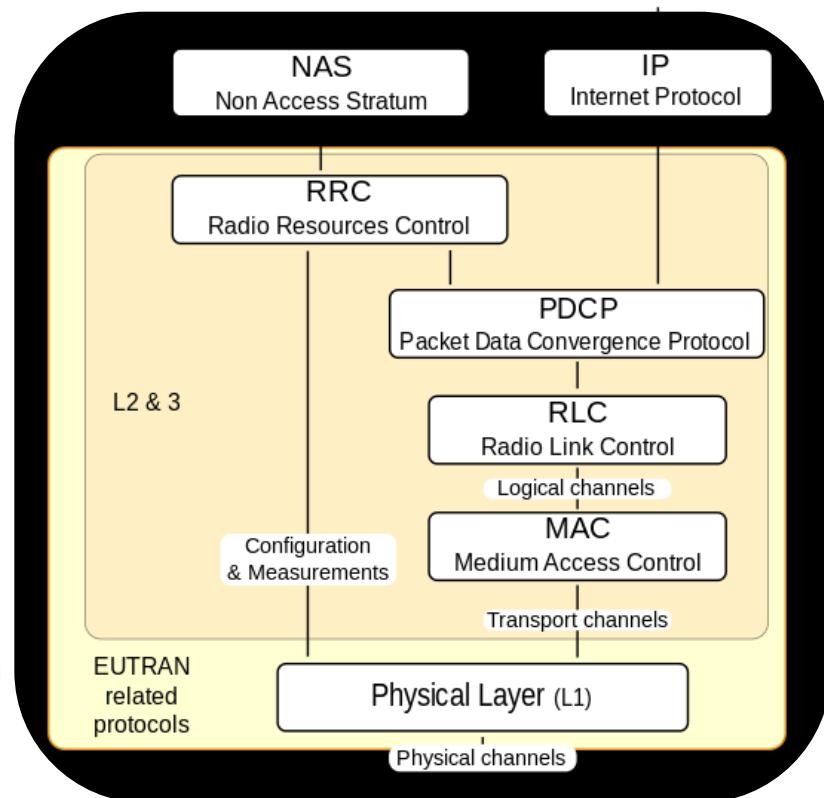
# 6. Sistemas celulares (xv)

- LTE:
  - Architecture:
    - E-UTRAN
    - SAE



# 6. Sistemas celulares (xvi)

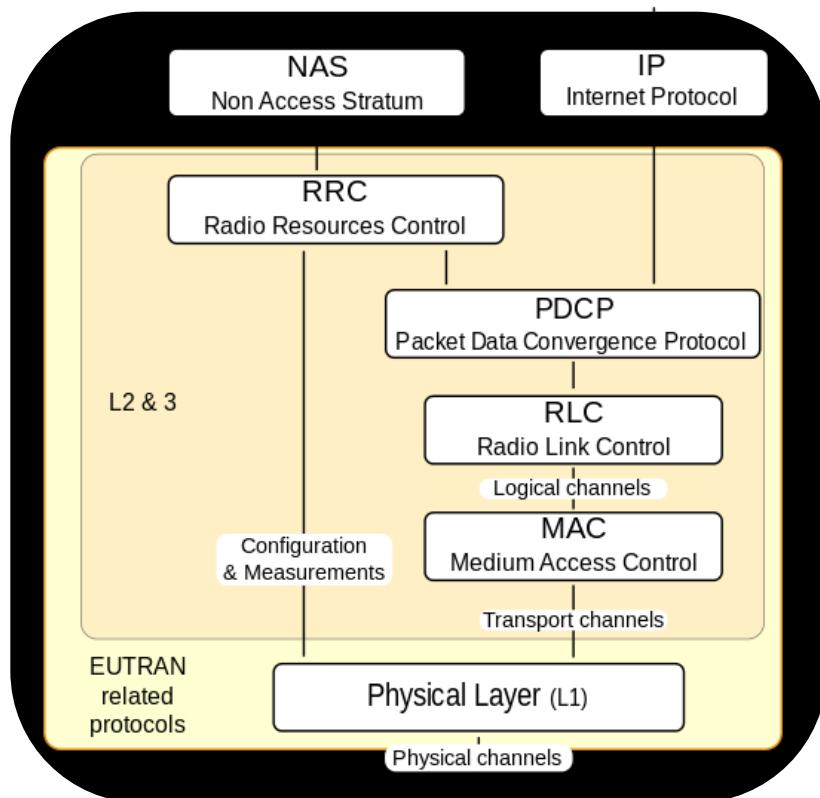
- LTE:
  - *E-UTRAN*: air interface for 3GPP LTE
  - Physical:
    - OFDMA / SC-FDMA
    - MIME
    - FDD / TDD
    - TDMA frame 10 ms
    - 15 kHz intercarrier
  - physical channels:
    - 6 DL, 3 signals
    - 3 UP, 2 signals
  - MAC: multiplexing logical channels on physical, prioritization and monitoring errors



Protocol stack

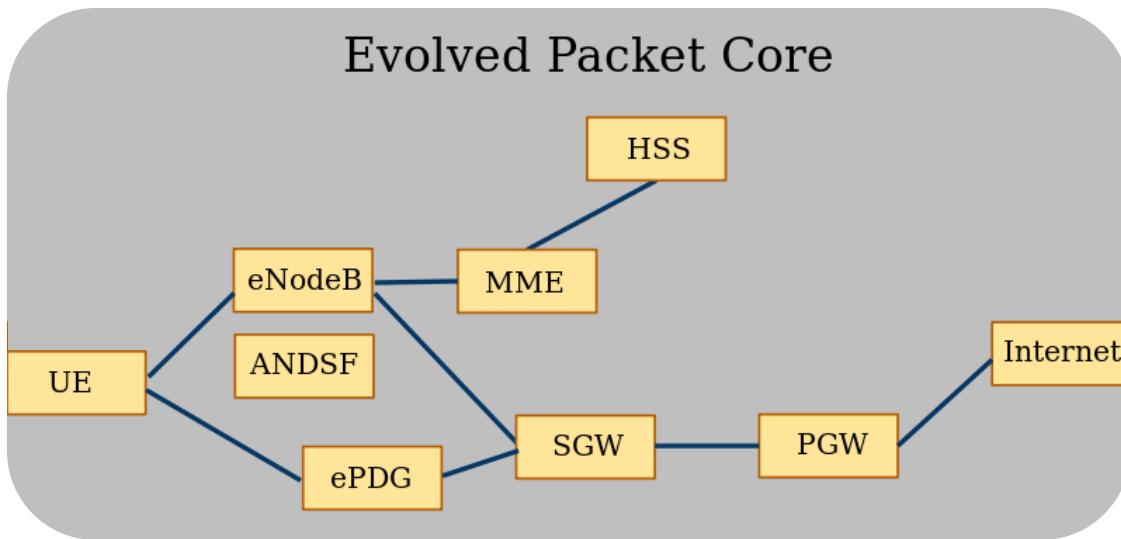
# 6. Sistemas celulares (xvii)

- LTE:
  - *E-UTRAN*: air interface for 3GPP LTE
  - RLC (3 modes):
    - ARQ
    - PDU segmenting
    - Realignment
  - PDCP:
    - Security
    - PDU segmenting
    - Realignment
  - RRC:
    - key management
    - *handover*
    - QoS
  - NAS:
    - authentication EU



## 6. Sistemas celulares (xviii)

- LTE:
  - *SAE ( "System Architecture Evolution")*: LTE backbone



**MME:** Mobility Management Entity

**SGW:** Serving GateWay

**PGW:** PDN GateWay

**HSS:** Home Subscriber Server

**ANDSF:** Access Network Discovery and Selection Function

**ePDG:** Evolved Paket Data Gateway

**eNodeB:** Evolved Node B



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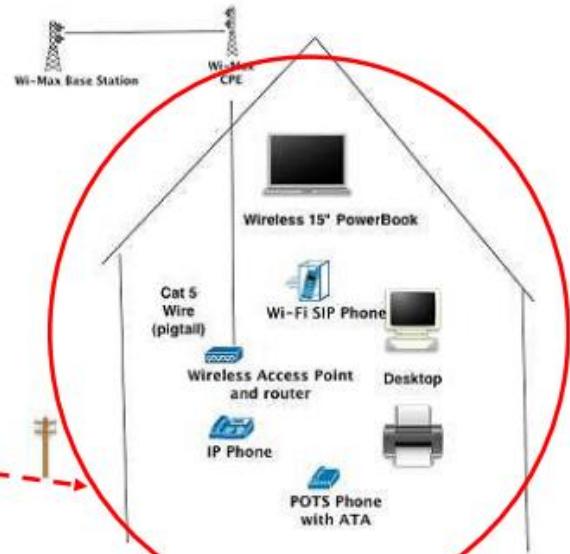
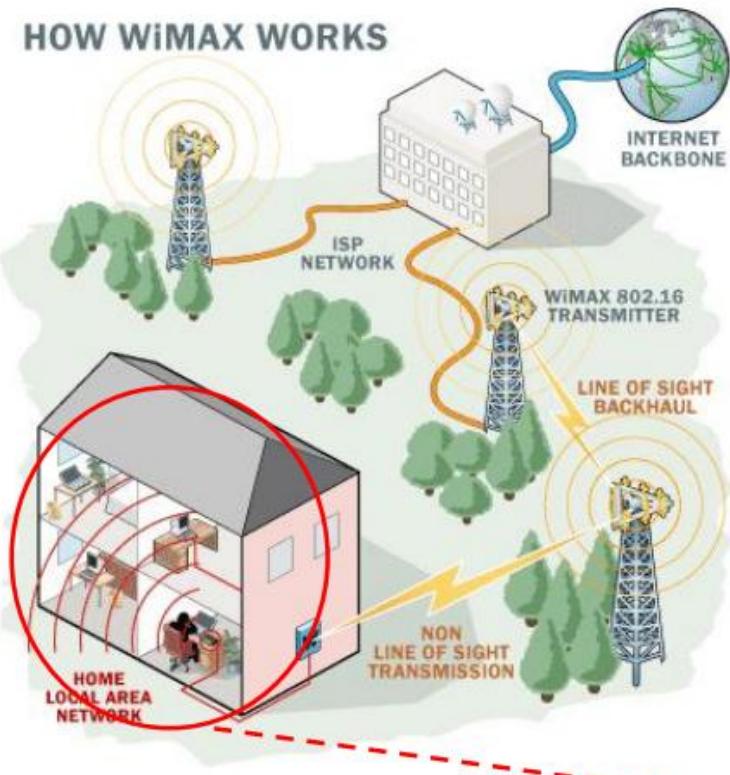
8. satellite systems

## 7. WiMAX (i)

- "Worldwide Interoperability for Microwave Access"
- IEEE 802.16 ( • HiperMAN ETSI)
- Red MAN: 50-60 Km radius
- 70 Mbps
- Protocol independent
- It supports packet services and commutated
- Service levels
- systems:
  - 802.16: without mobility, fixed antenna, 10-60 GHz
  - 802.16a: 2-11 GHz, different antennas
  - 802.16d: coverage without line of sight (NLOS)
  - 802.16d: Mobility



## 7. WiMAX (ii)



## 7. WiMAX (iii) (iii)

- comparative table with other systems:

	802.11	802.16	802.16a	802.16e	802.20
Status	Complete	Dec 2001	Jan. 2003	January. 2004	ETA '05-'06
Target App.	LAN	MAN	MAN	MAN	WAN
Range	Up to 300 ft. optimized for indoor LAN	Up to 5 miles Average Cell Radius 1-3 mi	Up to 25 miles Average Cell Radius 4-6 mi	Average Cell Radius 1-3 mi	
Channel Conditions	LOS when outdoors	LOS	nLOS	nLOS	nLOS
Spectrum	2.4 GHz & 5 GHz – Unlicensed	10-66 GHz Licensed	2-11 GHz Licensed and Unlicensed	2-6 GHz Licensed and Unlicensed	<3.5 GHz Licensed
Mobility Support	Portable – Local Roaming	Fixed	Fixed	Pedestrian Mobility – Regional Roaming	Vehicular Mobility – Global Roaming
Channelization	20 MHz	Scalable 1.5-20 MHz	Scalable 1.5-20 MHz	Scalable 1.5-5 MHz w/ sub-channels	1.25 or 5 MHz
Spectral Efficiency	< 2.7 bps/Hz	< 4.8 bps/Hz	< 3.75 bps/Hz	< 3 bps/Hz	< 1.25 bps/Hz
Bit Rate	54 Mbps (20 MHz BW)	< 134 Mbps (20 MHz BW)	< 75 Mbps (20 MHz BW)	15 Mbps (5 MHz BW)	< 6 Mbps (5 MHz BW)

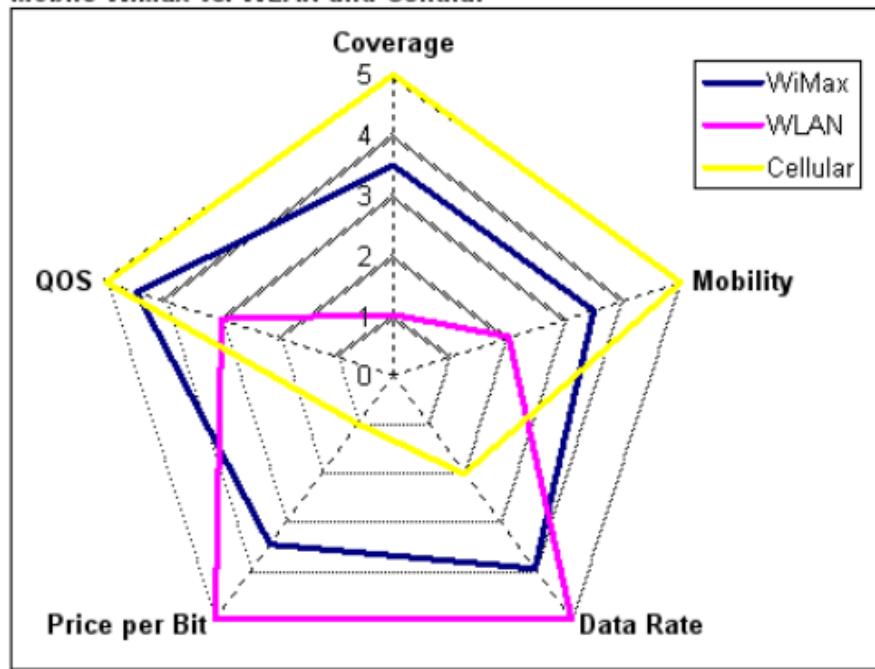
Fuente: Intel Wireless Division

## 7. WiMAX (iv)



- WiMAX Forum
- WiMAX vs. Wifi vs. Mobile

Mobile WiMax vs. WLAN and Cellular



Source: Samsung and Unstrung Insider

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## 8. Satellite Systems (i)

- various applications: weather, observation, navigation, communications
- Frequency Bands:

Tipo de Banda	Rango de Frecuencias
HF	1.8-30 MHz
VHF	50-146 MHz
P	0.230-1.000 GHz
UHF	0.430-1.300 GHz
L	1.530-2.700 GHz
S	2.700-3.500 GHz
C	Downlink: 3.700-4.200 GHz Uplink: 5.925-6.425 GHz
X	Downlink: 7.250-7.745 GHz Uplink: 7.900-8.395 GHz
Ku (Europa)	Downlink: FSS: 10.700-11.700 GHz DBS: 11.700-12.500 GHz Telecom: 12.500-12.750 GHz Uplink: FSS y Telecom: 14.000-14.800 GHz; DBS: 17.300-18.100 GHz
Ku (America)	Downlink: FSS: 11.700-12.200 GHz DBS: 12.200-12.700 GHz Uplink: FSS: 14.000-14.500 GHz DBS: 17.300-17.800 GHz
Ka	Entre 18 y 31 GHz

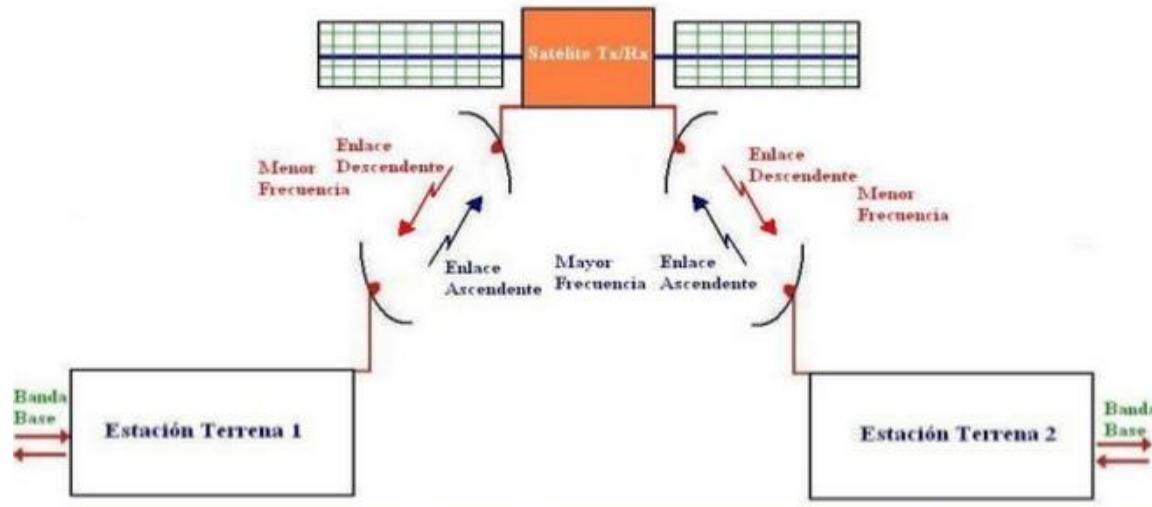
## 8. Satellite Systems (ii)

- Affectation of the weather
- Delay and loss
- Access: FDMA

TDMA

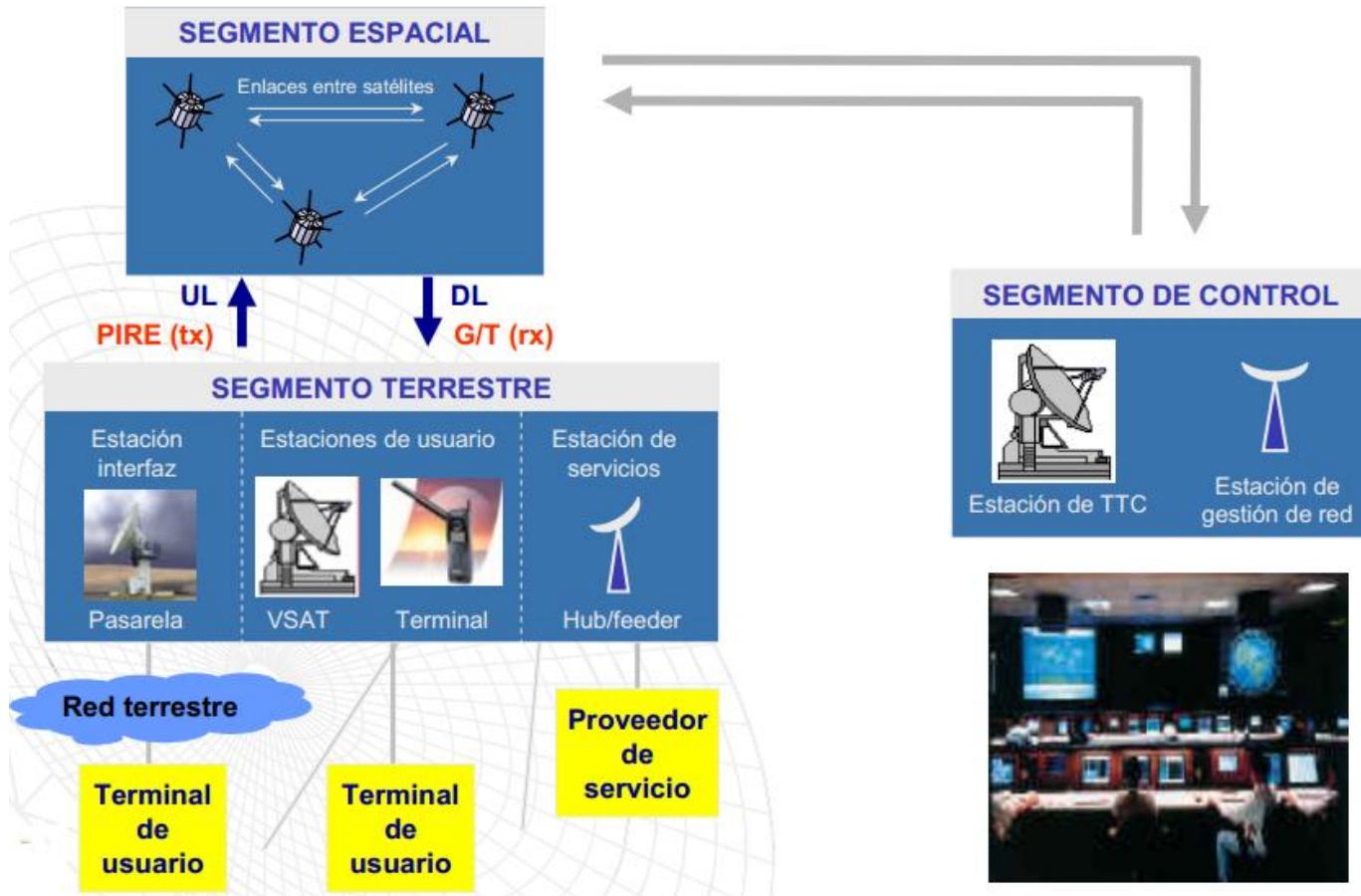
CDMA

ALOHA



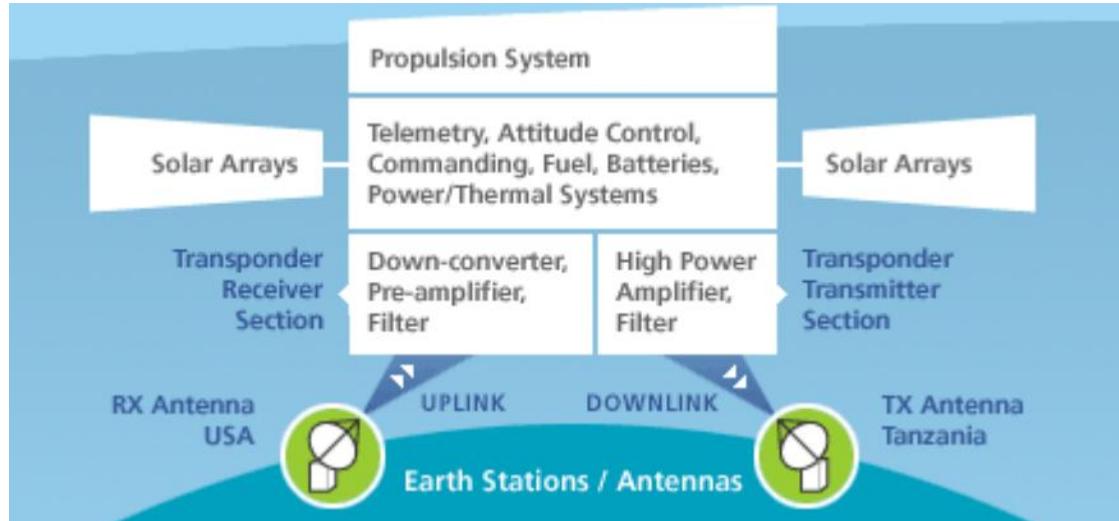
## 8. Satellite Systems (iii)

- Architecture of a complete satellite system:



## 8. Sistemas satélite (iv)

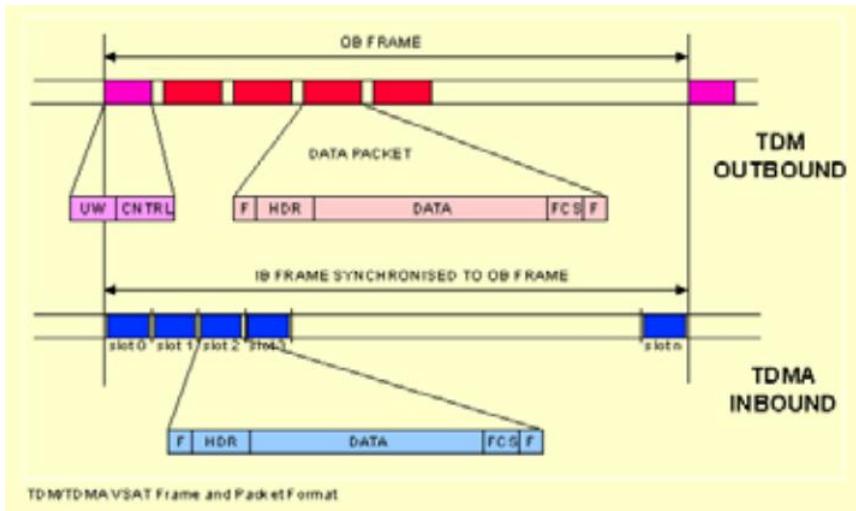
- A satellite structure:



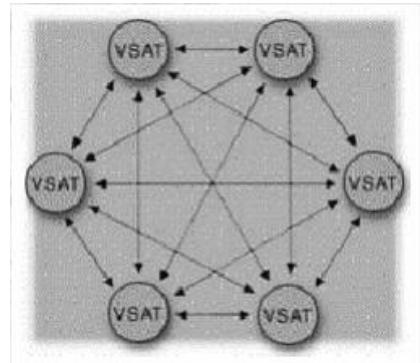
- topologies:
  - Point to Point (**SCPC, Single Channel Per Carrier**)
    - 64kbps-10 Mbps
  - Star (**VSAT; Very Small Aperture Terminals**)
    - ALOHA for access, then TDMA

## 8. Satellite Systems (v)

- Wefts VSATs (50-250 bytes):



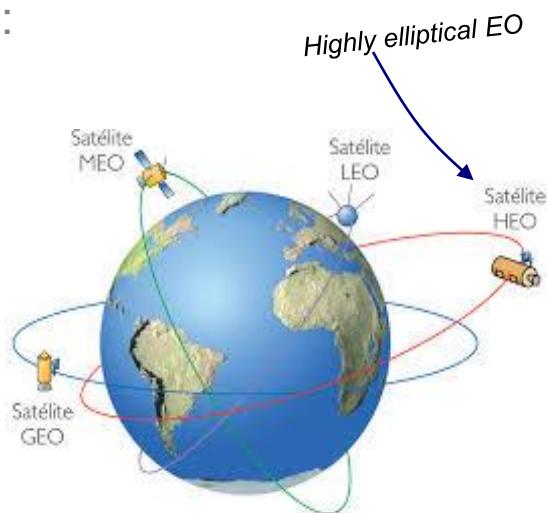
- Mesh (PAMA / DAMA; *Pre-Assigned / Demand Multiple Access*)
  - FDM, with pre-assigned channels and DAMA demand DAMA
  - Larger antennas
  - NCS ("Network Controller System") for monitoring channels



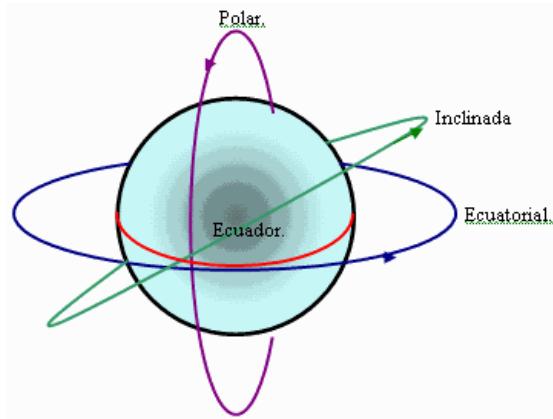
## 8. Satellite Systems ( saw) (vi)

- Systems according to its orbit: LEO / MEO / GEO:

	GEO	MEO	LEO
Height (km)	36,000	6,000-12,000	200-3000
orbital period (Hr)	24	05.12	1.5
Speed (Km / hr)	11,000	19,000	27,000
Delay (round trip) (ms)	250	80	10
Visibility period	Forever	2-4 Hr	<15 min
Satellites needed for global coverage	3	10-12	50-70

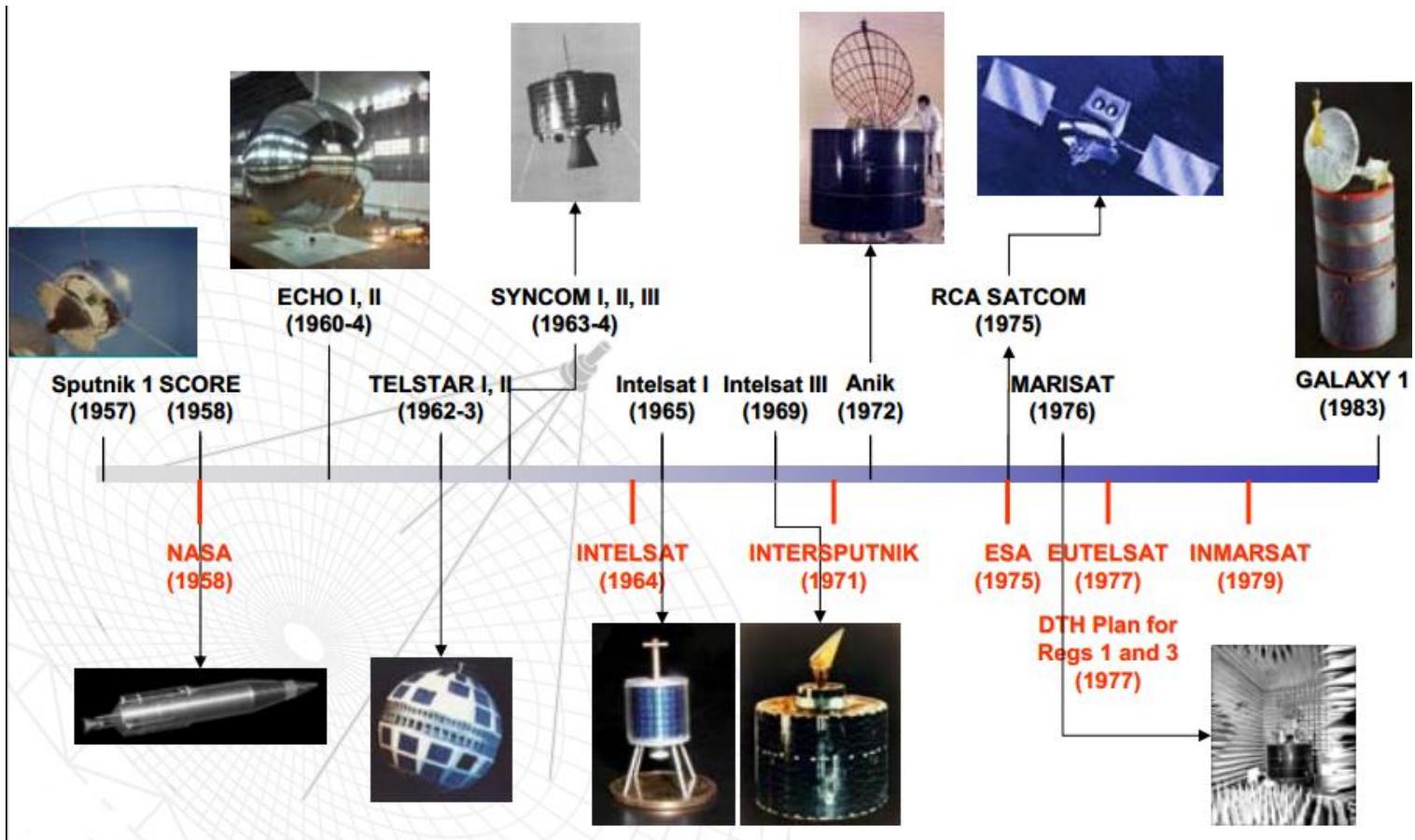


- Depending on the type of orbit:
  - Polar
  - Equatorial
  - Leaning



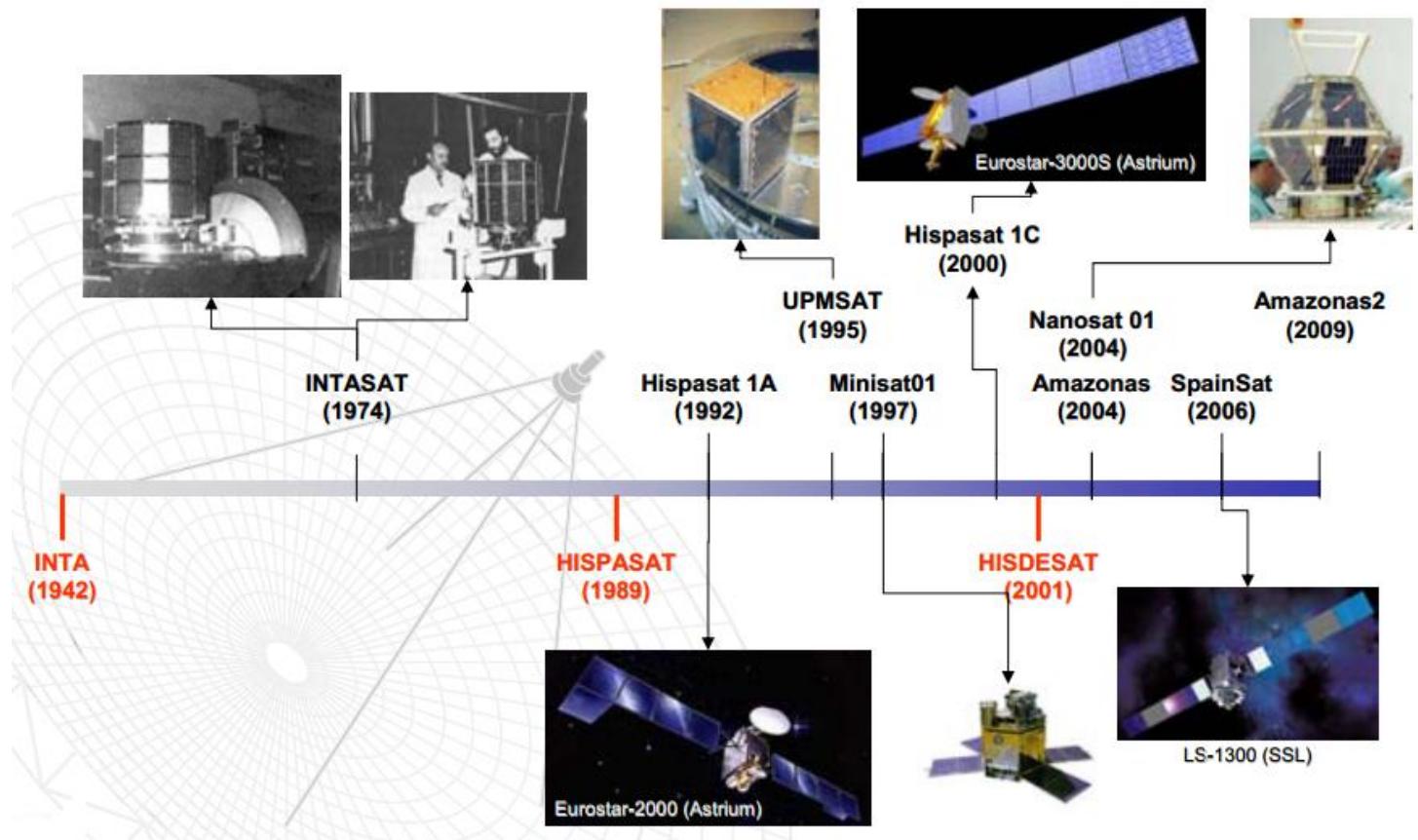
## 8. Satellite Systems (vii)

- First communications satellites:



## 8. Satellite Systems (viii)

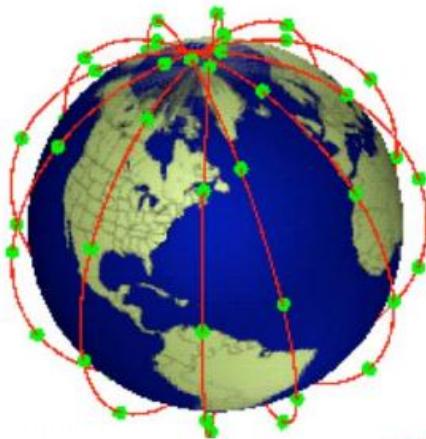
- Satellites in Spain:



## 8. Satellite Systems ( ix)

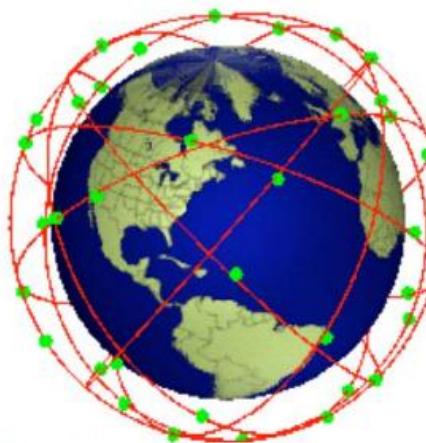
- Examples of LEO systems:

**h=780 Km**  
**66 satélites**  
**en 6 planos**  
**i=86.4°**



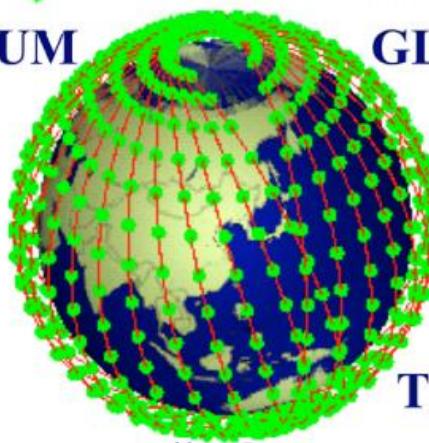
**IRIDIUM**

**h=1400 Km**  
**48 satélites**  
**en 8 planos**  
**i=52°**



**GLOBALSTAR**

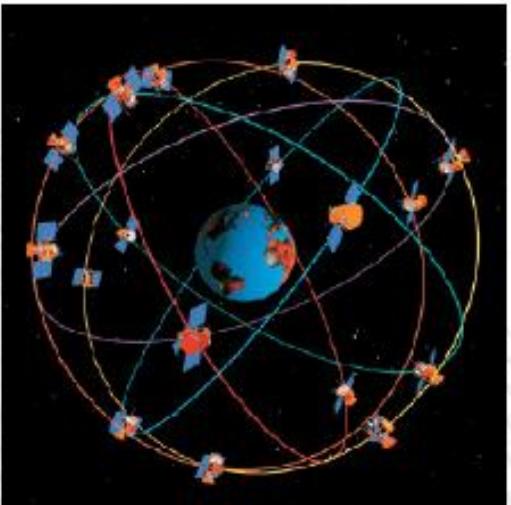
**El dibujo corresponde a una versión antigua:**  
**840 satélites en 21 planos**  
**i=98.16°**



**TELEDESIC**

## 8. Satellite Systems (x)

- Examples of MEO systems:



24 satélites en 6 planos  
 $h=20200$  km  
 $i=55^\circ$

GPS

- 27 satélites (+ 3 de reserva)
- 3 planos orbitales
- Inclinados  $56^\circ$
- Nodos ascendentes separados  $120^\circ$  en el plano ecuatorial
- Cada plano, 9 satélites, separados  $40^\circ$  en anomalía
- $h=23222$  km ( $T=14h07m$ , que se repite cada 10 días)



Galileo

## 8. Satellite Systems ( xi)

- GEO belt:

